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West African Agriculture for Jobs, Nutrition, Growth, and Climate Resilience

Keith Wiebe, Gert-Jan Stads, Nienke Beintema, Karen Brooks,

Nicola Cenacchi, Shahnila Dunston, Daniel Mason-D'Croz,

Timothy B. Sulser, and Timothy Thomas

Environment and Production Technology Division

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

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AUTHORS

Keith Wiebe (k.wiebe@cgiar.org) is a senior research fellow in the Environment and Production Technology Division of International Food Policy Research Institute (IFPRI), Washington, DC.

Gert-Jan Stads (g.stads@cgiar.org) is a senior program manager in the Environment and Production Technology Division of IFPRI.

Nienke Beintema (n.beintema@cgiar.org) is program head in the Environment and Production Technology Division of IFPRI.

Karen Brooks (k.brooks@cgiar.org) is director, CGIAR Research Program on Policies, Institutions, and Markets (CRP 2) led by IFPRI.

Nicola Cenacchi (n.cenacchi@cgiar.org) is a senior research analyst in the Environment and Production Technology Division of IFPRI.

Shahnila Dunston (s.dunston@cgiar.org) is a senior research analyst in the Environment and Production Technology Division of IFPRI.

Daniel Mason-D'Croz (d.mason-dcroz@cgiar.org) is a scientist in the Environment and Production Technology Division of IFPRI.

Timothy B. Sulser (t.sulser@cgiar.org) is a scientist in the Environment and Production Technology Division of IFPRI.

Timothy Thomas (t.sulser@cgiar.org) is a research fellow in the Environment and Production Technology Division of IFPRI.

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West African Agriculture for Jobs, Nutrition, Growth, and Climate Resilience[1]

By

Keith Wiebe, Gert-Jan Stads, Nienke Beintema, Karen Brooks, Nicola Cenacchi,

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Contents

List of Selected Acronyms

AgGDP	agricultural gross domestic product
AgMIP	Agricultural Model Intercomparison and Improvement Project
ARCN	Agricultural Research Council of Nigeria
ARIPO	African Regional Intellectual Property Organization
AR5	IPCC Fifth Assessment Report
ASTI	Agricultural Science and Technology Indicators
CAADP	Comprehensive Africa Agriculture Development Programme
CARGS	Competitive Agricultural Research Grant Scheme
CARI	Central Agricultural Research Institute (Liberia)
CC	climate change
CCAFS	CGIAR Research Program on Climate Change, Agriculture and Food Security
CGE	computable general equilibrium
CNRA	National Center for Agricultural Research (Côte d'Ivoire)
CNRA	National Agricultural Research Council (Niger)
CNRST	National Center for Scientific and Technological Research (Burkina Faso)
CORAF/WECARD	West and Central African Council for Agricultural Research and Development
CSIR	Council for Scientific and Industrial Research (Ghana)
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DSSAT	Decision Support System for Agrotechnology Transfer
ECOWAS	Economic Community of West African States
FAO	Food and Agriculture Organization of the United Nations
FAOSTAT	FAO Statistical Databases
FARA	Forum for Agricultural Research in Africa
FTE	full-time equivalent
GFRP	Global Food Response Program
GDP	gross domestic product
GHG	greenhouse gas
IAASTD	International Assessment of Agricultural Knowledge, Science and Technology for Development
IDA	International Development Association
IER	Rural Economy Institute (Mali)
IFPRI	International Food Policy Research Institute
ILWAC	Integrated Land and Water Management
IMPACT	International Model for Policy Analysis of Agricultural Commodities and Trade
INERA	Environment and Agricultural Research Institute (Burkina Faso)
INIDA	National Agricultural Research and Development Institute (Cabo Verde)
INRAB	National Agricultural Research Institute of Benin
INRAN	National Agricultural Research Institute of Niger
IRAG	Guinean Agricultural Research Institute
ISRA	Senegalese Agricultural Research Institute
ITRA	Togolese Agricultural Research Institute
IPCC	Intergovernmental Panel on Climate Change
MDTF	Multi-Donor Trust Fund
MIROC	Model for Interdisciplinary Research on Climate

MS	master of science
NARI	national agricultural research institute
NARI	National Agricultural Research Institute (The Gambia)
NARS	national agricultural research system
NCoS	national centers of specialization
NERICA	New Rice for Africa
NGO	nongovernmental organization
NoCC	no climate change
OAPI	African Organization of Intellectual Property
PHRD	Policy and Human Resources Development
PIM	CGIAR Research Program on Policies, Institutions, and Markets
PPP	purchasing power parity
RCP	Representative Concentration Pathway
R&D	research and development
ReSAKSS	Regional Strategic Analysis and Knowledge Support System
RIAPA	Rural Investment and Policy Analysis
SLARI	Sierra Leone Agricultural Research Institute
SSP	Shared Socioeconomic Pathway
UNESCO	United Nations Educational, Scientific and Cultural Organization
USAID	United States Agency for International Development
WAAPP	West Africa Agricultural Productivity Program

Executive Summary

West Africa as a region is projected to continue robust economic growth in the decades ahead, according to scenarios developed by the global modeling community in the context of the Intergovernmental Panel on Climate Change (IPCC) assessment reports. Many countries will enter middle-income status by 2030, and more will do so by 2050. The combination of rising incomes and population will lead demand for food to grow more rapidly than supply if output and productivity continue to grow at rates observed in recent years. Net imports of food will increase. Imports of cereals will roughly double, with the greatest growth in maize. Meat imports will rise roughly fivefold. Exports of pulses will decline by about half, and the region will retain net exporter status. For roots and tubers, fruits and vegetables, and oilseeds, the region will shift from net export to net import status. These changes in trade are expected to occur even before considering the impact of climate change, which is evident in projections for 2030 and quite strong by 2050. Climate change in the absence of adaptation further increases the growth in net imports for most commodities, although in some cases, the impact is counterintuitively modest (due to the dampening effects of steeper price increases).

Most prices in 2030 are projected to increase between 10 and 20 percent in real terms relative to a base year of 2010, even without climate change. The cost of imports thus rises due to both price and quantity changes. Including climate change raises all prices in 2030, with some prices increasing an additional 1 percent and others up to an additional 15 percent. Based on the combined effects of changes in prices, population, income, climate, and productivity, the number of people at risk of hunger in West Africa is projected to rise from 30.1 million in 2010 to 32.5 million in 2030 and 33.5 million in 2050. Climate change is expected to more than offset the modest improvement that would be projected in its absence.

Scenarios that illustrate the rising import bill and impact of climate change argue for robust efforts to increase productivity in specific ways that facilitate adaptation to climate change. The population may adapt by using new varieties and technologies, adjusting the product mix, and/or diversifying income sources. Preliminary analysis indicates that new varieties of drought- and heat-tolerant maize can more than compensate for the yield loss associated with climate change. Similarly, drought-tolerant groundnut shows potential to outperform current varieties, even under adverse climatic conditions. In contrast, even improved sorghum is projected to perform poorly under climate change. Technologies such as no-till, integrated soil fertility management, and enhanced nitrogen efficiency can also increase productivity and counter the effects of climate change. Realizing the benefits of new technologies will depend on investment in their development and proactive efforts at dissemination.

Climate resilience is an important objective of agricultural transformation in West Africa, but it is not the only one. Poverty reduction, the traditional goal of agricultural growth, remains important, because many of the poor remain dependent on agriculture. Agriculture is called upon to create jobs for millions of young people joining the labor force each year, given slow growth in labor-intensive manufacturing, the low labor intensity of mining, and uncertain prospects for growth in the service sector. Nutritional issues, including obesity, are of increasing importance, and agriculture can contribute, largely through rapid growth in production (and hence increased affordability) of foods high in protein and micronutrients. Agriculture must also continue to contribute to general macroeconomic growth and management of trade balances.

The agenda for agricultural transformation between now and 2030 is thus more complex than in the recent past. Agriculture must address a multifunctional mandate, including growth, poverty reduction,

climate resilience, job creation, and improved nutrition. In addition, farm households help manage natural resources of national and global importance, including soil, water, forests, biodiversity, and climate. Managing the sector to achieve multiple objectives requires decisions on the part of policy makers, farmers, traders, and others, and a set of analytical tools to allow examination of options for investment and reform.

Effective investment programs will include funds for research and development (R&D) to discover and disseminate new varieties and technologies, funds for irrigation and water management, and funds for infrastructure to improve market access, among other program areas (such as rural health and education, power, social safety nets, and insurance). Within this broad agenda, different portfolios of investment carry different returns and trade-offs among objectives. For example, scenarios examined at the global level emphasizing investments in agricultural research and productivity growth offer moderate improvements in income, agricultural supply, and food security and little impact on environmental improvement by 2030, but larger improvements by 2050, at relatively low cost. A scenario combining irrigation expansion and increased water use efficiency offers reductions in water use and small improvements in income, supply, and food security. Improved market access through reduced marketing costs increases income, supply, and food security, but at the cost of increased conversion of forestland and greenhouse gas (GHG) emissions, largely due to the investment in roads and infrastructure that underlies the reduction in marketing costs. These outcomes highlight the importance of a mixed portfolio of investments that combines those addressing different objectives. A comprehensive scenario combining agricultural research, irrigation and water management, and infrastructure achieves significant improvements in all outcome areas, particularly by 2050, but comes at a significantly higher cost. These global results are suggestive for West Africa, and could be refined to look specifically at investment portfolios under consideration within the region.

Investment in agricultural science is fundamental to all scenarios that meet multiple objectives. 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. In 2014, the subregion as a whole spent $948 million on agricultural research (in 2011 purchasing power parity [PPP] prices). This subregional growth is almost entirely driven by Nigeria and Ghana. Investment levels in many other countries in the region either stagnated or fell during 2000–2014, although the data indicate an upsurge in spending levels in more recent years, largely in response to the launch of the West Africa Agricultural Productivity Program (WAAPP).

The projections described above are predicated on the assumption that funding for agricultural science (a primary driver of growth in productivity) will continue to grow at rates roughly similar to those observed in recent years. More rapid growth could result in more favorable outcomes; conversely, failure to maintain investment in agricultural science would present more pessimistic results. Past efforts to benchmark investment in agricultural science for cross-country comparison have relied primarily on simple indicators of funding as a share of agricultural gross domestic product (AgGDP). In light of well-known shortcomings associated with this indicator, the International Food Policy Research Institute (IFPRI) recently developed an alternative multifactor indicator that takes into account the size of a country's agricultural sector, degree of agroecological diversity, and other inputs. Application of this indicator suggests that the gap measured against what West African countries have actually invested in recent years, once standardized for size and other factors, is still substantial, but less than measured with the older indicator. At around $500 million PPP of incremental funds per year, governments could mobilize this sum by adjusting the composition of agricultural public spending within the commitments they have already made to Comprehensive Africa Agriculture Development Programme (CAADP) spending targets. Closing that gap would equalize the relative contributions of West African countries to a joint regional effort of agricultural research. More funds would be needed to fully rebuild staff numbers, construct needed infrastructure, and attain ambitious growth targets, but closing the initial $500 million (PPP) gap would be a feasible target consistent with absorptive capacity.

An effective investment in agricultural science entails choices about the composition of a portfolio of scientific research projects; the volume and time path of investment; institutional reforms to assure regional integration of scientific effort and high payoffs on investment; and policy and regulatory reforms to speed adoption and use of technical innovations. Different portfolios of agricultural research will address different objectives of agricultural transformation. Food staples remain important contributors to the incomes of the rural poor. Growing food staples, however, does not often yield high labor productivity or generate jobs, both on and off the farm, in such areas as packing, sorting, cleaning, and transport. Similarly, staples do not address nutritional deficits among populations that need more dietary diversity and micronutrient content. In such instances, increased availability of animal products, legumes, fruits and vegetables, and biofortified crops is required. An investment portfolio of agricultural research that takes into account nutritional needs and job creation will in general give greater weight to animal products, legumes, fruits and vegetables, and export crops than will one focusing on poverty reduction more narrowly.

The scientific foundations to support transformational and multifunctional agriculture in West Africa will require continued construction of a truly regional scientific establishment. The process started in the last decade and achieved notable progress with the support of WAAPP and regional coordination by the West and Central African Council for Agricultural Research and Development (CORAF/WECARD). Regionalization of the research effort is, however, still at an early stage and must accelerate quickly if gains are to be realized. Further integration will require specific institutional design.

To support continued integration, a regional study of congruence should be undertaken to provide a baseline diagnostic of existing research programs and highlight links that should be strengthened now, and those that should be incorporated into research priorities for the future. Congruence should be assessed at the regional—not national—level, with detailed accounting of the investment of each national system into the aggregate regional effort for the commodity in question. A monitoring system should be put in place to track regional or transboundary work and results. The system should include cross-national collaboration in research, counting of publications with authors from several national institutions, tracking of release and adoption of varieties and new technologies across borders, movement of staff among institutes across borders, and collaboration with international partners, including CGIAR. The monitoring system should also include national modules drawing on the Agricultural Science and Technology Indicators (ASTI) methodology and tracking of allocations, release of funds, expenditures, and human resources by country and source of funding. This will allow regional transparency in oversight of national contributions to the shared regional scientific effort.

At a higher level of funding corresponding to a closed or narrowed investment gap, effective use of research money will require significant adjustment among and within institutions. Investment in human capacity will need to continue at a high level for several years and then can settle to a steady state, given the accomplishments in the last five years (including 1,000 young scientists of the national agricultural research institutes (NARIs), that have undergone or are currently undergoing master of science (MS) and PhD-degree training under WAAPP—30 percent of whom are female). Mechanisms should be put in place to deploy staff regionally, instead of nationally. To retain trained staff, NARIs will need to be able to set salaries and working conditions competitive with local universities and regional and international research organizations. This will in many cases require relaxation of some of the constraints of civil service human resource practices.

Sustained funding requires a commitment of national governments and regional bodies and cannot depend largely on donors or external contributions. This, in turn, requires clear demonstration of the benefits of agricultural R&D, and creation of national advocacy groups to assure vocal and visible support.

Returns on research depend on effectively selecting areas of emphasis to assure demand by final users, and then establishing good procedures to work with the users for successful adoption. Geospatial analysis should be used to target the release of varieties and technologies and to estimate ex ante adoption rates. Where adoption either leads or lags projections, specific studies should be undertaken to assess barriers or identify accelerating factors.

The regional agrifood system described above is complex and raises significant managerial challenges for decision makers. It is not, however, new or a radical departure from the system that is already in place and evolving. In addition to the specific messages summarized above, this report emphasizes the importance of and benefits from applying analytical tools in decision making for agricultural transformation. A sample of such tools is presented in this report. The applications of the tools and findings herein reported are sound, but also limited by context and availability of data. Capacity for continuous analysis and reanalysis should be built into the management process, with regular convening of researchers by a regional body to evaluate new scenarios and process new data. Capacity already exists within the West African region to work with foresight models, computable general equilibrium (CGE) models, geospatial tracking tools, analysis of returns on investment in research, impact assessment, and the ASTI methods of tracking investments in agricultural science. An ongoing analytical effort should be built into investments in agricultural transformation under the leadership of a regional body and with collaboration of CGIAR and other advanced research institutes.

1. Introduction

West African countries are projected to continue the substantial macroeconomic growth observed in recent decades. Many will enter middle-income status by 2030, and more will do so by 2050. The dynamism observable now in many rural areas will accelerate as towns grow and villages link to them through roads, power, and people who travel. Other localities not well positioned for dynamic change will be increasingly isolated, reflecting and augmenting demographic shifts. Climate change will have a discernible impact on rural West Africa by 2030, and even greater effect as the horizon stretches to 2050 and beyond. Agriculture will grow absolutely but decline as a share of national and regional economies as services and manufacturing increase more rapidly than primary agriculture. How rapidly agriculture's share declines will depend in large part on how durable the forces are that propelled rapid growth in the first decade of the 21st century, and particularly how commodity prices move in the future.

Because prospects for growth based on mining, manufacturing, and services are uncertain, agriculture will need to respond to a multifaceted growth agenda, and its importance will exceed its share of gross domestic product (GDP). Agriculture's traditional role in reducing rural poverty remains important. Additionally, agriculture will be called upon to create jobs for a rapidly growing population, to contribute to improved nutrition and health, to underpin growth in the private sector (particularly in food processing and handling), and to facilitate adaptation to climate change.

Achievement of multiple objectives through agricultural growth is feasible, but will require an approach to sectoral management quite different from that of the past. An earlier singular focus on agriculture's contribution to poverty reduction emphasized the products and technologies of most importance to the poor, and especially the staple grains. A broader set of objectives requires different criteria for decision making and different decision tools. West African agriculture will need to become technologically more sophisticated and derive more benefit from a strong foundation in agricultural science. A decision simply to invest more in agricultural science, however, will not be sufficient. Choices will need to be made about the composition of a portfolio of scientific research projects; the volume and time path of investment; institutional reforms to assure regional integration of scientific effort and high payoffs from investment; complementary commitments to infrastructure, water management, and agricultural services; and policy and regulatory reforms to speed adoption and use of technical innovations. These decisions require the weighing of alternatives and choice among trade-offs, all within a framework of uncertainty. The decisions are complex. Although an array of choices may lead to desirable outcomes, scope for costly mistakes is also substantial. Analytical tools designed to help assess evidence as it accumulates and evaluate relevant scenarios should be built into the management strategy. The suite of investments to support West African agricultural transformation should include development of national and regional capacity to apply and refine relevant decision tools.

The pages that follow provide several examples of such analytical tools and their applications. The analysis presented is most fully developed with regard to climate resilience, growth, and the requirements to strengthen the scientific foundations for technical dynamism. Analysis addressing job creation and nutrition is sketched more lightly and can be more fully developed in subsequent work. Continued analysis of scenarios during implementation of reinvestment in agricultural science can facilitate adjustments in course to keep science on track to achieve impact. Foresight analysis can also provide early warning of locally specific agricultural challenges in time to assist affected populations and highlight new opportunities.

2. Key Trends and Challenges

Demand Side Drivers of Change

Total global demand for food has grown by an average of 2.6 percent per year over the past two decades. It has grown by 3.9 percent per year in Africa south of the Sahara (SSA), and by 4.3 percent per year in West Africa (Table 2.1). Key drivers of demand are changes in population and income, both of which have grown more rapidly in SSA and in West Africa than in the world as a whole over the past two decades. Population has grown roughly twice as fast in SSA and in West Africa as it has globally. GDP in West Africa has grown faster than in SSA and nearly twice as fast as global average growth. Within West Africa, income has grown most rapidly in Nigeria, and population in Niger.

Table 2.1 Change in key drivers of demand for food in West Africa, 1990–2015

	Annual percentage change, 1990–2015			
Geographic region	**Population**	**GDP**	**Per capita income**	**Total food demand**
World	1.7	6.2	4.4	2.6
SSA	3.4	8.7	5.2	3.9
West Africa	3.4	11.6	7.9	4.3
Benin	3.8	7.5	3.5	4.8
Burkina Faso	3.7	6.6	2.8	4.0
Cabo Verde	3.4	8.5	6.1	3.1
The Gambia	3.5	5.6	1.6	3.2
Ghana	2.2	9.7	6.3	4.0
Guinea	3.2	4.7	1.1	6.1
Guinea-Bissau	3.9	7.6	4.6	4.0
Côte d'Ivoire	3.2	5.7	2.4	2.8
Liberia	2.8	8.7	4.6	2.6
Mali	3.9	8.1	4.3	2.9
Mauritania	3.7	8.1	4.3	4.5
Niger	3.7	5.4	0.7	4.3
Nigeria	4.7	14.7	11.1	5.0
Senegal	3.3	4.4	0.9	4.3
Sierra Leone	3.5	9.9	7.0	3.5
Togo	2.6	4.7	1.2	4.1

Source: World Bank (2017a) and FAO (2017a).

Note: Total food demand data are only available through 2013. SSA = Africa south of the Sahara; GDP = gross domestic product.

The relationship between food demand and population and income is not simple. Both are important drivers, but their influence varies at different income levels and for different commodities. Other factors such as urbanization, education, and marketing also influence preferences (Palazzo et al. 2017). The particular measure of food demand presented in Table 2.1 (from FAO) is derived in terms of weight, and is therefore dominated by lower-value staple commodities (cereals and roots and tubers) relative to higher-value foods. Given their low responsiveness to changes in income and prices, demand for the former is more closely related to population, while demand for the latter is more sensitive to increases in income. These relationships are not easily summarized in aggregate statistics, but they are captured in the model projections presented later in this report. Although different measures of demand will yield different values, the observation that demand for food in West Africa is growing rapidly due both to population and income remains valid. The observation carries strong implications for needed adjustment on the supply side, and for failure to do so adequately and in a timely fashion.

Agricultural growth in West Africa has been robust since 1995, although it slowed in the latter part of the period (Table 2.2).

Table 2.2 Growth rate of agricultural value-added (%) by region

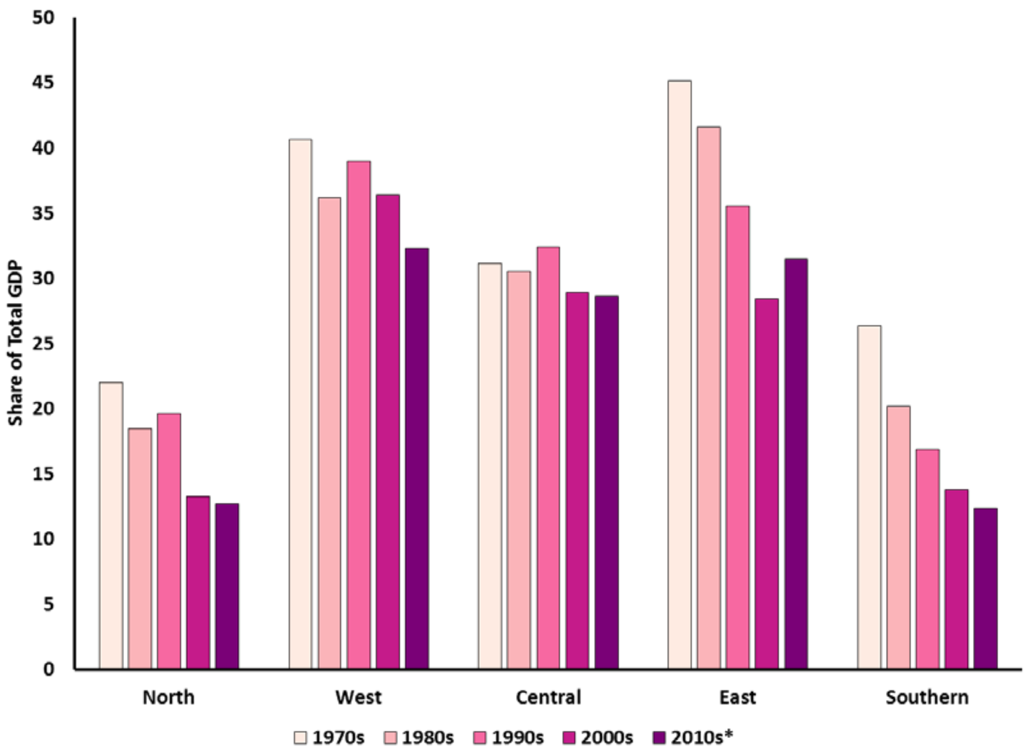
	Annual percentage change	
	1995–2005	**2006–2014**
World	2.7	2.8
Africa	5.1	4.7
North Africa	3.5	4.3
SSA	5.5	4.8
East Africa	2.8	3.9
Central Africa	1.1	4.9
Southern Africa	2.4	3.0
West Africa	9.9	5.4
Benin	5.3	2.7
Burkina Faso	6.0	3.2
Cabo Verde	5.5	2.6
The Gambia	5.8	1.4
Ghana	—	4.1
Guinea	4.3	4.1
Guinea-Bissau	—	-4.8
Côte d’Ivoire	—	21.9
Liberia	—	4.1
Mali	3.4	4.9
Mauritania	-0.5	3.3
Niger	—	5.3
Nigeria	11.6	5.2
Senegal	1.3	3.4
Sierra Leone	3.5	4.7
Togo	2.1	0.7

Source: World Bank (2012a) (constant 2010 US dollars)

Note: Trend growth for given period; SSA = Africa south of the Sahara; — = data not available.

As shown in Figure 2.1, West African economies are developing in a pattern consistent with global experience, according to which manufacturing, services, and mining grow more rapidly than agriculture, resulting in a declining share of total GDP for primary agriculture as the economy grows and its structure changes. Figure 2.1 also shows, however, that this process of structural change in West Africa is not rapid. Agriculture's share has declined modestly since 1970, and considerably less than is the case in eastern and southern Africa.

Figure 2.1 ReSAKSS regional trends of country averages for value-added agricultural GDP as a share of total GDP



Source: World Bank (2015); Sulser et al. (2015).

Note: Agriculture corresponds to International Standard Industrial Classification (ISIC) divisions 1–5 and includes forestry, hunting, and fishing as well as cultivation of crops and livestock production. *Value-added* is the net output of a sector after adding all outputs and subtracting intermediate inputs. It is calculated without making deductions for depreciation of fabricated assets or depletion and degradation of natural resources. The origin of value-added is determined by ISIC, revision 3.

ReSAKSS = Regional Strategic Analysis and Knowledge Support System; * = including latest available data; GDP = gross domestic product.

The continued high importance of agriculture in West Africa reflects the current strength and potential of the sector. Although it is often the case that the poorest and least structurally dynamic countries are most dependent on agriculture, West Africa is not poor relative to East and Central Africa (see Table 2.3). Agriculture in West Africa remains important even in countries most advanced in structural change and heading toward middle-income status, as well as in the poorer countries. Change and modernization in agriculture in the most advanced West African countries that have good agricultural endowments allow agriculture to grow at rates approaching those of other sectors. The continued size and strength of the sector signals the potential for it to contribute to growth and job creation and enhances the case for reinvestment with sound sectoral management.

Table 2.3: Baseline (SSP2) per capita GDP trends, 2010, 2030, and 2050 (US$1,000, constant year 2005)

	2010	2030	2050
East Asia & Pacific	8.81	22.34	35.41
South Asia	2.74	6.98	13.88
Middle East & North Africa	9.96	17.09	26.04
SSA	1.97	3.81	7.79
Latin America & Caribbean	10.01	16.94	25.85
Former Soviet Union	10.23	21.38	32.40
Europe	27.23	36.24	48.15
North America	41.49	56.72	66.52
World	9.82	17.29	25.19
North Africa	6.23	12.26	22.16
West Africa	1.70	3.88	8.60
Central Africa	1.22	2.35	5.63
East Africa	1.22	2.59	6.13
Southern Africa	4.79	7.94	12.00
AMU	6.87	13.15	21.89
CENSAD	2.65	5.34	10.70
COMESA	2.05	3.97	8.25
EAC	1.23	2.69	6.26
ECCAS	1.72	2.99	5.90
ECOWAS	1.70	3.88	8.60
IGAD	1.26	2.63	6.19
SADC	2.83	4.71	8.10

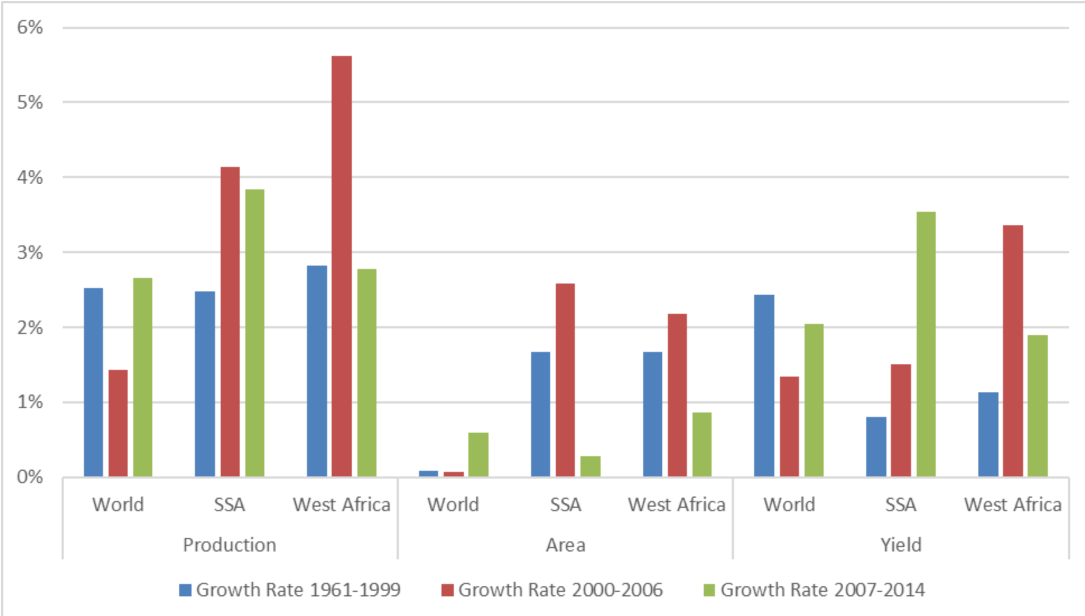
Source: IIASA SSP database (2013); Sulser et al. (2015).

Note: Small island nations not included (for example, Cape Verde, Comoros, Mauritius, Seychelles, São Tomé, and Príncipe); AMU = Arab Maghreb Union; CENSAD = Community of Sahel-Saharan States; COMESA = Common Market for Eastern and Southern Africa; EAC = East African Community; ECCAS = Economic Community of Central African States; ECOWAS = Economic Community of West African States; IGAD = Intergovernmental Authority on Development; SADC = Southern African Development Community; SSA = Africa south of the Sahara; GDP = gross domestic product. SSP2 = Shared Socio-economic pathway 2.

Supply-Side Drivers of Change

At the global scale, production has kept pace with growth in demand, as evidenced by a secular decline in real food prices between 1970 and 2000 and subsequent modest reversal of the trend (FAO 2017b). Over the past half century, most of the increase in global food production has come from yield improvements, with the remainder coming from an increase in land area used for agriculture and increased cropping intensity. In the case of cereals, almost the entire increase in global production over the past half century has come from increased yields, with virtually no increase in area (Figure 2.2). In SSA and in West Africa, the area devoted to cereals grew more rapidly than yields during 1961–1999, but that pattern had reversed by 2007–2014. Experiences have varied across crops, generally with increasing area devoted to rice, maize, and wheat and declining area used for millet and sorghum (Figures 2.2–2.7).

Figure 2.2 Annual percentage increase in cereal production, area, and yields, 1961–2014



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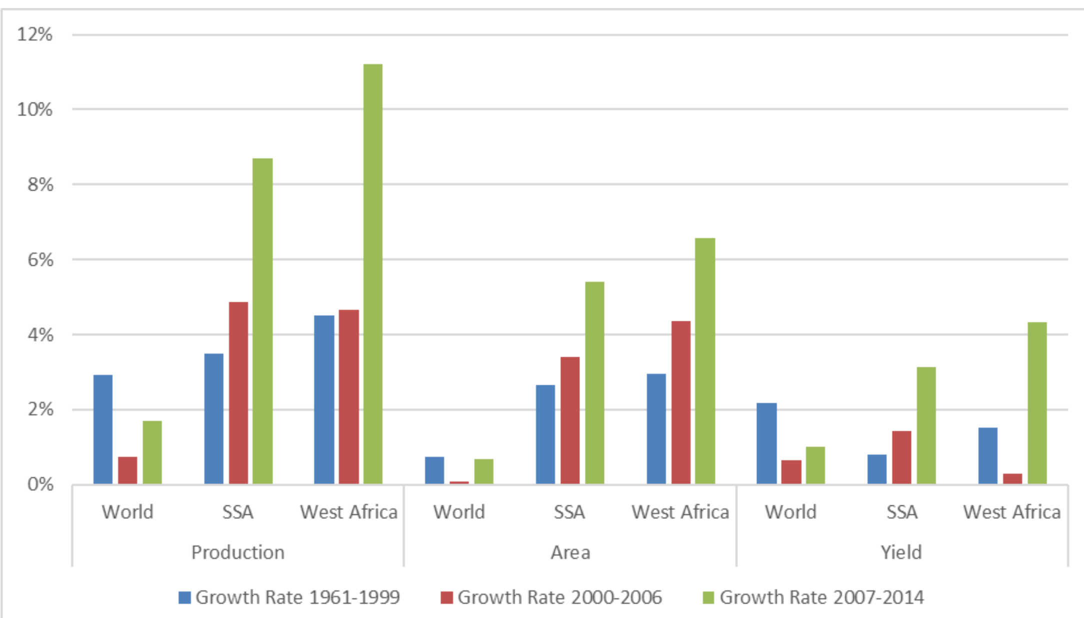
Source: IFPRI, based on data from FAO (2017a).

Note: Cereals includes some that are not reported individually in Figures 2.3–2.7; SSA = Africa south of the Sahara.

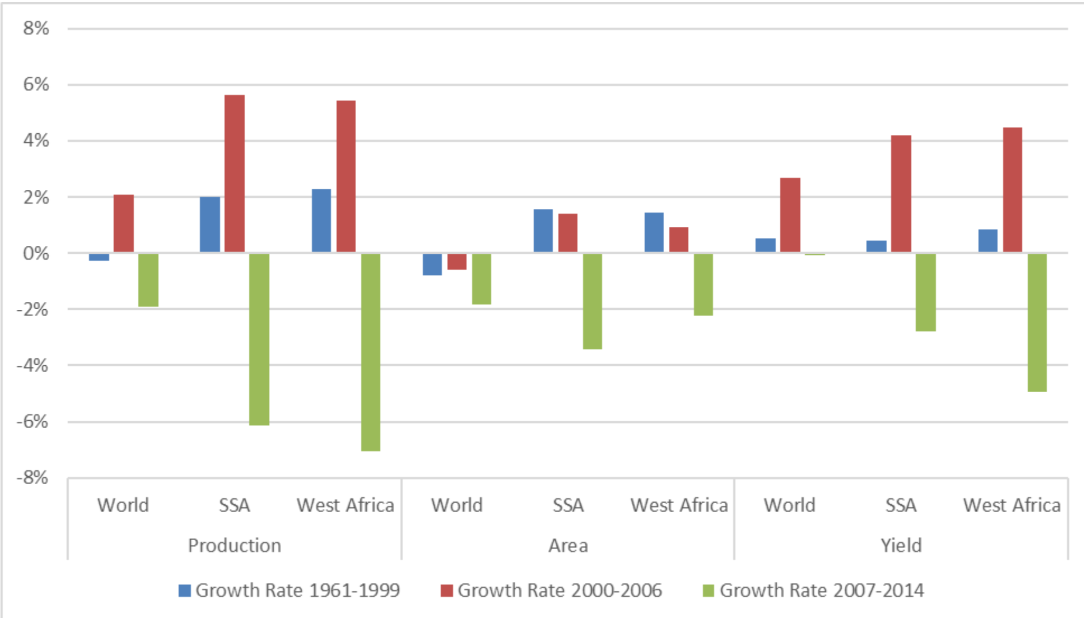
Figure 2.3 Annual percentage increase in rice production, area, and yields, 1961–2014



Source: IFPRI, based on data from FAO (2017a).

Note: SSA = Africa south of the Sahara.

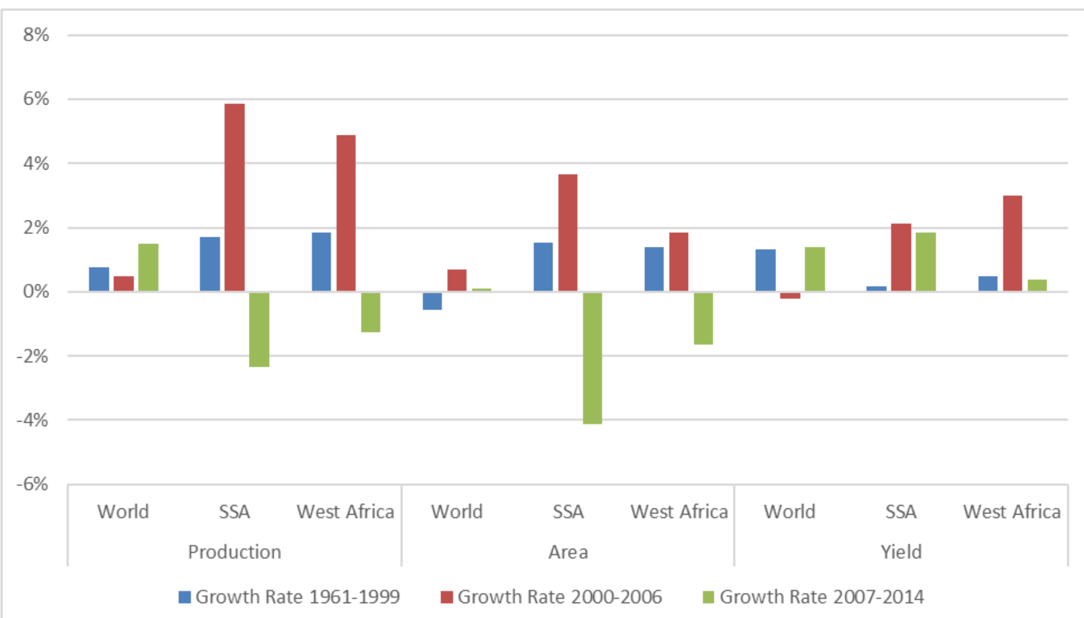
Figure 2.4 Annual percentage increase in millet production, area, and yields, 1961–2014



Source: IFPRI, based on data from FAO (2017a).

Note: SSA = Africa south of the Sahara.

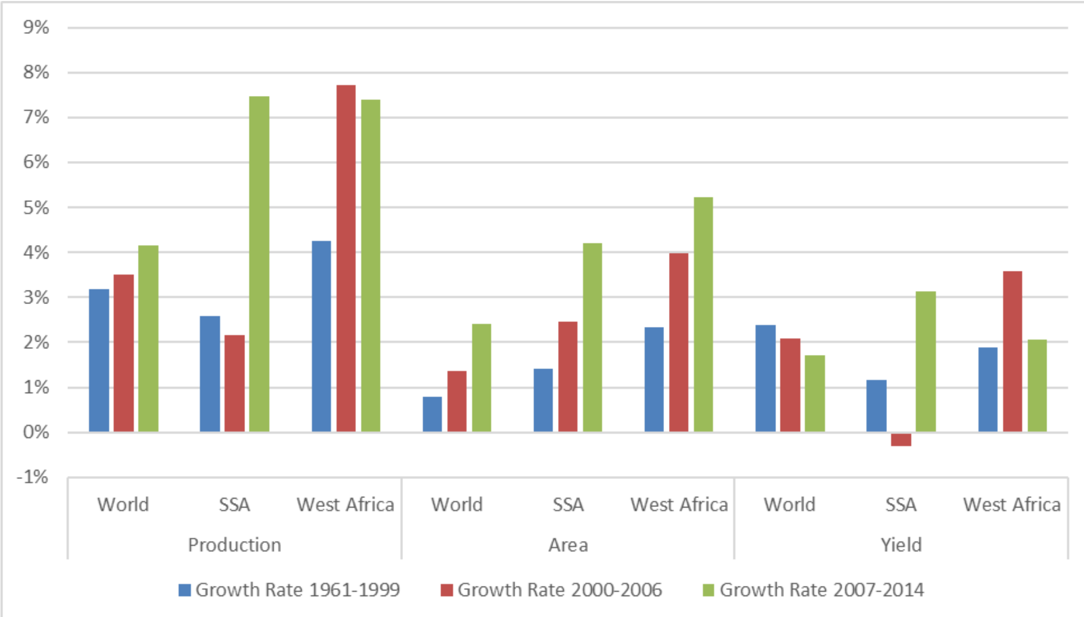
Figure 2.5 Annual percentage increase in sorghum production, area, and yields, 1961–2014



Source: IFPRI, based on data from FAO (2017a).

Note: SSA = Africa south of the Sahara.

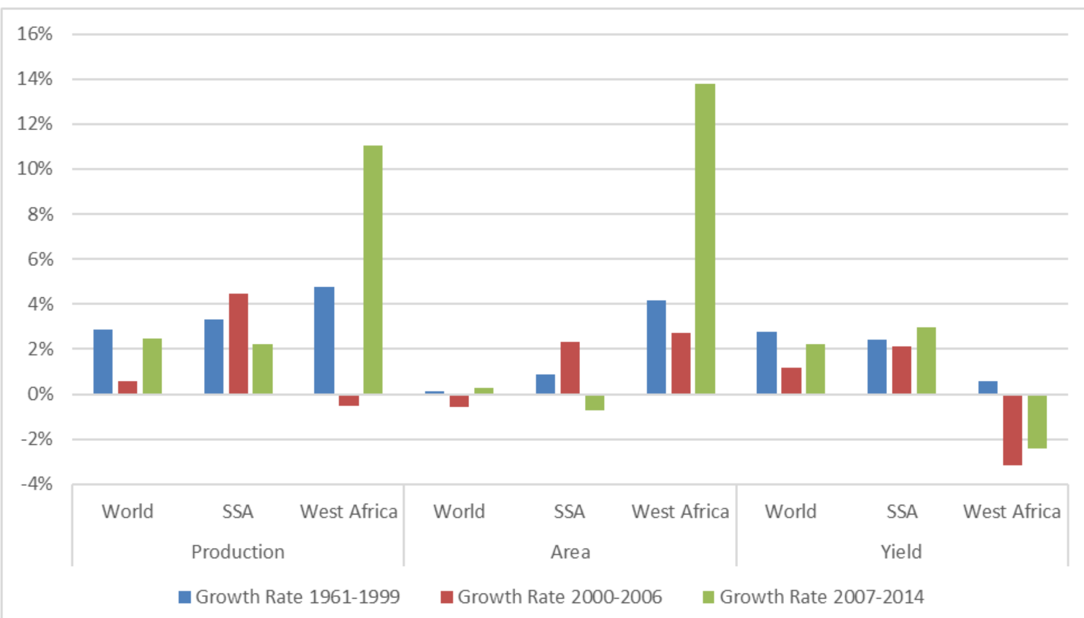
Figure 2.6 Annual percentage increase in maize production, area, and yields, 1961–2014



Source: IFPRI, based on data from FAO (2017a).

Note: SSA = Africa south of the Sahara.

Figure 2.7 Annual percentage increase in wheat production, area, and yields, 1961–2014

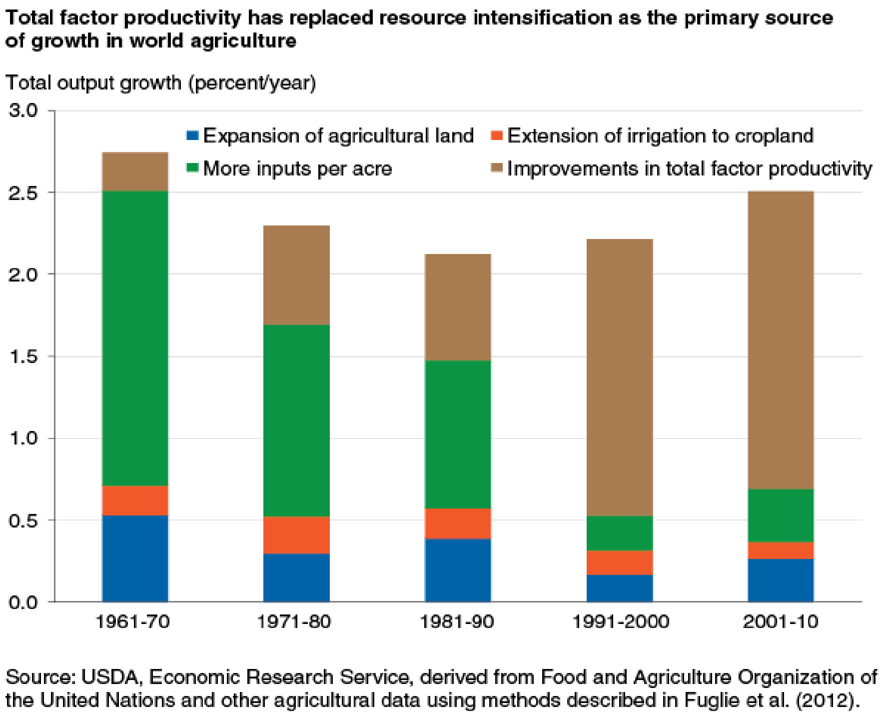


Source: IFPRI, based on data from FAO (2017a).

Note: SSA = Africa south of the Sahara.

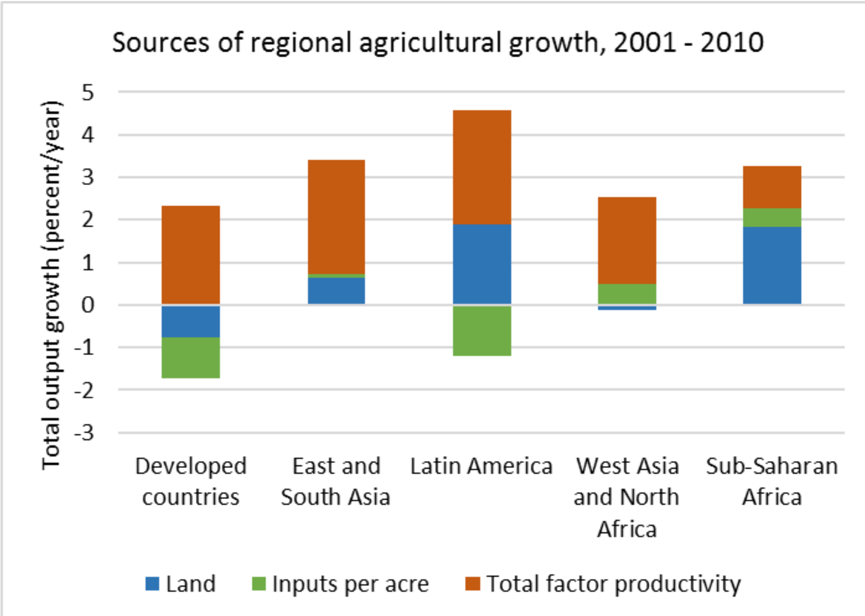
Increases in productivity have in turn come from a combination of increased application of inputs (such as irrigation water, fertilizer, and pesticides) and improvements in genetic material and management practices. Globally and in most regions, the share of growth in total output that comes from area expansion and increased input use has declined over the past half century to around one-quarter (Figure 2.8), but in SSA that share has remained high—with around 60 percent of output growth coming from expansion of cultivated area and another 20 percent from increased application of inputs per acre (Figure 2.9). This indicates both the magnitude of potential gains still to be realized from technical change and the persistence of barriers to realizing those gains. Total factor productivity in West African agriculture is estimated to have increased modestly, with growth in most countries at less than 1 percent annually, and a few in the range of 1–3 percent annually over the past two decades (Figure 2.10).

Figure 2.8 Sources of productivity growth in world agriculture, 1960–2010



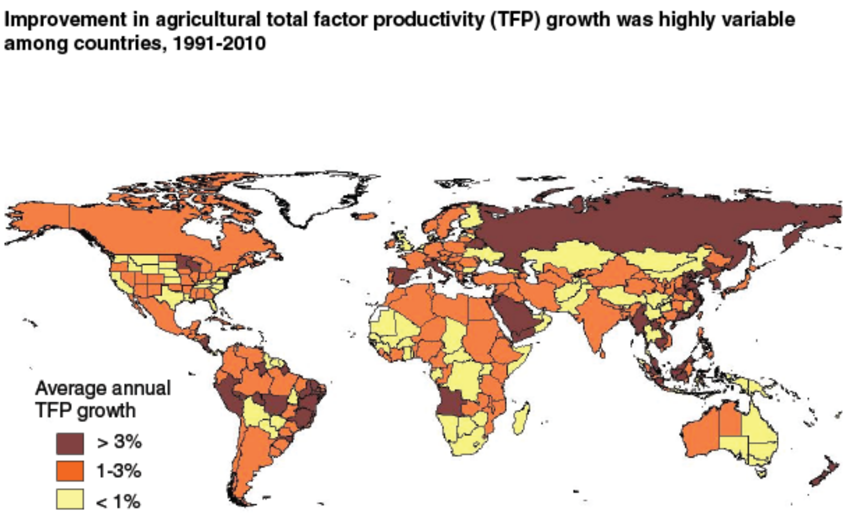
Source: Fuglie and Rada (2013).

Figure 2.9 Sources of regional productivity growth in agriculture, 2001–2010



Source: The authors, based on data from Fuglie and Rada (2013).

Figure 2.10 Total factor productivity growth in agriculture by country, 1991–2010



Source: Fuglie and Rada (2013).

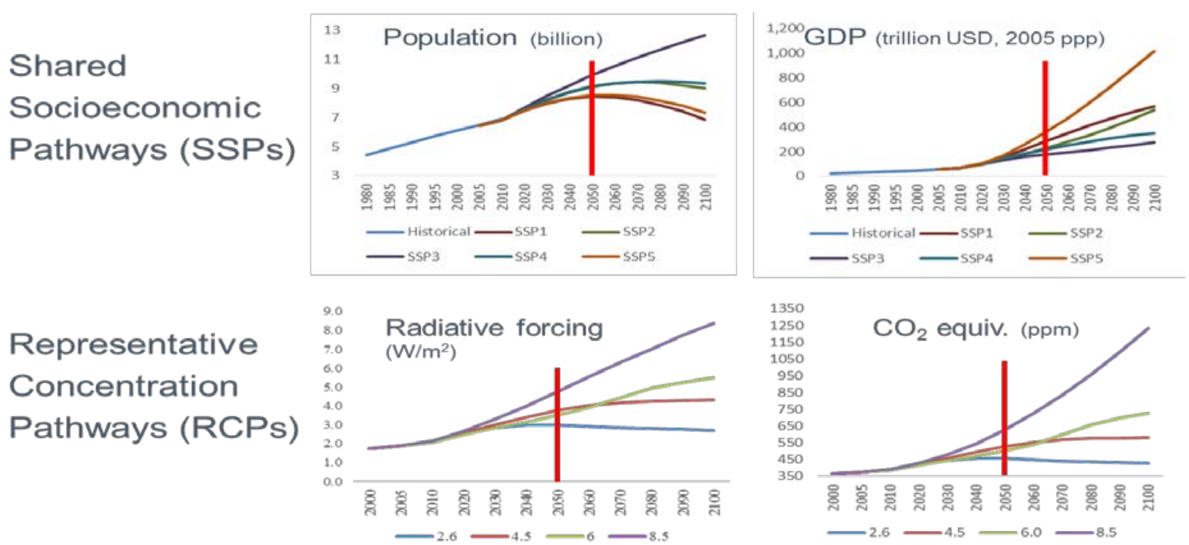
Both area expansion (extensification) and increased input use (intensification) involve environmental costs. Extensification may involve conversion of grassland, wetland, or forestland to cropland, with associated losses in biodiversity and water storage capacity and increases in soil erosion and GHG emissions. Intensification may involve increased runoff of agricultural chemicals, water pollution, soil compaction, and loss of soil fertility, as well as impacts on biodiversity and GHG emissions.

Agricultural productivity and production also depend on changes in the quality of the natural resource base. An estimated 28 percent of SSA's population lives in areas that have experienced land degradation over the past three decades (Le et al. 2014, cited in Nkonya et al. 2016). Poor access to markets, insecure land tenure, low levels of public and private investment, and government ineffectiveness are among the factors cited that lead to unsustainable cultivation practices and accelerate land degradation in many areas. Changes in temperature and precipitation are also critical to crop and livestock production. Since 1880, global average surface temperatures have increased by about 0.85 degrees Celsius (IPCC 2014). Precipitation patterns vary with El Nino cycles as well as with longer-term patterns that affect the timing and duration of growing seasons.

Changes in Key Drivers in the Future

How will demand and supply change in the coming decades? Although the future cannot be predicted with certainty, an understanding of possible future scenarios and likelihoods associated with them can inform investment choices made now. Given the complexity and uncertainty inherent in projecting changes in climate and other key drivers, the global modeling community, in the context of the IPCC assessment reports, has developed scenarios of change in key biophysical and socioeconomic drivers to help explore alternative possible futures. Representative Concentration Pathways (RCPs) provide a standardized set of alternative assumptions about the rate and ultimate level of climate change, while Shared Socioeconomic Pathways (SSPs) provide a standardized set of alternative assumptions about changes in population, income, and other factors (Figure 2.11). SSP2 is considered a middle-of-the-road scenario in terms of population and income growth, while the other SSPs vary in terms of population and income as well as sustainability of production technologies, degree of global market integration, and other factors. RCPs range from RCP 2.6 (relatively minor climate change) to RCP 8.5 (relatively rapid climate change). These may well differ from projections by others, but they are used in our work (and that of other leading research groups) because they facilitate consistent and comparable analysis by the global modeling community.

Figure 2.11 Alternative pathways for socioeconomic and climate change, 2010–2100



Source: Downloaded from the RCP Database version 2.0.5 (2015). RCP 2.6: van Vuuren et al. (2006); van Vuuren et al. (2007). RCP 4.5: Clark et al. (2007); Smith and Wigley (2006); Wise et al. (2009). RCP 6.0: Fujino et al. (2006); Hijioka et al. (2008). RCP 8.5: Riahi and Nakicenovic (2007).

In the discussion that follows, our analysis focuses on scenarios based on the assumptions of SSP2 and RCP 8.5 (that is, middle-of-the-road socioeconomic change and rapid climate change).[2] Under SSP2, population and income are projected to increase more slowly during 2010–2050 than they did during 1990–2010, but still more rapidly in SSA and West Africa than in the world as a whole (Table 2.4). Within West Africa, population growth is projected to remain most rapid in Niger (at an average of 3.3 percent per year to 2030 and 3.0 percent per year during 2010–2050), and GDP is projected to grow most rapidly in Guinea and Liberia (at an average of over 9 percent per year to 2030 and over 8 percent per year during 2010–2050). Per capita income in West Africa is projected to increase at an average annual rate of 4.1 percent to 2050, for a cumulative fivefold increase between 2010 and 2050.

Table 2.4 Changes in key drivers of demand for food, 2010–2030 and 2010–2050 (SSP2)

	Annual percentage change					
	Population		GDP		Per capita income	
	2010–2030	2010–2050	2010–2030	2010–2050	2010–2030	2010–2050
World	0.9	0.7	3.8	3.1	2.9	2.4
SSA	2.2	1.8	5.6	5.4	3.3	3.5
West Africa	2.3	2.0	6.6	6.2	4.2	4.1
Benin	2.4	2.0	5.0	5.3	2.5	3.3
Burkina Faso	2.6	2.2	6.5	6.4	3.9	4.1
Cabo Verde	0.6	0.4	4.3	6.8	3.7	5.6
The Gambia	2.1	1.6	5.7	5.6	3.6	3.9
Ghana	2.0	1.6	7.3	6.3	5.2	4.6
Guinea	1.5	1.1	9.8	8.1	8.2	6.9
Guinea-Bissau	1.6	1.2	5.4	5.9	3.7	4.6
Côte d'Ivoire	1.4	1.1	7.3	6.8	5.8	5.6
Liberia	3.3	2.6	9.2	8.4	5.8	5.6
Mali	2.6	2.1	5.4	5.9	2.7	3.7
Mauritania	1.9	1.5	5.4	5.2	3.5	3.6
Niger	3.3	3.0	6.7	6.9	3.3	3.8
Nigeria	2.4	2.2	6.5	6.2	4.0	3.9
Senegal	2.1	1.7	5.3	5.4	3.1	3.6
Sierra Leone	2.0	1.6	7.0	6.6	4.9	4.8
Togo	1.7	1.4	5.4	5.4	3.7	4.0

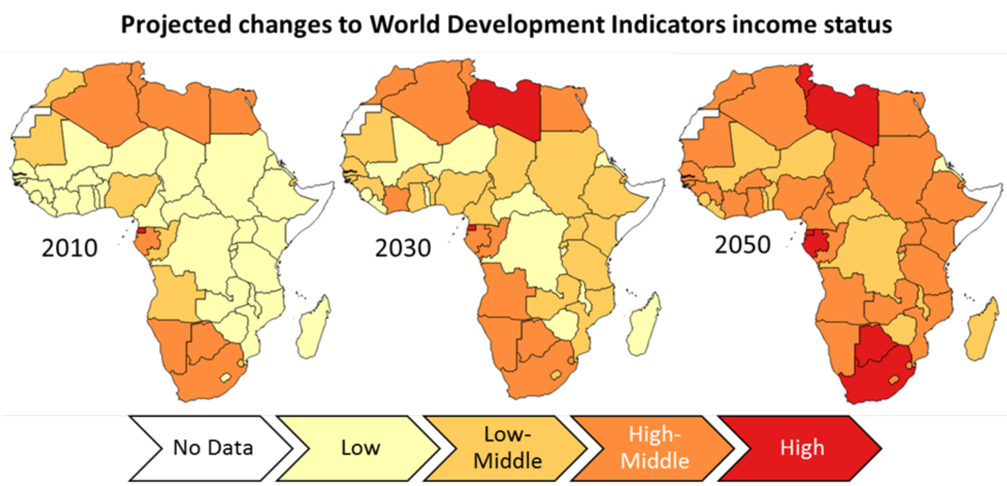
Source: IIASA SSP database (2013); for Shared Socioeconomic Pathway 2.

Note: GDP = gross domestic product

[2] SSP2 and RCP 8.5 (a high-emissions pathway) were chosen in order to illustrate the range of possible climate change impacts relative to a no-climate-change scenario. Actual impacts would be expected to fall somewhere between the no-climate-change and the RCP 8.5 scenarios.

Many countries in Africa are on a path to become middle-income countries in the coming decades (Sulser et al. 2015). Each country will face its own challenges in raising incomes and is starting from a different position when compared with other African nations, but the outlook for improving income status is clearly positive across the regions. According to this scenario, West Africa will be growing fast, but at roughly the average rate for the continent as a whole, behind northern and southern Africa and ahead of eastern and central Africa. Table 2.3 and Figure 2.12 reflect the increasing levels of per capita GDP and their income-level classification according to the World Bank's standard definition (held constant at today's specification) that are embedded in the middle-of-the-road SSP2 socioeconomic scenario specification commonly used by global foresight modelers. These assumptions for economic and population growth for Africa are somewhat optimistic, with most of the continent achieving at least middle-income status by 2030 (and only two or three countries left in low-income status by 2050). Reality may play out much differently from what is shown here, but the outlook for socioeconomic growth is positive and optimistic. This will have important implications for other sectors of the economy and production and consumption patterns.

Figure 2.12 Baseline (SSP2) per capita GDP classification and transitions, 2010, 2030, and2050

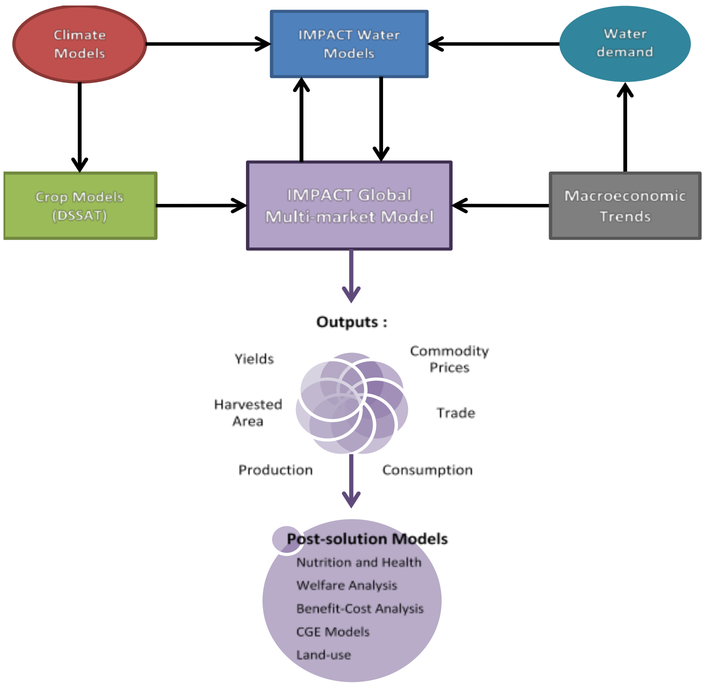


Source: IIASA SSP database (2015); World Bank (2015); and Sulser et al. (2015).

Note: GDP = gross domestic product

To explore how changes in these factors will affect agriculture and food in West Africa in the coming decades, we use a system of models developed by IFPRI, called the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT). IMPACT is a linked system of climate, water, crop, and economic models (Figure 2.13). IMPACT has been further developed in recent years through ongoing collaboration among the 15 Centers of CGIAR through the Global Futures and Strategic Foresight program and with other climate, crop, and economic modeling groups through the Agricultural Model Intercomparison and Improvement Project (AgMIP). More details on the IMPACT model and methodology can be found at www.ifpri.org/program/impact-model.

Figure 2.13 The IMPACT system of models



Source: Robinson et al. (2015b).

Note: IMPACT = International Model for Policy Analysis of Agricultural Commodities and Trade.

In the next section we explore how changes in population, income, and climate are projected to affect agriculture and food in West Africa by 2050 according to the scenario outlined above.

3. Baseline Projections for Agriculture and Food to 2030 and 2050

Using the IMPACT model with standard assumptions on changes in population, income, and climate as reflected in SSP2 and RCP 8.5, together with assumptions of moderate growth in agricultural productivity, we recently released a new set of baseline projections of agricultural production, food consumption, trade, and risk of hunger in IFPRI's 2017 Global Food Policy Report (IFPRI, 2017). Selected results from those projections are presented in the following tables. (The full set of results can be found online at https://dataverse.harvard.edu/dataverse/impact.)

Cereal production is projected to increase by about 50 percent in West Africa by 2030 and to double by midcentury, but production will be about 6 percent less than it would have been in the absence of climate change by 2030 and 10 percent less by 2050 (Table 3.1). (The result assumes moderate growth in agricultural productivity—an assumption that can be adjusted according to decisions made regarding investment in agricultural R&D.) Net imports of cereals in the region are projected to double by 2030, and to increase fourfold by 2050 relative to 2010 levels. Climate change is not projected to affect cereal imports by 2030, but, perhaps counterintuitively, net cereal imports into the region are projected to be lower in 2050 with climate change than they would have been in the absence of climate change. This is because temperature increases are projected to be greater at higher latitudes, reducing growth in production by the major cereal-producing and -exporting countries, and raising prices. Higher prices will in turn reduce cereal imports by West African and other developing countries. The combined impact of increased population, slower growth in production due to climate change, and imports that are lower than they would have been in the absence of climate change means that per capita consumption of cereals will remain basically unchanged in the region in 2030 and 2050 relative to 2010.

Table 3.1 IMPACT projections of cereal and meat production, consumption, and trade to 2030 and 2050

	Total Production (million metric tonnes)					Per Capita Food Consumption (kg per capita per year)					Net Trade (million metric tonnes)				
		Without climate change		With climate change			Without climate change		With climate change			Without climate change		With climate change	
	2010	2030	2050	2030	2050	2010	2030	2050	2030	2050	2010	2030	2050	2030	2050
Cereals															
World	2,155	2,746	3,235	2,621	2,990	143.5	146.7	148.3	143.4	140.3	0.0	0.0	0.0	0.0	0.0
Developing	1,390	1,826	2,154	1,802	2,109	148.7	151.6	153.0	148.0	144.5	-86.6	-124.0	-224.3	-61.5	-96.2
Developed	765	920	1,081	819	882	116.3	118.3	120.4	116.7	115.3	86.6	124.0	224.3	61.5	96.2
Asia & Pacific	859	1,067	1,195	1,047	1,165	148.7	152.1	154.3	148.9	146.0	-39.7	-69.7	-129.4	-28.8	-6.4
East Asia	393	451	479	464	511	145.2	148.2	147.3	145.4	140.0	-43.3	-63.3	-74.5	-6.4	65.6
South Asia	279	384	454	362	415	148.5	150.7	154.1	147.5	145.8	-5.1	-8.3	-52.7	-22.1	-67.0
Southeast Asia & Pacific	187	232	262	221	239	158.1	164.6	167.6	159.9	157.4	8.6	1.9	-2.2	-0.3	-5.0
Africa & Middle East	229	337	428	328	409	149.3	151.0	151.5	146.7	142.4	-91.5	-157.6	-261.3	-153.1	-239.2
Africa South of the Sahara	114	184	254	179	239	121.8	129.3	134.4	124.2	124.6	-32.2	-63.5	-119.9	-58.0	-103.0
West	49	79	110	75	99	143.5	152.4	155.3	146.9	144.8	-13.7	-29.8	-60.3	-29.1	-56.9
Central	7	12	18	12	17	59.3	65.4	68.9	62.4	63.0	-3.1	-6.3	-11.8	-5.9	-10.5
East	39	65	91	64	91	115.7	125.6	134.1	119.7	123.1	-8.7	-17.1	-31.9	-13.7	-21.8
Southern	13	18	21	19	23	182.8	194.8	201.5	187.5	187.3	-3.5	-7.1	-12.5	-4.6	-7.2
Middle East & North Africa	114	153	174	149	170	201.4	198.3	194.4	195.8	187.2	-59.3	-94.1	-141.4	-95.2	-136.2
The Americas	600	817	1,033	713	806	120.6	121.7	121.5	118.8	115.1	100.8	189.9	312.3	132.9	128.1
Latin America & the Caribbean	164	245	322	236	294	128.0	129.6	129.8	126.0	122.7	-23.4	-18.4	-5.8	-18.1	-64.2
North America	436	572	711	478	511	108.2	108.3	107.8	106.5	102.6	124.3	208.3	318.1	151.0	192.2
Europe & Former Soviet Union	467	525	579	532	611	135.9	140.6	144.2	139.1	138.8	30.4	37.4	78.4	49.0	117.5
Former Soviet Union	156	206	244	217	272	162.1	170.8	174.5	169.3	168.7	21.5	62.3	101.5	77.4	137.9
Europe	311	319	334	315	339	122.3	125.5	129.6	124.1	124.5	8.9	-24.9	-23.1	-28.4	-20.4
Meats															
World	274	381	460	380	455	39.4	45.6	49.5	45.4	49.1	0.0	0.0	0.0	0.0	0.0
Developing	174	254	312	253	309	30.5	37.7	41.9	37.5	41.5	-3.6	-14.4	-21.5	-14.4	-20.7
Developed	100	127	148	127	146	86.5	91.1	95.8	90.7	95.0	3.6	14.4	21.5	14.4	20.7
Asia & Pacific	109	150	166	149	165	30.3	39.6	43.3	39.4	42.9	-7.0	-25.3	-34.7	-25.6	-34.5
East Asia	79	99	93	98	91	56.5	76.3	81.3	75.9	80.6	-9.2	-22.5	-25.6	-22.9	-26.1
South Asia	10	19	31	19	31	6.0	10.7	17.8	10.6	17.6	0.2	-2.9	-11.4	-2.8	-11.0
Southeast Asia & Pacific	20	32	43	32	43	28.8	41.6	49.6	41.5	49.4	2.0	0.1	2.3	0.2	2.5
Africa & Middle East	22	40	66	40	65	18.3	23.7	31.3	23.6	31.0	-2.7	-6.1	-12.9	-6.0	-12.5
Africa South of the Sahara	11	20	35	20	35	13.0	18.1	26.8	18.1	26.6	-0.4	-3.6	-13.5	-3.5	-13.1
West	3	6	11	6	11	10.2	16.2	26.6	16.1	26.3	-0.3	-1.9	-7.3	-1.9	-7.1
Central	1	1	2	1	2	9.1	12.2	17.0	12.1	16.8	-0.4	-1.0	-2.1	-1.0	-2.0
East	3	6	10	6	10	10.3	14.4	22.5	14.3	22.2	0.0	-1.1	-4.9	-1.1	-4.7
Southern	2	4	5	4	5	45.2	61.0	73.3	60.8	72.7	-0.2	-0.1	-0.1	-0.1	-0.1
Middle East & North Africa	11	20	31	19	31	28.3	36.0	42.4	35.8	42.0	-2.3	-2.5	0.7	-2.5	0.5
The Americas	89	127	158	127	156	82.2	88.0	93.0	87.5	92.1	11.5	29.1	44.5	29.0	43.8
Latin America & the Caribbean	44	67	85	66	84	61.4	69.9	76.6	69.4	75.6	7.2	16.7	25.9	16.7	26.0
North America	45	61	73	60	72	117.6	119.0	120.2	118.6	119.3	4.4	12.5	18.7	12.3	17.8
Europe & Former Soviet Union	54	64	69	64	69	67.5	72.0	76.3	71.6	75.5	-1.8	2.3	3.0	2.6	3.3
Former Soviet Union	10	12	14	12	13	46.0	55.3	59.5	55.0	59.0	-3.0	-3.3	-3.2	-3.3	-3.2
Europe	44	52	56	52	56	78.6	80.3	84.4	79.8	83.5	1.2	5.6	6.2	5.9	6.4

Source: IFPRI 2017.

Note: World figures include other regions and countries not reported separately. Country-level details are available online at https://dataverse.harvard.edu/dataverse/impact. Total production is aggregated across irrigated and rainfed systems at the national level and aligned with years as reported in FAO (2017b). Per capita food consumption is based on food availability at the national level. Net trade includes negative and positive numbers, indicating that a region is a net importer or exporter, respectively, and balances to zero at the global level. Cereals include barley, millet, rice, sorghum, wheat, and aggregated other cereals. Meats include beef, pork, poultry, sheep, and goats. Values reported for 2010 are calibrated model results. Projections for 2030 and 2050 assume changes in population and income as reflected in the IPCC's Shared Socioeconomic Pathway 2.

Climate- change impacts are simulated using the IPCC's Representative Concentration Pathway 8.5 and the HadGEM general circulation model. Further documentation is available at www.ifpri.org/program/impact-model. IMPACT = International Model for Policy Analysis of Agricultural Commodities and Trade.

At the level of individual cereals, we see that per capita consumption of maize will decline slightly in West Africa, while consumption of other cereals will increase (Table 3.2). Production of maize in West Africa is projected to increase by half by 2050, production of millet and sorghum will double, and production of rice will triple over the same period. In all cases, net imports are projected to increase.

Table 3.2 IMPACT projections of maize, millet, rice, sorghum, and wheat production, consumption, and trade to 2030 and 2050

	Total Production (million metric tonnes)					Per Capita Food Consumption (kg per capita per year)					Net Trade (million metric tonnes)				
		Without climate change		With climate change			Without climate change		With climate change			Without climate change		With climate change	
	2010	**2030**	**2050**	**2030**	**2050**	**2010**	**2030**	**2050**	**2030**	**2050**	**2010**	**2030**	**2050**	**2030**	**2050**
Cereals															
World	**2,155**	**2,746**	**3,235**	**2,621**	**2,990**	**143.5**	**146.7**	**148.3**	**143.4**	**140.3**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Africa	**151**	**230**	**303**	**220**	**279**	**139.9**	**143.8**	**145.9**	**138.9**	**136.2**	**-59.7**	**-106.6**	**-185.0**	**-103.2**	**-169.2**
West	49	79	110	75	99	143.5	152.4	155.3	146.9	144.8	-13.7	-29.8	-60.3	-29.1	-56.9
Central	7	12	18	12	17	59.3	65.4	68.9	62.4	63.0	-3.1	-6.3	-11.8	-5.9	-10.5
East	39	65	91	64	91	115.7	125.6	134.1	119.7	123.1	-8.7	-17.1	-31.9	-13.7	-21.8
Southern	13	18	21	19	23	182.8	194.8	201.5	187.5	187.3	-3.5	-7.1	-12.5	-4.6	-7.2
Northern	42	55	62	49	50	204.7	202.5	198.7	199.6	191.0	-30.6	-46.4	-68.5	-49.9	-72.8
Maize															
World	**754**	**1,025**	**1,296**	**913**	**1,021**	**16.7**	**18.5**	**19.5**	**17.4**	**17.6**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Africa	**52**	**74**	**87**	**73**	**82**	**38.9**	**39.0**	**37.8**	**36.1**	**33.1**	**-17.4**	**-41.7**	**-88.7**	**-33.0**	**-65.4**
West	12	18	21	16	17	24.2	24.6	23.4	22.5	20.1	-1.6	-7.9	-22.3	-7.0	-18.7
Central	3	6	7	6	7	22.0	23.6	23.4	21.5	20.1	-0.9	-2.8	-8.1	-2.3	-6.4
East	19	27	32	27	30	54.8	56.5	56.5	51.9	48.8	-3.7	-9.6	-20.7	-6.6	-14.3
Southern	10	14	16	16	19	103.9	104.0	101.4	98.0	91.9	-0.5	-3.1	-7.9	-0.1	-1.2
Northern	7	10	12	9	10	28.9	28.2	27.2	27.3	25.8	-10.8	-18.3	-29.8	-17.0	-24.9
Millet															
World	**34**	**49**	**67**	**48**	**64**	**3.6**	**4.3**	**5.2**	**4.2**	**5.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Africa	**18**	**32**	**49**	**30**	**45**	**12.8**	**14.1**	**15.9**	**13.8**	**15.2**	**-0.4**	**1.0**	**2.2**	**0.3**	**0.8**
West	15	25	37	23	33	33.8	35.0	37.3	34.2	35.8	0.0	0.3	-0.6	-0.3	-2.1
Central	1	2	3	2	3	5.8	6.7	7.6	6.5	7.2	0.0	0.2	0.8	0.1	0.5
East	2	4	7	4	7	3.8	4.1	4.4	4.0	4.2	0.0	0.7	2.0	0.8	2.7
Southern	0	0	0	0	0	1.3	1.5	1.7	1.5	1.6	0.0	0.1	0.2	0.1	0.2
Northern	1	1	2	1	1	4.3	4.8	5.2	4.7	5.1	-0.3	-0.2	-0.1	-0.4	-0.5
Rice															
World	**435**	**508**	**537**	**495**	**511**	**50.8**	**48.4**	**45.6**	**47.2**	**43.2**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Africa	**15**	**25**	**35**	**25**	**36**	**18.8**	**20.6**	**21.2**	**19.7**	**19.5**	**-7.8**	**-12.4**	**-16.5**	**-10.9**	**-11.7**
West	6	12	17	12	17	32.3	34.8	33.9	33.3	31.0	-5.9	-8.2	-11.1	-7.6	-9.2
Central	1	1	2	1	2	8.9	10.2	11.0	9.8	10.1	-0.6	-1.0	-1.3	-0.9	-1.1
East	4	8	13	9	14	13.0	14.8	16.1	14.2	14.8	-0.6	-0.6	-0.5	0.1	2.0
Southern	0	0	0	0	0	15.3	18.0	20.0	17.4	18.5	-0.9	-1.2	-1.5	-1.2	-1.3
Northern	4	4	4	4	4	15.0	14.7	14.4	14.2	13.4	0.2	-1.4	-2.1	-1.4	-2.1
Sorghum															
World	**65**	**93**	**128**	**90**	**120**	**4.1**	**5.0**	**6.0**	**4.9**	**5.8**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Africa	**28**	**46**	**69**	**45**	**65**	**18.4**	**19.8**	**21.1**	**19.3**	**20.3**	**-1.2**	**-2.0**	**-5.1**	**-2.4**	**-5.6**
West	15	24	34	23	31	33.1	34.8	36.3	34.0	35.0	0.2	-2.3	-8.8	-2.6	-9.6
Central	2	3	5	3	5	8.2	8.3	9.0	8.1	8.6	0.2	0.7	1.7	0.6	1.5
East	5	10	18	11	20	11.0	11.4	11.5	11.2	11.1	-0.3	1.0	4.1	1.7	6.6
Southern	0	1	1	1	1	2.8	3.1	3.2	3.0	3.0	-0.2	-0.1	-0.1	-0.1	0.0
Northern	6	9	12	8	9	18.9	21.1	23.0	20.8	22.2	-1.2	-1.2	-2.0	-2.1	-4.2
Wheat															
World	**647**	**797**	**890**	**788**	**929**	**65.1**	**66.9**	**67.9**	**66.1**	**64.6**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Africa	**26**	**35**	**40**	**30**	**32**	**44.3**	**42.4**	**39.9**	**41.8**	**37.8**	**-30.8**	**-45.3**	**-60.1**	**-49.0**	**-66.2**
West	0	0	0	0	0	19.0	21.6	22.1	21.2	20.6	-6.2	-10.8	-15.6	-10.7	-15.0
Central	0	0	0	0	0	11.8	13.9	15.0	13.6	14.0	-1.6	-2.9	-4.1	-2.9	-4.0
East	4	7	11	7	9	20.3	21.9	22.9	21.5	21.4	-3.7	-5.7	-7.5	-6.3	-8.1
Southern	2	3	4	2	3	57.8	65.5	71.6	64.9	68.5	-1.7	-1.9	-1.9	-2.5	-3.4
Northern	20	24	25	21	19	128.3	125.2	121.2	124.1	116.6	-17.7	-23.9	-31.0	-26.7	-35.7

Source: IFPRI (2017).

Note: See notes for Table 3.1.

Meat production in West Africa is projected to grow by around 3 million metric tons (doubling) by 2030, and by 8 million metric tons (a fourfold increase) by 2050 (Table 3.1). Net imports are projected to grow by similar amounts, resulting in a 60 percent increase in per capita meat consumption by 2030 and a 150 percent increase by 2050. Fish is not included in these results, but related work in collaboration with WorldFish shows that Africa lags other regions in fish consumption, with an average of around 10 kilograms per capita per year (compared to 20 kilograms globally and 38 kilograms in Southeast Asia) (Chan et al. 2017). In West Africa most of this comes from capture fisheries, but the share from aquaculture is increasing, and could increase further with additional investment.

Pulse production in the region is projected to nearly double by 2030 and to triple by 2050, with a shift from a position of small net exports to one of small net imports by 2050 (Table 3.3). Per capita consumption is projected to rise by about a third.

Table 3.3 IMPACT projections of pulse and root and tuber production, consumption, and trade to 2030 and 2050

	Total Production (million metric tonnes)					Per Capita Food Consumption (kg per capita per year)					Net Trade (million metric tonnes)				
		Without climate change		With climate change			Without climate change		With climate change			Without climate change		With climate change	
	2010	**2030**	**2050**	**2030**	**2050**	**2010**	**2030**	**2050**	**2030**	**2050**	**2010**	**2030**	**2050**	**2030**	**2050**
Pulses															
World	66	94	121	92	118	6.2	7.5	8.9	7.5	8.8	0.0	0.0	0.0	0.0	0.0
Developing	52	74	97	72	91	6.7	8.2	9.8	8.1	9.6	-2.8	-6.5	-9.9	-7.6	-12.8
Developed	14	19	24	20	26	3.5	3.8	4.0	3.8	4.0	2.8	6.5	9.9	7.6	12.8
Asia & Pacific	28	37	44	36	42	5.2	6.2	7.3	6.2	7.2	-0.5	-3.3	-5.2	-3.1	-5.2
East Asia	6	8	11	8	12	1.5	1.9	2.1	1.9	2.1	0.5	1.8	4.7	2.3	5.6
South Asia	16	21	24	20	23	9.4	10.6	11.7	10.5	11.5	-2.9	-6.1	-10.1	-6.2	-10.6
Southeast Asia & Pacific	7	8	8	8	8	3.1	3.6	3.9	3.5	3.8	1.9	1.0	0.2	0.8	-0.3
Africa & Middle East	16	25	35	23	32	9.7	11.3	13.4	11.2	13.1	-1.9	-5.6	-11.6	-6.5	-13.5
Africa South of the Sahara	12	19	28	19	27	10.4	12.3	14.7	12.1	14.4	-0.9	-4.0	-9.4	-4.0	-9.2
West	5	9	16	9	14	8.5	9.8	11.6	9.6	11.1	0.3	0.1	-0.3	0.0	-0.6
Central	1	2	2	2	2	6.7	7.4	8.7	7.3	8.4	-0.1	-0.2	-0.3	-0.2	-0.2
East	5	7	9	7	10	15.3	18.2	22.0	18.0	21.6	-0.7	-3.3	-7.9	-3.2	-7.5
Southern	0	0	0	0	0	3.8	4.2	4.5	4.1	4.4	-0.1	-0.1	0.0	-0.1	0.0
Middle East & North Africa	4	6	7	5	5	8.2	9.2	10.0	9.2	10.0	-1.0	-1.7	-2.3	-2.5	-4.3
The Americas	14	21	28	21	30	8.9	9.7	10.4	9.7	10.3	3.2	7.2	12.5	8.0	14.4
Latin America & the Caribbean	7	11	16	11	15	11.4	12.6	13.8	12.5	13.6	-0.7	1.1	4.4	0.7	3.1
North America	7	10	12	11	15	4.6	4.8	4.9	4.8	4.9	3.8	6.0	8.0	7.3	11.4
Europe & Former Soviet Union	8	11	14	11	14	2.6	2.7	2.8	2.7	2.8	-0.8	1.7	4.4	1.6	4.3
Former Soviet Union	3	4	5	4	5	1.5	1.6	1.6	1.6	1.6	0.4	1.3	2.4	1.3	2.5
Europe	5	7	9	7	8	3.1	3.3	3.4	3.3	3.4	-1.2	0.5	2.0	0.3	1.8
Roots and Tubers															
World	780	1,006	1,185	963	1,103	65.0	70.5	73.4	67.8	69.0	0.0	0.0	0.0	0.0	0.0
Developing	682	897	1,068	858	997	65.8	72.4	75.7	69.5	71.1	5.6	-0.6	-5.4	-0.8	-1.0
Developed	97	109	118	105	106	61.2	59.8	59.3	57.5	56.0	-5.6	0.6	5.4	0.8	1.0
Asia & Pacific	298	351	365	356	380	46.9	50.9	49.5	48.4	45.8	-4.9	-23.4	-18.8	1.2	28.2
East Asia	181	201	185	201	182	71.4	76.3	73.5	72.9	68.7	-18.5	-14.2	-0.1	-3.3	12.2
South Asia	50	75	103	79	120	27.3	35.7	38.0	33.1	34.1	-6.2	-24.2	-30.6	-12.4	1.2
Southeast Asia & Pacific	67	76	77	76	78	37.5	39.4	39.9	38.6	38.6	19.9	15.0	11.9	16.9	14.8
Africa & Middle East	245	377	524	362	486	109.3	117.3	123.1	113.9	117.0	-1.8	-13.0	-31.6	-16.6	-39.8
Africa South of the Sahara	224	349	490	333	450	146.4	152.7	156.1	149.1	149.2	-1.1	-11.0	-29.0	-17.9	-43.3
West	133	207	297	201	281	197.5	199.0	198.8	194.9	191.1	1.5	-4.3	-11.7	-4.2	-10.2
Central	37	59	80	56	72	172.5	170.6	166.7	167.1	159.9	1.0	2.6	-2.2	0.1	-8.2
East	50	78	107	71	91	129.6	138.5	142.0	134.6	134.4	-3.2	-9.4	-15.3	-13.9	-24.6
Southern	3	4	5	4	5	36.8	37.7	38.7	36.6	37.1	0.0	0.7	1.3	0.9	1.3
Middle East & North Africa	21	28	34	29	36	39.0	39.9	40.5	37.0	36.3	-0.8	-2.1	-2.6	1.3	3.5
The Americas	86	112	130	110	127	55.7	54.5	53.0	52.3	49.9	-0.3	10.2	19.1	14.3	26.6
Latin America & the Caribbean	60	82	97	83	99	51.1	49.9	47.9	48.3	45.6	0.2	11.5	20.4	16.2	29.8
North America	26	29	33	27	28	63.3	62.5	61.5	59.3	56.9	-0.4	-1.4	-1.3	-1.9	-3.2
Europe & Former Soviet Union	150	166	166	134	111	89.0	86.5	85.3	83.4	80.8	7.0	26.3	31.3	1.1	-15.1
Former Soviet Union	82	89	84	63	42	115.3	112.1	109.6	107.2	102.7	8.5	18.7	18.3	-4.1	-19.5
Europe	68	77	82	72	69	75.3	73.8	73.6	71.5	70.3	-1.5	7.7	13.0	5.2	4.4

Source: IFPRI (2017).

Note: World figures include other regions and countries not reported separately. Country-level details are available online at https://dataverse.harvard.edu/dataverse/impact. Total production is aggregated across irrigated and rainfed systems at the national level and aligned with years as reported in FAO (2017b). Per capita food consumption is based on food availability at the national level. Net trade includes negative and positive numbers indicating that a region is a net importer or exporter, respectively, and balances to zero at the global level. Pulses include beans, chickpeas, cowpeas, lentils, pigeon peas, and aggregated other pulses. Roots and tubers include cassava, potato, sweet potato, yams, and aggregated other roots and tubers. Values reported for 2010 are calibrated model results. Projections for 2030 and 2050 assume changes in population and income reflected in the IPCC's Shared Socioeconomic Pathway 2. Climate-change impacts are simulated using the IPCC's Representative Concentration Pathway 8.5 and the HadGEM general circulation model. Documentation is available at www.ifpri.org/program/impact-model. IMPACT = International Model for Policy Analysis of Agricultural Commodities and Trade.

West Africa is projected to remain Africa's largest producer and consumer of **roots and tubers** (Table 3.3) and Africa's largest producer of **oilseeds** (Table 3.4), with a doubling in production by 2050 and a small increase in net imports. Changes in imports for these commodities are driven primarily by population growth, as per capita consumption changes only slightly; that of roots and tubers is projected to decline slightly, and that of oilseeds to increase slightly.

Table 3.4 IMPACT projections of fruit and vegetable and oilseed production, consumption, and trade to 2030 and 2050

	Total Production (million metric tonnes)					Per Capita Food Consumption (kg per capita per year)					Net Trade (million metric tonnes)				
		Without climate change		With climate change			Without climate change		With climate change			Without climate change		With climate change	
	2010	**2030**	**2050**	**2030**	**2050**	**2010**	**2030**	**2050**	**2030**	**2050**	**2010**	**2030**	**2050**	**2030**	**2050**
Fruits and Vegetables															
World	1,592	2,334	3,044	2,297	2,945	196.2	240.0	284.7	236.2	275.5	0.0	0.0	0.0	0.0	0.0
Developing	1,304	1,952	2,554	1,925	2,476	191.2	239.7	290.6	235.9	281.2	15.1	-20.1	-90.5	-15.5	-81.8
Developed	288	383	490	373	470	222.8	241.4	248.6	237.8	241.2	-15.1	20.1	90.5	15.5	81.8
Asia & Pacific	868	1,259	1,586	1,262	1,583	209.7	278.7	358.7	274.4	347.4	-44.8	-141.4	-279.9	-116.1	-222.7
East Asia	609	800	938	823	992	351.0	432.7	430.1	427.1	419.4	-20.4	-5.4	192.7	28.1	265.6
South Asia	158	318	467	302	417	104.7	197.7	366.8	194.1	354.2	-29.7	-127.5	-466.1	-136.1	-483.4
Southeast Asia & Pacific	101	141	181	138	174	134.0	176.0	205.1	172.4	196.5	5.3	-8.5	-6.6	-8.2	-4.9
Africa & Middle East	251	436	661	423	623	155.9	171.4	190.1	168.5	183.5	1.9	33.1	77.8	26.4	60.3
Africa South of the Sahara	101	188	301	174	261	95.4	119.7	150.0	117.2	143.9	-1.0	-9.3	-34.1	-19.2	-60.1
West	40	74	118	70	106	117.2	145.3	174.4	142.4	167.9	0.3	-3.5	-14.8	-6.0	-22.1
Central	10	17	27	16	22	66.0	82.4	103.1	80.2	97.7	0.1	-1.3	-4.4	-2.5	-7.5
East	36	70	121	65	107	82.2	105.5	138.5	103.2	132.4	-1.2	-5.4	-12.9	-8.1	-20.3
Southern	9	15	21	14	17	76.2	89.2	98.3	87.4	94.3	2.9	6.4	10.1	5.2	7.2
Middle East & North Africa	150	248	361	249	362	270.2	284.3	290.5	280.6	282.9	3.0	42.4	111.9	45.6	120.4
The Americas	255	351	447	338	422	187.0	212.1	226.7	208.4	218.7	49.2	74.6	123.8	67.4	110.9
Latin America & the Caribbean	164	236	299	225	273	159.6	182.9	202.9	179.7	195.7	46.3	76.3	108.3	67.4	88.7
North America	91	114	147	114	149	233.6	262.4	265.9	257.7	256.7	2.9	-1.7	15.4	0.0	22.2
Europe & Former Soviet Union	218	289	351	274	317	209.2	230.9	241.8	227.8	235.3	-6.3	33.7	78.4	22.3	51.5
Former Soviet Union	62	81	95	79	90	181.6	223.0	239.5	219.9	232.6	0.1	5.0	14.0	3.9	11.1
Europe	156	208	255	195	227	223.5	234.8	242.9	231.7	236.7	-6.4	28.7	64.4	18.3	40.4
Oilseeds															
World	673	1,033	1,293	1,017	1,257	6.8	8.2	7.8	7.9	7.3	0.0	0.0	0.0	0.0	0.0
Developing	525	842	1,079	833	1,057	7.0	8.6	8.2	8.3	7.6	-3.0	-8.5	-11.5	-7.4	-9.6
Developed	148	191	214	184	200	5.6	5.9	5.9	5.6	5.5	3.0	8.5	11.5	7.4	9.6
Asia & Pacific	322	536	713	534	707	8.1	10.4	9.5	10.0	9.0	-35.4	-59.6	-69.9	-56.0	-62.1
East Asia	49	63	68	64	70	10.9	15.9	15.1	15.4	14.4	-44.3	-62.8	-66.7	-59.2	-59.5
South Asia	41	52	57	51	52	3.6	4.5	4.3	4.4	4.0	0.5	-4.5	-9.7	-4.7	-9.9
Southeast Asia & Pacific	231	421	589	420	586	13.1	14.7	14.6	14.3	13.9	8.4	7.7	6.4	8.0	7.2
Africa & Middle East	61	101	126	98	119	5.5	6.4	7.2	6.1	6.5	-6.1	-8.8	-13.5	-8.1	-11.5
Africa South of the Sahara	53	90	113	87	105	5.9	6.8	7.7	6.5	7.0	0.2	-1.2	-4.6	-1.0	-3.9
West	43	74	94	72	88	8.1	9.3	10.1	8.8	9.2	0.3	-0.5	-2.7	-0.4	-2.5
Central	4	6	8	6	7	9.0	10.0	10.6	9.4	9.5	0.1	0.1	0.1	0.2	0.4
East	4	6	7	6	7	3.7	4.4	5.3	4.2	4.8	0.1	-0.3	-1.3	-0.2	-0.9
Southern	1	1	2	1	1	1.9	2.1	2.1	2.0	2.0	-0.2	-0.3	-0.3	-0.2	-0.2
Middle East & North Africa	9	12	14	12	14	4.7	5.5	6.0	5.3	5.5	-6.3	-7.6	-8.8	-7.0	-7.6
The Americas	235	323	371	314	350	6.8	6.7	6.5	6.4	6.0	58.7	83.7	97.5	78.1	85.2
Latin America & the Caribbean	126	184	215	180	206	6.6	6.4	6.0	6.1	5.5	27.2	46.3	56.6	43.5	49.6
North America	110	139	155	134	144	7.1	7.2	7.2	7.0	6.7	31.5	37.3	40.8	34.6	35.6
Europe & Former Soviet Union	55	72	83	71	81	2.6	2.7	2.9	2.6	2.7	-17.2	-15.3	-14.1	-14.0	-11.6
Former Soviet Union	14	19	22	19	23	1.1	1.2	1.2	1.2	1.2	-0.4	0.5	1.4	0.7	1.8
Europe	40	53	60	52	58	3.3	3.5	3.6	3.3	3.4	-16.8	-15.8	-15.4	-14.7	-13.4

Source: IFPRI (2017).

Note: World figures include other regions and countries not reported separately. Country-level details are available online at https://dataverse.harvard.edu/dataverse/impact. Total production is aggregated across irrigated and rainfed systems at the national level and aligned with years as reported in FAOSTAT. Per capita food consumption is based on food availability at the national level. Net trade includes negative and positive numbers indicating that a region is a net importer or exporter, respectively, and balances to zero globally. Fruits and vegetables include banana, plantain, aggregated temperate fruits, aggregated tropical fruits, and aggregated vegetables. Oilseeds include groundnuts, rapeseed, soybean, sunflower, and aggregated other oilseeds. Values reported for 2010 are calibrated model results. Projections for 2030 and 2050 assume changes in population and income as reflected in the IPCC's Shared Socioeconomic Pathway 2. Climate-change impacts are simulated using the IPCC's Representative Concentration Pathway 8.5 and the HadGEM general circulation model. Documentation is available at www.ifpri.org/program/impact-model. IMPACT = International Model for Policy Analysis of Agricultural Commodities and Trade.

Fruit and vegetable production in the region is projected to increase by 75 percent by 2030 and by 2.5 times by 2050, and per capita consumption by half (Table 3.4). The region is projected to become a net importer of fruits and vegetables, with about one-sixth of total demand being met by imports.

Based on the combined effects of changes in population, income, climate, and productivity, the number of people at risk of hunger in West Africa is projected to rise from 30.1 million in 2010 to 32.5 million in 2030 and 33.5 million in 2050 in this scenario (Table 3.5), with climate change more than offsetting the modest improvement that would be projected in the absence of climate change. Because of growth in total population, the share of the population at risk of chronic hunger (in terms of average caloric deficiency) is projected to decline to around 6 percent in West Africa by 2030 (the target date for the Sustainable Development Goals) in the absence of climate change. (A prevalence of 5 percent is sometimes considered to be the best that can be achieved without social safety nets.) Climate change reverses these gains in West Africa as in other regions (Figure 3.1), but its effects can be offset by a comprehensive set of investments in agricultural research and infrastructure, as will be described in the following sections. It is important to note that the assessments of population at risk of chronic hunger are based on average availability of food energy and do not take into account other dimensions of food insecurity, such as micronutrient deficiencies or episodes of conflict or other shock that create localized vulnerability.

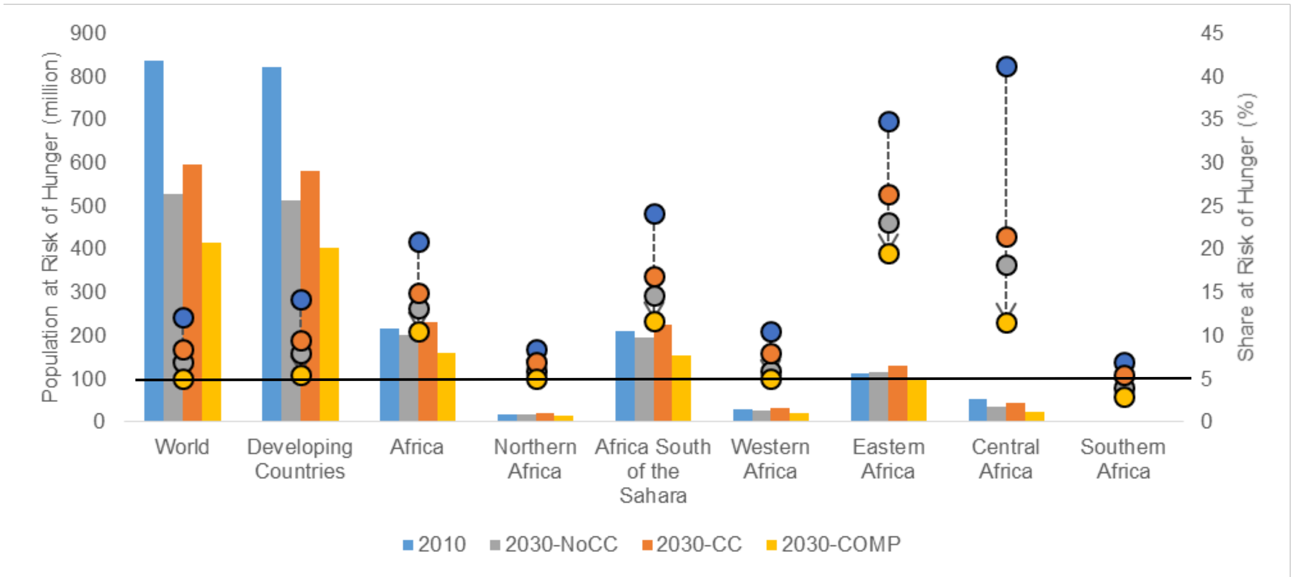
Table 3.5 IMPACT projections of aggregate food production, consumption, and hunger to 2030 and 2050

	Aggregate Food Production (index, 2010 = 1.00)					Per Capita Food Consumption (KCAL per capita per day)					Hunger (millions of people at risk)				
		Without climate change		With climate change			Without climate change		With climate change			Without climate change		With climate change	
	2010	2030	2050	2030	2050	2010	2030	2050	2030	2050	2010	2030	2050	2030	2050
World	**1.00**	**1.37**	**1.69**	**1.33**	**1.60**	**2795**	**3032**	**3191**	**2982**	**3079**	**838.1**	**528.2**	**405.8**	**592.3**	**476.9**
Developing	**1.00**	**1.42**	**1.76**	**1.39**	**1.71**	**2683**	**2961**	**3137**	**2909**	**3020**	**823.3**	**513.3**	**392.2**	**576.7**	**461.1**
Developed	**1.00**	**1.24**	**1.47**	**1.15**	**1.29**	**3384**	**3439**	**3513**	**3406**	**3435**	**14.8**	**14.9**	**13.6**	**15.7**	**15.8**
Asia & Pacific	**1.00**	**1.37**	**1.64**	**1.36**	**1.63**	**2656**	**3003**	**3185**	**2954**	**3072**	**539.8**	**249.8**	**181.8**	**280.9**	**204.6**
East Asia	**1.00**	**1.23**	**1.35**	**1.26**	**1.41**	**3009**	**3509**	**3628**	**3459**	**3516**	**187.2**	**59.2**	**54.7**	**60.3**	**56.8**
South Asia	**1.00**	**1.57**	**2.05**	**1.50**	**1.91**	**2361**	**2669**	**2959**	**2623**	**2848**	**268.5**	**138.3**	**87.7**	**161.6**	**97.0**
Southeast Asia & Pacific	**1.00**	**1.48**	**1.89**	**1.46**	**1.84**	**2551**	**2852**	**3051**	**2796**	**2931**	**84.1**	**52.3**	**39.4**	**58.9**	**50.8**
Africa & Middle East	**1.00**	**1.60**	**2.24**	**1.55**	**2.11**	**2623**	**2795**	**3002**	**2735**	**2873**	**238.7**	**229.8**	**185.0**	**258.7**	**227.1**
Africa South of the Sahara	**1.00**	**1.65**	**2.37**	**1.57**	**2.17**	**2358**	**2587**	**2853**	**2518**	**2713**	**209.5**	**195.7**	**150.5**	**223.0**	**188.7**
West	1.00	1.65	2.36	1.59	2.19	2637	2853	3056	2778	2909	30.1	28.0	29.0	32.5	33.5
Central	1.00	1.66	2.33	1.56	2.07	2101	2432	2843	2366	2701	52.3	36.5	21.2	43.2	25.4
East	1.00	1.68	2.50	1.59	2.28	2110	2345	2629	2273	2488	112.1	115.6	89.2	130.6	116.3
Southern	1.00	1.50	1.87	1.49	1.81	2881	3134	3308	3059	3165	3.8	3.0	2.3	3.3	2.8
Middle East & North Africa	**1.00**	**1.51**	**2.01**	**1.50**	**2.00**	**3125**	**3250**	**3377**	**3208**	**3275**	**29.3**	**34.2**	**34.5**	**35.7**	**38.4**
The Americas	**1.00**	**1.37**	**1.69**	**1.27**	**1.48**	**3188**	**3290**	**3392**	**3244**	**3297**	**42.5**	**35.7**	**27.7**	**39.3**	**32.7**
Latin America & the Caribbean	**1.00**	**1.46**	**1.83**	**1.42**	**1.72**	**2878**	**3036**	**3184**	**2985**	**3081**	**39.5**	**32.1**	**24.0**	**35.8**	**28.7**
North America	**1.00**	**1.29**	**1.58**	**1.15**	**1.29**	**3714**	**3725**	**3735**	**3689**	**3654**	**3.0**	**3.6**	**3.7**	**3.6**	**4.0**
Europe & Former Soviet Union	**1.00**	**1.18**	**1.33**	**1.14**	**1.26**	**3275**	**3390**	**3491**	**3359**	**3414**	**17.1**	**13.0**	**11.4**	**13.4**	**12.5**
Former Soviet Union	**1.00**	**1.26**	**1.42**	**1.20**	**1.36**	**3092**	**3321**	**3423**	**3288**	**3338**	**9.7**	**5.9**	**5.2**	**6.2**	**5.5**
Europe	**1.00**	**1.15**	**1.28**	**1.11**	**1.21**	**3370**	**3424**	**3523**	**3395**	**3450**	**7.4**	**7.0**	**6.2**	**7.3**	**6.9**

Source: IFPRI (2017).

Note: World and regional figures include other regions and countries not reported separately. Aggregate food production is an index, by weight, of cereals, meats, fruits and vegetables, oilseeds, pulses, and roots and tubers (which are reported separately in Tables 3.1 – 3.4). Per capita food consumption is a projection of daily dietary energy supply. Estimates of the number of people at risk of hunger are based on a quadratic specification of the relationship between national-level calorie supply and the share of population that is undernourished as defined by the FAO and adapted from the work by Fischer at al. (2005). More details can be found in Robinson et al. (2015b, p. 28.) Values reported for 2010 are calibrated model results. Projections for 2030 and 2050 assume changes in population and income as reflected in the IPCC's Shared Socioeconomic Pathway 2. Climate-change impacts are simulated using the IPCC's Representative Concentration Pathway 8.5 and the HadGEM general circulation model. Further documentation is available at www.ifpri.org/program/impact-model. IMPACT = International Model for Policy Analysis of Agricultural Commodities and Trade.

Figure 3.1 Prevalence of hunger in millions of people and as a share of the total population (%)



Source: Mason-D'Croz et al. (2016).

Note: NoCC assumes a constant 2005 climate; CC reflects a climate future using RCP 8.5 and the HadGEM climate model (Jones et al. 2011); and COMP refers to a comprehensive investment scenario described below in Table4.2. The bars represent the number of people at risk of hunger in each region (left axis). The bubbles represent the share of the region's total population at risk of hunger (right axis). The dotted lines reflect the change in the share at risk of hunger over time and across scenarios. The solid black line represents a target threshold of 5 percent of the population at risk of hunger.

Implicit behind the projections for production, consumption, trade, and hunger is a set of global prices shown in Table 3.6. Prices are projected to rise in real terms relative to a baseline of 2010 even without climate change. The price increases with climate change (without adaptive measures) are significant even in 2030, and particularly so in 2050. The combination of increased projected imports as early as 2030 and higher global prices will raise the import bill on both counts. Higher prices and increased volume of imports also raise exposure to global price shocks. The sobering prospect of significantly more costly imports of food adds to the imperative of accelerating growth in productivity through increased and well prioritized investments in agricultural research and complementary funding for infrastructure, water management, and policy reform.

Table 3.6 Price projections from the IMPACT model in 2030 and 2050 with and without climate change (values are indexed to 2010 value)

	No Climate Change		With Climate Change	
	2030	2050	2030	2050
Cereals	1.11	1.20	1.25	1.55
Dairy	1.13	1.10	1.14	1.12
Fruits & Vegetables	1.16	1.32	1.25	1.51
Meats	1.26	1.22	1.29	1.27
Oilseeds	1.14	1.17	1.31	1.52
Pulses	1.12	1.13	1.20	1.29
Roots & Tubers	1.14	1.25	1.27	1.51
Stimulants & Other	1.19	1.25	1.30	1.49
Sugar	1.24	1.33	1.29	1.44
Vegetable Meals	1.09	1.16	1.10	1.19
Vegetable Oils	1.15	1.17	1.18	1.22

Source: IFPRI (2017).

Note: IMPACT = International Model for Policy Analysis of Agricultural Commodities and Trade.

4. The Potential for Improvements from Investments in Agricultural Research and Infrastructure

The projections above can be modified through achievement of higher than baseline rates of growth in agricultural productivity. Although increased investment in agriculture can lead to better outcomes, some investments will be more successful than others. Identification of emerging challenges and prioritization of options to respond can make good use of limited program resources, particularly in view of the long lead times required to develop and disseminate appropriate new technologies. Foresight modeling can help shed light on new and improved technologies to deal with the effects of climate change, such as drought and heat. Foresight modeling can also help discern which complementary investments will be most effective in meeting the objectives of multifunctional agriculture, such as growth, poverty reduction, job creation, climate resilience, and nutrition.

Drought- and Heat-Tolerant Varieties

The scenarios developed above assume moderate improvements in productivity associated with continued investment in agricultural research approximately as observed in recent years.[3] A more focused and better resourced effort to harness agricultural science for growth could bring better results. Conversely, if investment in R&D drops off relative to the improvements seen in recent years, the outlook for production and trade will be correspondingly more pessimistic. Productivity gains in

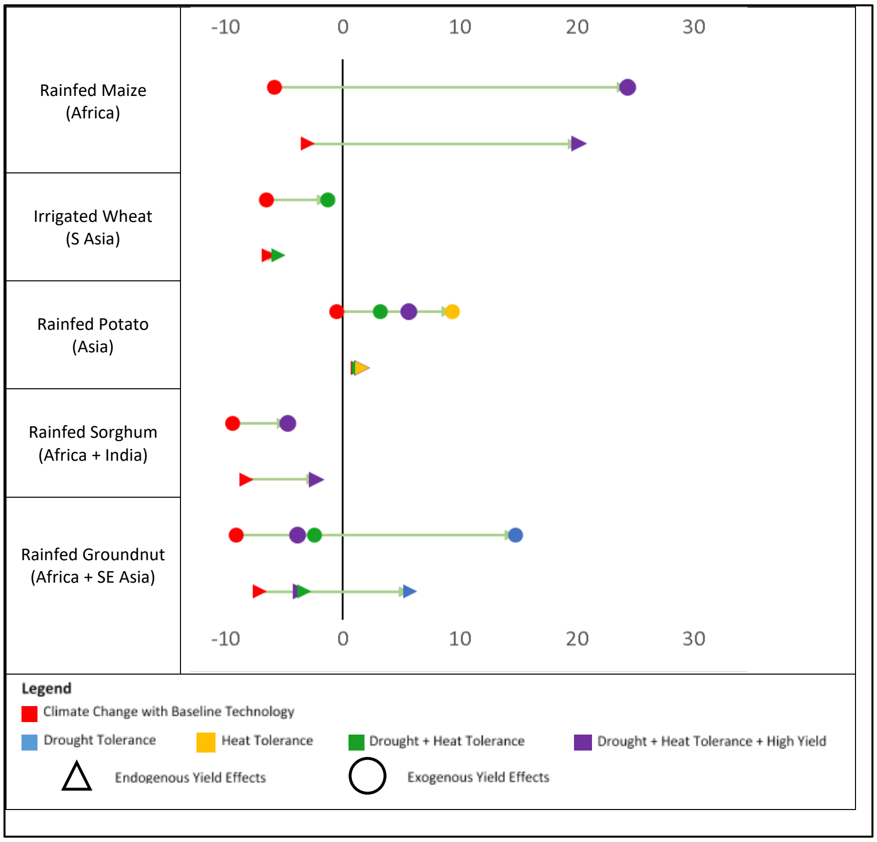
[3] Assumed improvements in productivity are based on historical data from 1961 to the present, but also take into account expected future changes for specific crops in specific countries. They are generally higher for developing countries where there is higher potential to reduce the yield gap. They also generally decline over time as the yield gap is reduced, as developing countries catch up to those that are already developed. More information can be found in Robinson et al. 2015b.

agriculture have the potential to achieve and maintain food security in the face of challenges such as population and income growth as well as climate change. One means to improve productivity is through research and investment in the development of new crop varieties, improved animal breeds, and better agricultural technologies. To understand how these new technologies might perform in the future under various stresses (climate change, water availability, etc.) and as a result of socioeconomic drivers (population and GDP growth), a structural approach that links biophysical modeling with economic modeling is useful (Islam et al. 2016).

Recent collaborative work undertaken by four CGIAR Centers (International Maize and Wheat Improvement Center, International Potato Center, International Crops Research Institute for the Semi-Arid Tropics, and IFPRI) aimed to evaluate the potential of heat- and drought-tolerant technologies. New technologies for maize, wheat, potatoes, sorghum, and groundnuts were modeled using the Decision Support System for Agrotechnology Transfer (DSSAT) family of crop models (Hoogenboom et al. 2012, Jones et al. 2003) to obtain biophysical information on how these technologies affect yields. The yield shocks were then used as inputs to the IMPACT model to simulate the effects of the new varieties under a no-climate-change (NoCC) and climate-change (CC) scenario. In these studies, the technologies were assumed to be adopted in countries where CGIAR scientists saw the greatest potential benefits from the new varieties, based on soil and climate characteristics. These included countries in West Africa, where new drought-tolerant maize was assumed to be adopted in Benin, Ghana, and Mali; sorghum in Burkina Faso, Mali, and Nigeria; and groundnuts in Burkina Faso, Ghana, Mali, Niger, and Nigeria. (More information about the specific assumptions made regarding adoption and other parameters in these particular studies can be found in Robinson et al. (2015a) and Islam et al. (2016). These and other technologies could also be simulated using different assumptions about the extent and location of adoption, to explore their impacts under different conditions.

As shown in Figure 4.1, the new technologies for specific crops are in some cases able to counteract the decline in yields associated with climate change; in other words, the technologies are adaptive to the new agroecology. In others (for example, rainfed sorghum in Africa and India) prospects are bleak, even under the adaptive technologies tested here. In the figure, we show both exogenous and endogenous yield effects. The exogenous effects come from the crop model and are purely biophysical (climate change and adoption of new technologies), whereas the endogenous results incorporate market effects that model how farmers respond to changes in prices. When supply increases (everything else being equal), prices fall, and farmers will change their behavior, which lowers yield (for example, through decreased use of fertilizer and chemicals). (It is important to note that these studies did not consider possible links to and from the wider economy. We are currently improving our ability to incorporate such effects in future work.) Thus, in most cases we see that the market effects dampen the exogenous yield-enhancing impacts. Even with the market effects, we see that the adoption of the technology can offset the impact of climate change in the region of adoption; for example, rainfed maize in Africa has 20 percent higher yields under the adaptive technologies (Robinson et al. 2015a, Islam et al. 2016). Further, we see that the regions that adopt the new technology improve their trade positions (additional production displaces imports or adds to exports). The lower dependence on imports reduces vulnerability to global price shocks (Robinson et al. 2015a).

Figure 4.1 Impact of climate change and promising technologies on yields of selected crops



Source: Islam et al. (2016).

Sustainable Intensification Practices

An earlier set of scenarios looked at a wider range of agricultural technologies selected based on their consistency with a sustainable-intensification paradigm (Rosegrant et al. 2014). Adoption of approaches ranging from new stress-tolerant crop varieties to no-till and precision agriculture was simulated worldwide, for maize, rice, and wheat crops, under two alternative climate-change scenarios, one representing a warmer and wetter future and the other a cooler and drier one.

The simulation results from the IMPACT model show that global adoption of improved technologies can increase crop yields and induce a substantial reduction (relative to the baseline scenario without the improved technologies) in world food prices of maize, rice, and wheat by 2050 (Table 4.1). Global adoption of no-till has an especially large dampening effect on the price of maize and wheat, whereas the adoption of nitrogen-use-efficient varieties may reduce the price of rice by 20 percent by 2050, compared with a scenario without adoption. We note that these projections illustrate the potential impacts of long-term changes in major drivers of agricultural supply and demand, but they do not capture the effects of important but shorter-term factors, such as extreme weather events or policy shocks.

Table 4.1 Percent change in world price for maize, rice, and wheat compared with baseline without adoption of improved technologies in 2050

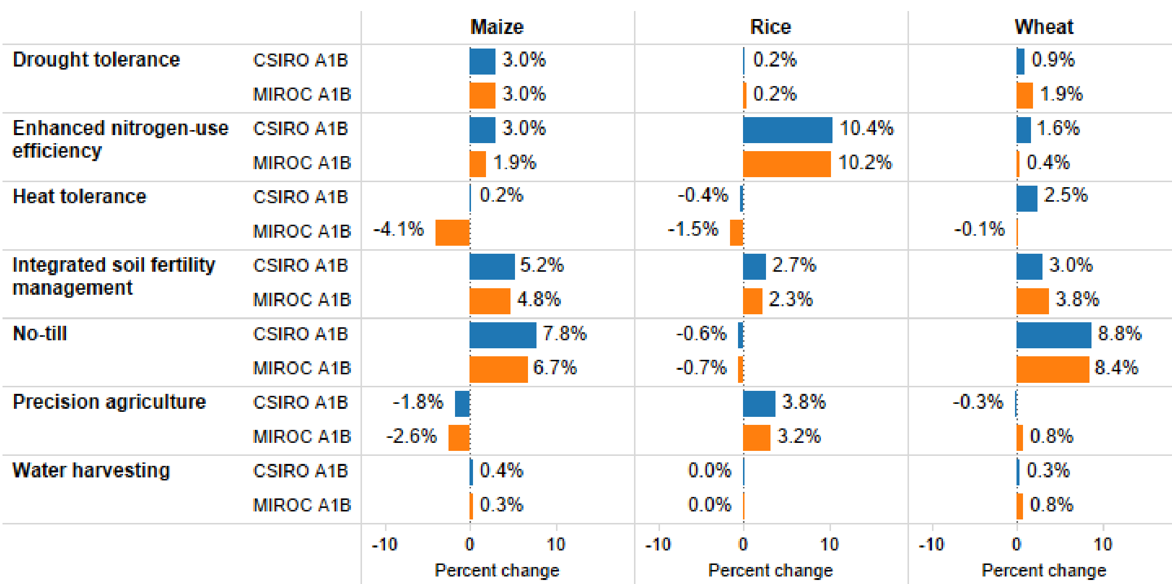
	Maize		Rice		Wheat	
	CSIRO A1B	MIROC A1B	CSIRO A1B	MIROC A1B	CSIRO A1B	MIROC A1B
Enhanced nitrogen-use efficiency	-11.14	-12.04	-20.43	-20.33	-8.22	-8.39
No-till	-15.16	-15.46	-2.71	-2.72	-14.21	-14.76
Precision agriculture	-3.75	-4.88	-10.54	-10.32	-10.63	-9.74
Heat tolerance	-7.61	-15.45	-3.64	-5.83	-5.37	-9.68
Integrated soil fertility management	-1.81	-2.44	-7.84	-7.77	-4.33	-4.44
Drought tolerance	-1.34	-1.24	-0.47	-0.44	-1.49	-1.45
Water harvesting	-0.68	-0.52	-0.07	-0.06	-0.18	-0.18

Source: Rosegrant et al. (2014).

Note: CSIRO A1B = drier and cooler climate; MIROC A1B = wetter and warmer climate; IMPACT = International Model for Policy Analysis of Agricultural Commodities and Trade.

In SSA, adoption of integrated soil fertility management may cause a consistent increase in production across maize, rice, and wheat crops, compared with a scenario without adoption. Results are of similar magnitude under either of the two climate scenarios, and generally maize is the crop that appears to benefit the most from this approach (+5 percent) (Figure 4.2). Overall, rice production in SSA receives the largest boost through the use of nitrogen-use-efficient varieties (+10 percent), while no-till is the most favorable technology for both maize (+7–8 percent) and wheat (+8–9 percent).

Figure 4.2 Percent change in production for maize, rice, and wheat in SSA compared with baseline without adoption of improved technologies in 2050

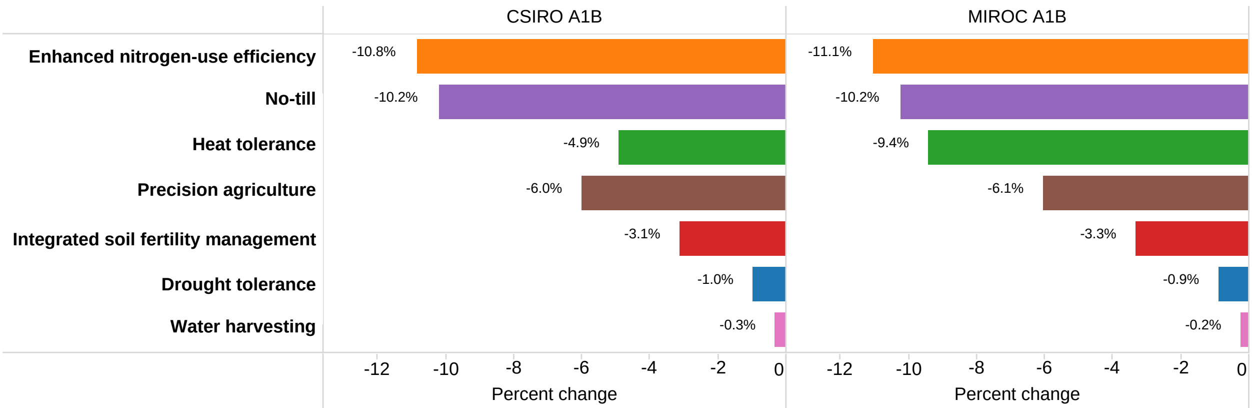


Source: Rosegrant et al. 2014.

Note: CSIRO A1B = drier and cooler climate (relative to MIROC); MIROC A1B = wetter and warmer climate; IMPACT = International Model for Policy Analysis of Agricultural Commodities and Trade.

Increased production and lower prices from adoption of the improved technologies translates into more calories available, and simulations show a potential reduction in the population at risk of hunger of more than 10 percent in SSA (Figure 4.3).

Figure 4.3 Percent change in population at risk of hunger in SSA compared with baseline without adoption of improved technologies in 2050



Source: Rosegrant et al. 2014

Note: CSIRO A1B = drier and cooler climate; MIROC A1B = wetter and warmer climate.

Climate-Smart Agriculture

Sustainable production practices that enhance equity and resilience of food systems while reducing GHG emissions are often described as climate smart. Climate-smart agriculture embodies important social and environmental goals, but evidence of its potential impact over the long run and at regional and global scales has been lacking. New work being done by IFPRI uses the IMPACT system of models to explore how adoption of climate-smart technologies for maize, rice, and wheat may affect production, prices, food security, and GHG emissions globally and in SSA to 2050 (De Pinto et al., forthcoming). We find that adoption of four climate-smart technologies—no-till and integrated soil fertility management in maize and wheat production and alternate wetting and drying and urea deep placement in rice production—in locations where those technologies offer higher yields than traditional practices can increase production of those three crops in SSA by up to 50 percent by 2050 relative to a baseline scenario. Area harvested and two measures of food insecurity (population at risk of hunger and number of undernourished children) are projected to decline, while reductions in GHG emissions depend on the extent to which farmers include that among the criteria in making their adoption decisions.

Investment in Productivity-Enhancing Research and Development, Water Management, and Infrastructure

Attainment of multiple objectives through agricultural growth requires consideration of trade-offs between and among portfolios of investment. A recent analysis by Rosegrant et al. (2017) in collaboration with colleagues in the 15 CGIAR Centers examined three sets of alternative investment scenarios, each of which increases investment in one of the areas described in the previous section. A fourth comprehensive scenario combines elements from the first three. The scenarios are as follows:

1. Enhanced productivity through increased investments in agricultural R&D

2. Improved water resource management
3. Improved marketing efficiency through increased investment in infrastructure
4. A comprehensive scenario combining select elements of 1–3

The analysis considered these scenarios on a global scale, including West Africa, but did not draw out implications specific to the subregion. Within each of the four basic scenarios, different options were examined. The baseline, or reference scenario, included three alternatives: significant climate change RCP 8.5 as modeled under two different systems and no climate change. The scenarios for productivity enhancement explored five options: medium levels of investment in CGIAR, high levels of investment in CGIAR, high investment in CGIAR plus increased investment in national partners, high investment in CGIAR plus increased efficiency in achieving research impacts, and specific targeting of CGIAR research toward SSA and south Asia. Each of these scenarios brings faster growth in total factor productivity than the baselines. A third set of scenarios addresses improved water management, with corresponding increased investments to achieve it. A fourth set examines returns on investments in infrastructure. A fifth combines the four scenarios at higher cost to examine additional returns that come from synergies among them. The scenarios are shown in summary in Table 4.2.

Table 4.2 Reference and alternative investment scenarios used in this analysis

Scenario Grouping	Scenario	Scenario Description
Reference	**REF_HGEM**	Reference scenario with RCP 8.5 future climate using HadGEM GCM
	REF_IPSL	Alternative reference with RCP 8.5 future climate using IPSL GCM
	REF_NoCC	Alternate reference with no climate change (constant 2005 climate)
Productivity Enhancement	**MED**	Medium increase in R&D investment across the CGIAR portfolio
	HIGH	High increase in R&D investment across the CGIAR portfolio
	HIGH+NARS	High increase in R&D investment across the CGIAR portfolio plus complementary NARS investments
	HIGH+RE	High increase in R&D investment across the CGIAR portfolio plus increased research efficiency
	REGION	Regionally focused high increase in CGIAR R&D investments Targets the highest increases to South Asia and SSA with medium levels of increase in Latin America and East Asia
Improved Water Resource Management	**IX**	Investments to expand irrigation in the developing world
	IX+WUE	Irrigation expansion plus increased water use efficiency
	ISW	Investments to increase soil water-holding capacity
Improved Infrastructure	**RMM**	Infrastructure improvements to improve market efficiency through the reduction of transportation costs and marketing margins
Comprehensive Investment	**COMP**	This comprehensive scenario is a combination of four scenarios: HIGH+RE; IX+WUE; ISW; and RMM

Source: Rosegrant et al. (2017).

Note: NARS = national agricultural research system. HadGEM = Hadley Centre Global Environment Model. IPSL = Institut Pierre Simon Laplace. GCM = General Circulation Model.

The alternative investment scenarios vary widely in their costs and generate a range of impacts on the various development objectives reflected in the United Nations Sustainable Development Goals and to which CGIAR has committed—in particular, poverty reduction, improved nutrition, and better natural resource management. In some cases, the impacts on different objectives are complementary, and in others there are significant trade-offs between objectives.

Table 4.3 summarizes key impacts of each scenario for each objective. The productivity enhancement scenarios generally offer moderate improvements in income, agricultural supply, and food security and little impact on environmental improvement by 2030, but larger improvements by 2050, at relatively low cost. The scenario combining irrigation expansion and increased water use efficiency (IX+WUE) offers reductions in water use and small improvements in income, supply, and food security. Improved market access through reduced marketing costs (RMM) increases income, supply, and food security, but at the cost of increased conversion of forestland and GHG emissions, largely due to the investment in roads and infrastructure that underlies the reduction in marketing costs. These outcomes highlight the importance of a mixed portfolio of investments that combines productivity enhancement with improved water resource management and market access. The comprehensive scenario (COMP) achieves significant improvements in all outcome areas, particularly in 2050, but comes at a significantly higher cost. Implications of the modeling of trade-offs specifically for West Africa and with particular focus on the role of investment in agricultural research (MED R&D, HIGH R&D, and NARS) will be relevant to design of the investments in research in the region and could be undertaken in collaboration with local partners.

Table 4.3 Scenario impacts on selected outcome indicators in 2030 and 2050 (Costs are in billion USD per year for the developing world; other values are percentage differences relative to the reference scenario REF_HGEM.)

		2030						2050					
Scenario	Avg. Annual Cost	GDP	Ag Supply	Hunger	Water Use	GHG	Forest	GDP	Ag Supply	Hunger	Water Use	GHG	Forest
MED R&D	1.4	0.7	1.4	-6.5	0.0	-5.5	0.03	1.9	2.7	-9.3	-0.2	-15.4	0.13
HIGH R&D	2.0	1.3	2.8	-12.4	-0.1	-7.5	0.04	3.4	5.7	-16.6	-0.4	-24.3	0.20
HIGH+NARS	3.0	1.6	3.7	-15.8	-0.1	-8.9	0.04	4.3	7.7	-20.2	-0.4	-26.5	0.22
HIGH+RE	2.0	2.6	6.4	-24.4	-0.2	-12.7	0.06	4.2	7.5	-20.0	-0.4	-26.9	0.22
REGION	2.5	1.1	2.4	-10.9	-0.1	-6.5	0.03	3.1	5.1	-15.4	-0.3	-22.6	0.18
Irrig Exp	3.6	0.1	0.1	-1.3	2.6	-1.8	0.01	0.2	0.2	-1.1	2.9	0.7	-0.01
IX+WUE	8.3	0.4	0.9	-4.5	-7.2	-1.9	0.01	0.5	0.9	-2.7	-7.5	-0.2	-0.01
ISWM	5.0	0.2	0.5	-2.1	-1.5	-0.5	0.00	0.5	0.9	-3.0	-2.9	-1.1	0.01
RMM	11.9	1.0	1.6	-5.8	0.1	6.4	-0.02	0.8	1.5	-4.2	0.0	8.9	-0.08
COMP	26.4	4.1	9.8	-30.6	-9.0	-11.5	0.07	5.7	11.5	-24.4	-11.0	-25.4	0.22

Less Advantageous — Neutral — More Advantageous

Source: Rosegrant et al. (2017).

Note: GDP = gross domestic product; Ag Supply = agricultural supply; GHG = greenhouse gas. See Table 4.2 for a full explanation of other abbreviations.

5. How Spatially Disaggregated Analysis Can Help Inform Policy and Investment in West Africa

In 2013, IFPRI published *West African Agriculture and Climate Change* (Jalloh, Nelson, Thomas, et al.), a book that was coedited by researchers from CORAF, the CGIAR Research Program on Climate Change, Agriculture, and Food Security, and IFPRI. Its goal was to help national and regional policy makers be better informed about how climate change will impact the agriculture of their countries and to present policy ideas that can help their countries adapt to that change. Key ideas from the monograph were synthesized in a chapter for an FAO publication (Thomas and Rosegrant 2015) and were used to help the

Economic Community of West African States (ECOWAS) develop a climate-smart agriculture policy (Zougmoré et al. 2016; Thomas and Zougmoré 2015).

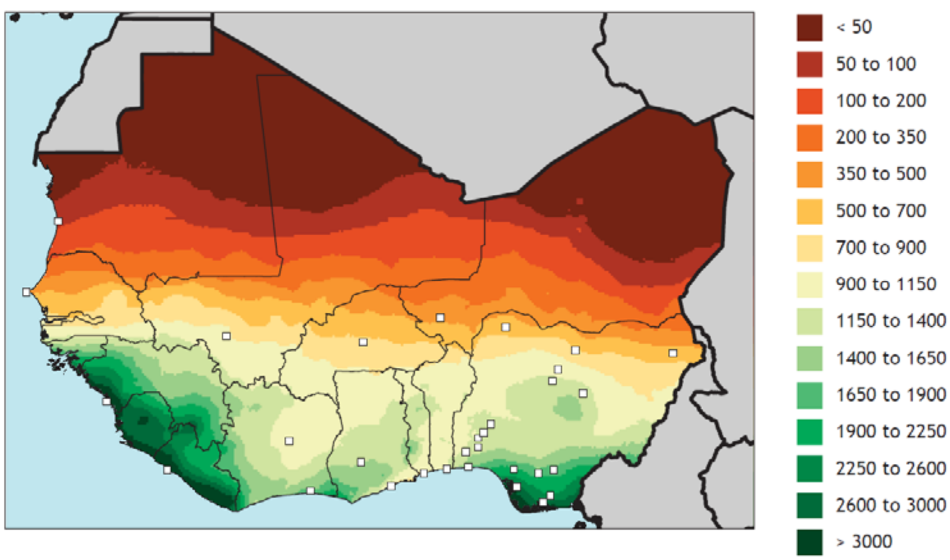
The following sections present some pixel-based results developed for the above analysis that are specifically relevant to West Africa and that complement analytical approaches of bioeconomic models. Pixel-level analysis gives information that can help identify issues at a subnational level, and can also be aggregated and used as key inputs in the global bioeconomic models that provide country- and regional-level results.

Climate Models

Jalloh, Nelson, Thomas, et al. (2013) use climate models generated by various teams for the IPCC fourth assessment report (AR4) and downscaled to the 5-arc-minute size (approximately 10 kilometers at the equator) by Jones, Thornton, and Heinke (2009). Each climate model is considered equally valid, so four different models were used in the analysis to get an estimate of the range of possible responses to climate change.

Rainfall for West Africa diminishes as one moves from south to north, which can be seen in Figure 5.1, which shows that rainfall near the coast in many countries is around 3,000 millimeters but falls to less than 50 millimeters per year in the northern part of the region, in Niger, Mali, and Mauritania.

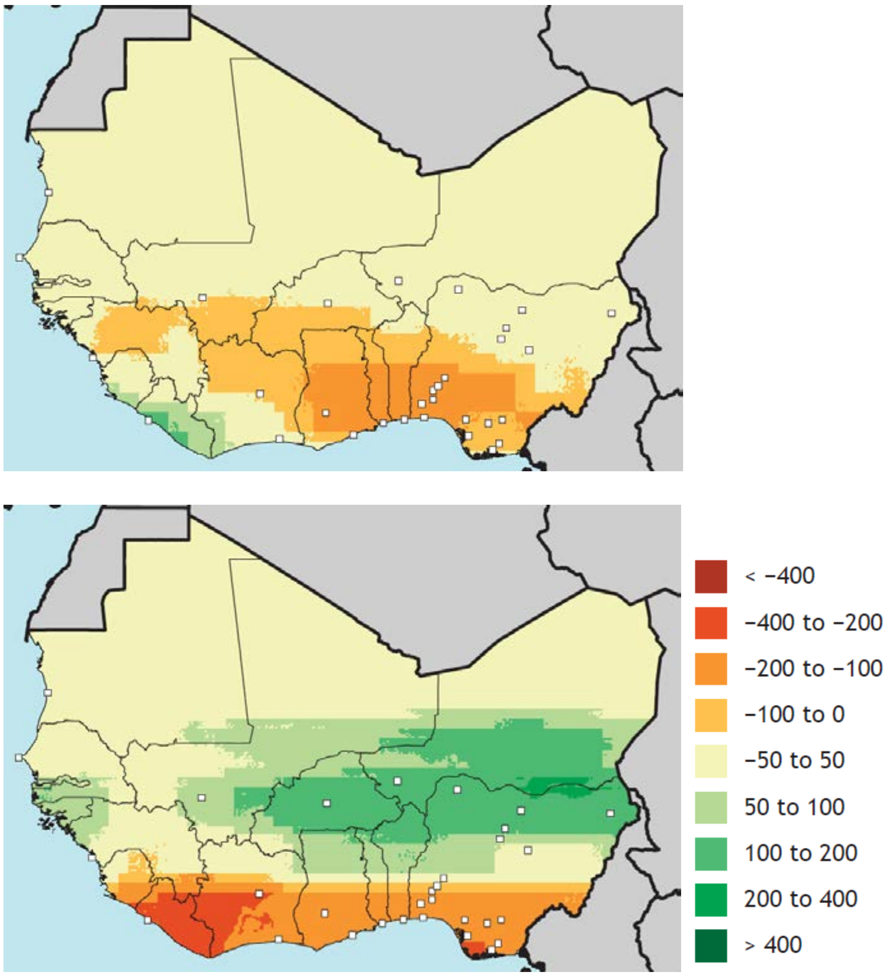
Figure 5.1 Mean annual precipitation, 1950–2000 (millimeters per year)



Source: WorldClim version 1.4 (Hijmans et al. 2005), as reported in Jalloh, Faye, Roy-Macauley, et al. (2013).

Figure 5.2 shows how rainfall is projected to change in two of the four climate models used in the analysis by Jalloh, Nelson, Thomas, et al. (2013). While both climate models project less rainfall by 2050 in much of the southern part of the region, they differ in magnitude and in geographic extent of the areas projected to have less rainfall. The Model for Interdisciplinary Research on Climate (MIROC) climate model shows a reduction of more than 200 millimeters of rain per year in most of Liberia and parts of Cote d'Ivoire, while the Commonwealth Scientific and Industrial Research Organisation (CSIRO) climate model shows an increase of more than 100 millimeters per year along the coast of Liberia. Much of the rainfall decline in the CSIRO model ranges from Ghana to Nigeria. And while the CSIRO model shows a small projected area of increased rainfall, in the MIROC model there is a large geographic area with an increase of 100 or more millimeters per year projected, covering Burkina Faso, northern Nigeria, southern Niger, and northern Benin.

Figure 5.2 Change in average annual precipitation, 2000–2050, CSIRO and MIROC A1B Scenario (millimeters per year)



Source: Based on Jones, Thornton, and Heinke (2009), as reported in Jalloh, Faye, Roy-Macauley, et al. (2013).

Note: A1B = greenhouse gas emissions scenario that assumes fast economic growth, a population that peaks midcentury, and the development of new and efficient technologies, along with a balanced use of energy sources; CSIRO (top) = Commonwealth Scientific and Industrial Research Organisation, a climate model developed at the Australia Commonwealth Scientific and Industrial Research Organization; MIROC (bottom) = Model for Interdisciplinary Research on Climate, developed at the University of Tokyo Center for Climate System Research.

While not presented here, there are similar climate maps for temperature corresponding to the 1950 to 2000 period, and projections for 2050. Together, the precipitation and temperature help determine the suitability of each location for various crops both now and in the future under climate change.

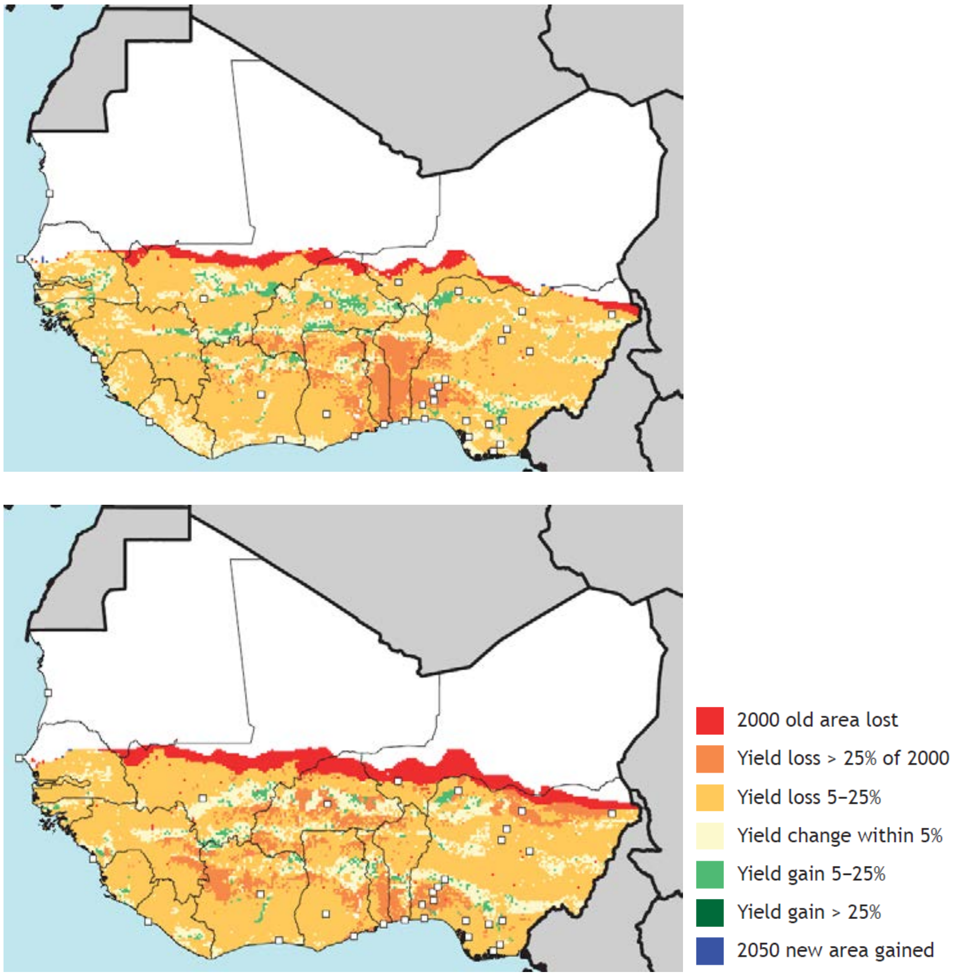
The IPCC has been producing an updated assessment report every six years. The climate models in Figure 5.2 are from the fourth assessment, which came out in 2007. A new set of climate models was produced for the fifth assessment, which was published in 2013. The new models were used in much of the economic analysis highlighted in this report. The uncertainty in the climate projections and changes as the new data and versions of the models are released highlights the importance of including ongoing quantitative modeling in the decision process for sectoral management in West Africa.

Biophysical Models

Crop models are used in Jalloh, Nelson, Thomas, et al. (2013) to measure the likely effect of climate on agricultural productivity. In particular, they use the DSSAT model (Jones, Hoogenboom, Porter, et al. 2003) to compute yields under the climate of 2000, and again under the climate presented by each of the four climate models for 2050. This is done at a very fine scale, using 5-arc-minute pixels, which are around 10 kilometers on each side at the equator. This gives a very spatially differentiated analysis. Furthermore, because DSSAT simulates the growth of crops using a daily time-step, DSSAT uses a weather generator to produce daily weather based on the monthly climate characteristics from the historical data and the climate models. Because the simulator uses stochastic methods to generate weather, the analysis is repeated 60 times to ensure that a representative yield is obtained.

Figure 5.3 reports the results of the DSSAT analysis for rainfed sorghum. Neither map in the figure reports encouraging results for rainfed sorghum under climate change, with only a smattering of areas that are not projected to change much or that have a projected increase. Instead, along the northern boundary of the sorghum-growing zone, we note a band for both climate models showing that sorghum will no longer be able to be grown there. The band for the MIROC model is considerably wider than the one for the CSIRO model, meaning that more area will be lost if in fact the climate of the future more closely approximates that of MIROC and not of CSIRO.

Figure 5.3 Percent change in yields for rainfed sorghum, 2000–2050, CSIRO and MIROC A1B Scenario



Source: Jalloh, Faye, Roy-Macauley, et al. (2013).

Note: A1B = greenhouse gas emissions scenario that assumes fast economic growth, a population that peaks midcentury, and the development of new and efficient technologies, along with a balanced use of energy sources; CSIRO (top) = Commonwealth Scientific and Industrial Research Organisation, a climate model developed at the Australia Commonwealth Scientific and Industrial Research Organization; MIROC (bottom) = Model for Interdisciplinary Research on Climate, developed at the University of Tokyo Center for Climate System Research.

Furthermore, Figure 5.3 shows us that there will be a large productivity loss for rainfed maize for Togo and Benin, as well as eastern Ghana and western Nigeria if the CSIRO climate is realized. These are the same areas with high rainfall decline in Figure 5.2. We see similar areas in the MIROC map with similar losses, but they are more dispersed than the ones in the CSIRO map.

Table 5.1 shows the fuller regional results of the analysis by DSSAT on various crops in West Africa. The losses for irrigated wheat are potentially the largest, if either the Centre National de Recherches Météorologiques (CNRM) or European Center Hamburg (ECHAM) climates prove to be the most accurate. Irrigated rice is also a potential major loser for the region, though surprisingly, rainfed rice looks like it could actually increase in productivity. If rainfed rice and irrigated rice were grown in the same location, this would be a very confusing result. But irrigated rice and rainfed rice are grown in different locations, and this result reflects the variable impact of climate across the region.

Table 5.1 Regionwide summary of climate change effect on crops in West Africa, 2000–2050, percent change

Water	Crop	CNRM	CSIRO	ECHAM	MIROC
Rainfed	Groundnuts	-5.8	-7.7	-9.2	0.3
Rainfed	Maize	-2.3	-8.1	-6.0	-4.9
Irrigated	Rice	-19.9	-12.4	-20.0	-18.2
Rainfed	Rice	4.4	0.5	0.9	1.0
Rainfed	Sorghum	-15.9	-9.5	-14.8	-13.0
Rainfed	Soybeans	-1.5	-8.4	-1.6	-14.2
Irrigated	Wheat	-37.8	-10.9	-28.5	-14.3

Source: Thomas and Rosegrant (2015).

Losses of rainfed groundnuts, maize, and soybeans due to climate change as a whole seem to be modest, though there is considerable geographic heterogeneity incorporated in these aggregate statistics.

It is important to keep in mind that this analysis does not take into consideration any adaptation. Research institutes and private corporations continue to develop seeds that are more resilient to pests and weather extremes, and more productive in general. Even so, we might expect that the maps pinpoint areas that will present challenges for farmers as well as for researchers and policy makers trying to support them. Further challenges arise from the fact that a broad range of uncertainty about climate change impacts themselves adds to the complexity of policy interventions to be implemented.

One mode of adaptation that is not entirely obvious is that over time, location of production tends to shift in response to climate. For example, it appears that in the United States, maize production has shifted northward as a result of warming trends. Similarly, production in West African countries will shift. Sometimes this involves farmers moving locations, but more often it involves farmers changing the crops they plant to those more suited to the climate and more profitable under evolving conditions. Foreseeing the likely shifts and helping farmers adapt will become an essential task of the research systems and extension programs in the coming decades.

Several other crop models are in use besides DSSAT. Some of these are included in the AgMIP Global Gridded Crop Model Intercomparison (GGCMI) project (Rosenzweig et al. 2014), which essentially generates the same kind of productivity projections as Jalloh, Nelson, Thomas, et al. (2013), but uses the IPCC's fifth assessment report (AR5) climate models along with seven different crop models. A team from IFPRI has synthesized the diverse data into a single measure of climate change, which is forming the basis of a forthcoming analysis focused on Latin America. IFPRI has used an updated version of DSSAT along with the new AR5 climate models to rerun the results presented here, not only for West Africa, but for the entire world. The spatial resolution is with half-degree pixels, which is 36 times coarser.

6. Agriculture for Jobs and Nutrition

The analysis above provides insight into the decision process that can position agriculture to perform under changing climatic conditions, but it offers little insight into the sector's role in job creation and nutrition defined other than as caloric deficits. A multifunctional agriculture must address not only growth and climate resilience but also job creation and nutrition. In the traditional conceptual model of agriculture's contribution to development, very poor smallholder producers grow staple crops largely for their own consumption. They suffer income and caloric deficits that can be remedied by increased production, some of which is taken to market for cash sales and some of which is consumed to meet minimal caloric needs. The increased income is spent on locally produced goods and services, which generates new jobs in the community and demand for labor. This conceptual framing trained its focus on increased productivity of food staples. For this reason, many development programs, national research institutes, and the early period of investment in CGIAR emphasized increased productivity of staples.

Food staples remain important contributors to incomes of the rural poor. An emphasis on multifunctional agriculture, however, argues for a broader perspective. Production of food staples does not often yield high labor productivity or generate jobs in such areas as packing, sorting, cleaning, and transport. Similarly, food staples do not address nutritional deficits that result from lack of dietary diversity and micronutrient content. In such instances, increased availability of animal products, legumes, fruits and vegetables, and biofortified crops is required. Different agricultural products and subsectors have different profiles with regard to poverty reduction, private sector growth, nutrition, and job creation. A portfolio of investments in subsectoral productivity growth is necessary to meet multiple objectives of agricultural growth.

IFPRI and the International Fund for Agricultural Development have developed a new set of tools called the Rural Investment and Policy Analysis (RIAPA) model to estimate how increasing production in different agricultural subsectors leads to changes in national and household outcomes, with particular focus on poverty, growth, job creation, and nutrition. RIAPA captures links between sectors and rural-urban economies, as well as changes throughout the agriculture-food system. RIAPA is a CGE model that simulates the functioning of a market economy, including markets for products and factors (that is, land, labor, and capital). RIAPA measures how impacts are mediated through prices and resource reallocations and ensures that resource and macroeconomic constraints are respected, such as when inputs or foreign exchange are limited. RIAPA provides a consistent "simulation laboratory" for quantitatively examining value-chain interactions and spillovers at national, subnational, and household levels.

The model is particularly helpful in illustrating the composite effects of different portfolios of productivity growth corresponding to different subsectors of emphasis in agricultural research. The model has been piloted in two countries in East Africa. Results for Ethiopia, for example, show that productivity growth in root crops generates employment and reduces poverty but does little for dietary diversity of the poor. Productivity growth in the dairy and poultry sectors, in contrast, also creates jobs and contributes to growth but has little impact on poverty. Table 6.1 shows a ranking of products within several portfolios constructed with different weights accorded to objectives for poverty, nutrition, and growth. Fruits, vegetables, and tree crops appear highly ranked under all four weighting schemes. Oilseeds are highly ranked for poverty and nutrition but low for growth.

Table 6.1 Final rankings of value chains under different weighting schemes

Rank	Equal weights	Poverty Bias	Nutrition Bias	Growth Bias
1	Oilseeds	Oilseeds	Vegetables	Cattle
2	Fruits/tree crops	Vegetables	Fruits/tree crops	Tobacco/cotton/tea
3	Vegetables	Fruits/tree crops	Oilseeds	Fruits/tree crops
4	Tobacco/cotton/tea	Tobacco/cotton/tea	Milk/dairy	Milk/dairy
5	Cattle	Pulses	Pulses	Vegetables
6	Milk/dairy	Milk/dairy	Tobacco/cotton/tea	Coffee
7	Pulses	Coffee	Cattle	Pulses
8	Coffee	Root crops	Coffee	Oilseeds
9	Poultry	Cattle	Poultry	Poultry
10	Goats/sheep/camels	Sorghum/millet	Goats/sheep/camels	Sorghum/millet

Source: Thurlow and Benfica (2017).

Note: Rankings based on weighted sum of outcome indicators. Equal weighting is one-third each; biased weighting favors one indicator (one-half) at the expense of others (one-quarter each).

The RIAPA model could be applied in West Africa and would very likely yield insights into which subsectors are most likely to contribute to growth, poverty reduction, jobs, and nutrition. The more important message of the exercise reported above, however, is the importance of a portfolio of investments in a diversified agriculture. If the objective of agricultural growth is narrowly defined or unidimensional, then analysis to determine which products and technologies can best deliver that objective is important. If the objectives are multiple, then a dynamic process of productivity growth engaging all subsectors will be needed.

This insight has important implications for policy and investment. Success will depend not on selection of the one or two commodities or technologies at the national level to receive emphasis in research and innovation, but rather in interlinkage of national R&D systems to create a truly regional space with shared effort and shared rewards over a broad spectrum of commodities and technologies. The scientific effort needed to achieve broad-based productivity growth will require increased investment, greater productivity of scientific effort, and significant deepening of institutional reforms well started with support of the West Africa Agricultural Productivity Program (WAAPP). The following section of this report addresses the required agenda to strengthen agricultural research and innovation systems.

7. Research Finance, Scientific Institutions, and Skilled Staff to Support Dynamic Growth in Multifunctional Agriculture in West Africa

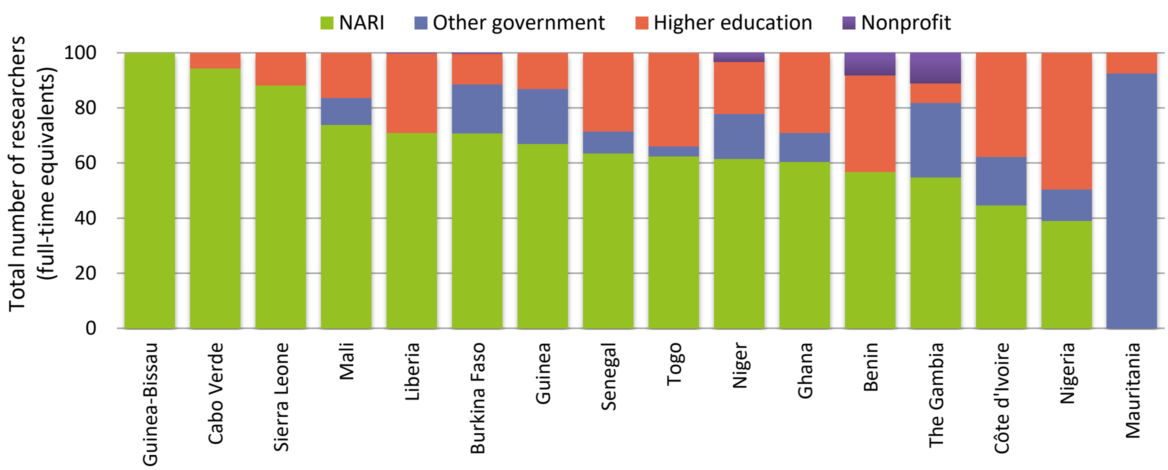
This section of the report assesses long-term investment, human capacity, research output, and institutional trends in agricultural research in West Africa, particularly focusing on developments during 2000–2014. The analysis uses information collected by ASTI—led by IFPRI and within the portfolio of the CGIAR Research Program on Policies, Institutions, and Markets—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 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 subregions.

8. 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 research departments within ministries of agriculture or the equivalent; (2) as semiautonomous government institutes 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 most West African NARS (Figure 8.1).

Figure 8.1 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.

Note: 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.

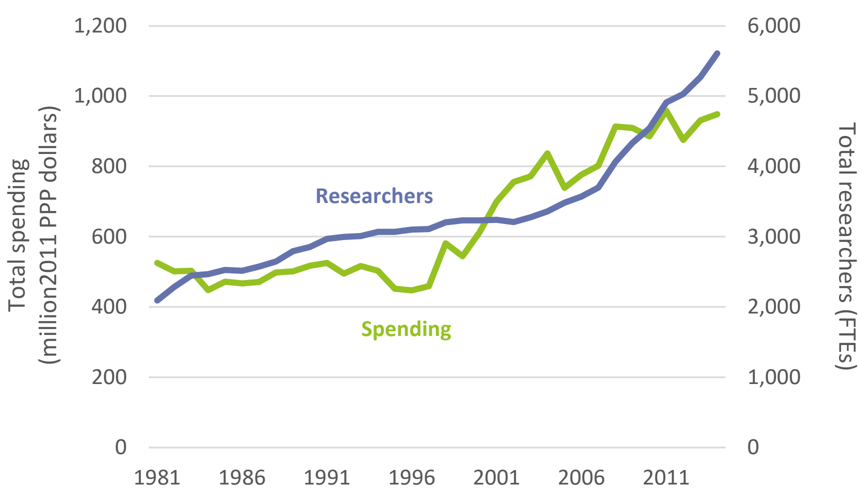
Most NARS in West Africa are small, but they tend to focus on the same range of issues as their large neighbors, thereby often exceeding the limits of their capacity. As a result, these smaller systems mostly conduct research to adapt technologies developed elsewhere to meet their local needs. Spillovers 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.

Linkages across research agencies—and between research agencies and extension providers, policy makers, and farmers' organizations—are often weak due to the fragmentation within NARS and lack of coordination mechanisms. Collaboration across NARS is facilitated through 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 depend heavily on unstable donor funding—do not conduct research themselves, but instead promote the conduct of regionally beneficial research by their NARS members. One of the main objectives of WAAPP has been to promote collaboration between NARS, creating national centers of specialization (NCoS), which focus on a number of priority commodities. CORAF/WECARD works to ensure that the research outputs of these NCoS are shared widely throughout the subregion.

9. 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 9.1).[4] [5] Nigeria alone accounted for nearly half of this total (Table 9.1). 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 9.1 Agricultural research capacity and trends in research spending, West Africa, 1981–2014



Source: Calculated by authors based on ASTI data and various secondary sources.

Note: Data for subperiods were estimated for some countries. Data for the private for-profit sector were unavailable and have been excluded from this graph.

[4]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 most private firms are not accessible.
[5] 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.

Table 9.1 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. Data for 2014 for Nigeria's and Sierra Leone's higher education sectors have been extrapolated based on available data for 2008 and 2011, respectively. 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 assignment to other agencies, or unrelated administrative duties. For more information, see www.asti.cgiar.org/methodology.

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. It 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 indicate an upsurge in spending levels in more recent years, largely in response to the launch of the WAAPP.

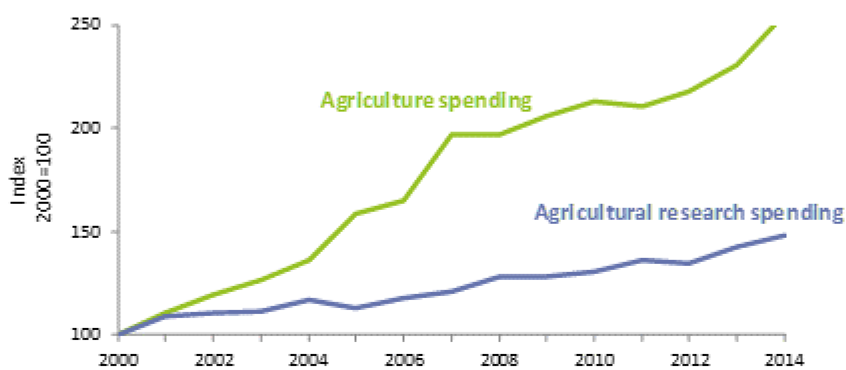
In 2014, West Africa employed more than 5,600 full-time equivalent (FTE) researchers in agricultural and related sciences, up from 3,232 FTEs in 2000, representing a 73 percent increase. Once again, Nigeria (2,975 FTEs in 2014) accounted for more than half of this total and was the main driver behind 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 9.1 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 many African countries have yet to attain CAADP's ambitious targets (that is, 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 more than doubled its investments in agriculture during 2000–2014 after long periods of neglect in prior decades (see figure below). Agricultural research spending also grew during this timeframe, albeit at a considerably slower rate (48 percent during 2000–2014). Data indicate that many African countries have increased investments in areas such as farm support, subsidies, training, irrigation, and extension, but that 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 on such investments in Africa, especially compared with investments in fertilizer, machinery, labor, and land improvement (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 produce results and, hence, for decision makers to reap the political benefit of prioritizing such investments.

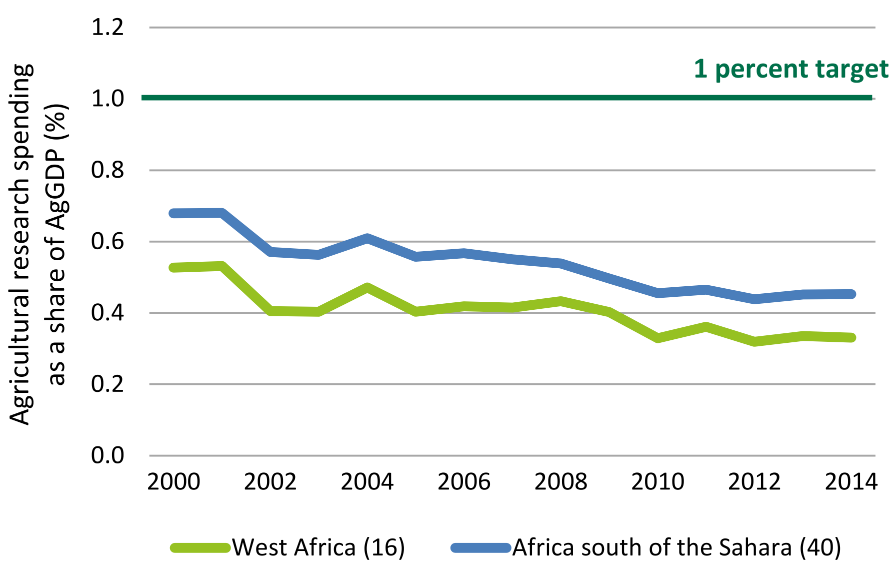
Spending on agriculture and on agricultural research in Africa south of the Sahara, 2000–2014



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 AgGDP—dropped markedly, from 0.53 percent in 2000 to just 0.33 percent in 2014 (Figure 9.2). 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 9.2). In fact, 9 of these 16 countries spent less than 0.5 percent of their AgGDP on agricultural research (Figure 9.3). 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.

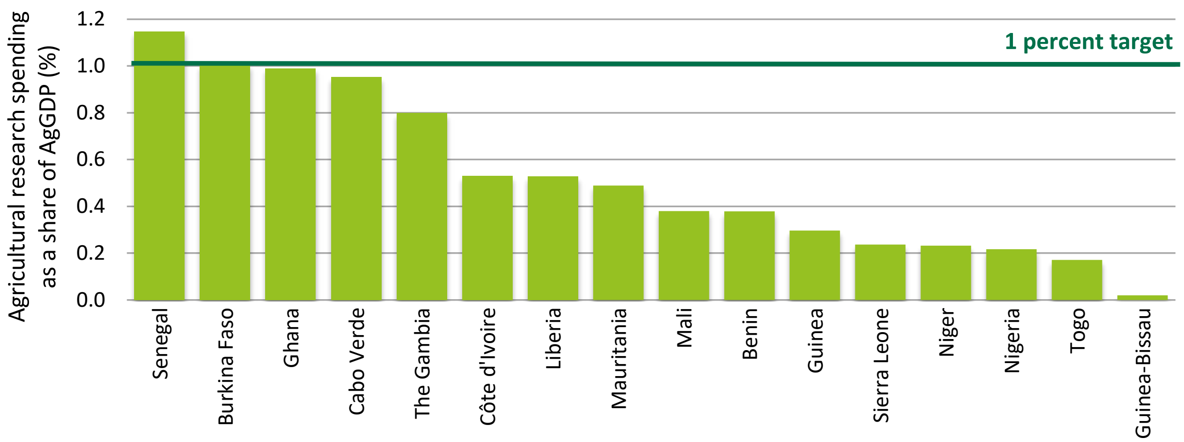
Figure 9.2 Agricultural research spending as a share of agricultural GDP, 2000–2014



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

Note: The numbers in brackets denote the number of countries included in each sample; GDP = gross domestic product

Figure 9.3 Agricultural research intensity ratios, 2014



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

Note: 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.

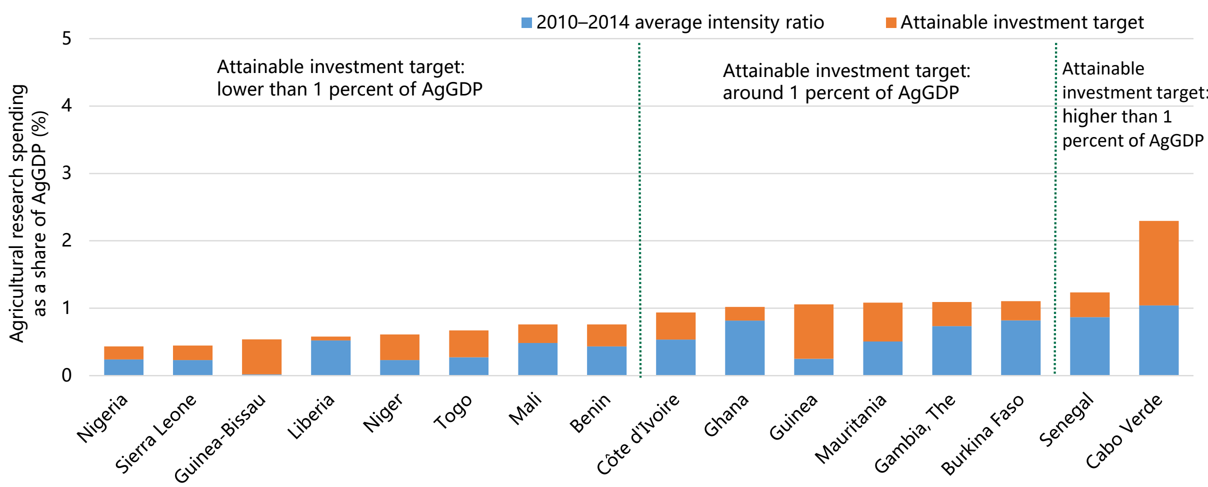
Although research-intensity ratios provide useful insights into relative investment levels across countries and over time, they do not take into account the policy and institutional environment within which agricultural research occurs, the broader size and structure of a country's agricultural sector and economy, or qualitative differences in research performance across countries; hence, they should be interpreted with care. Small countries, for instance, cannot take advantage of economies of scale, so their returns on 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 the 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 multifactored 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).

This weighted indicator of research intensity suggests that, for five West African countries, the 1 percent investment target is simply unattainable. Based on the structural characteristics of the economies and agricultural sectors of Mali, Niger, Nigeria, Togo, and 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 9.4). 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.

Figure 9.4 Five-year average agricultural research intensity ratios versus estimated attainable investment targets by country, 2014



Source: Calculated by Nin-Pratt (IFPRI) based on ASTI (2017); data on AgGDP are from World Bank (2017a).

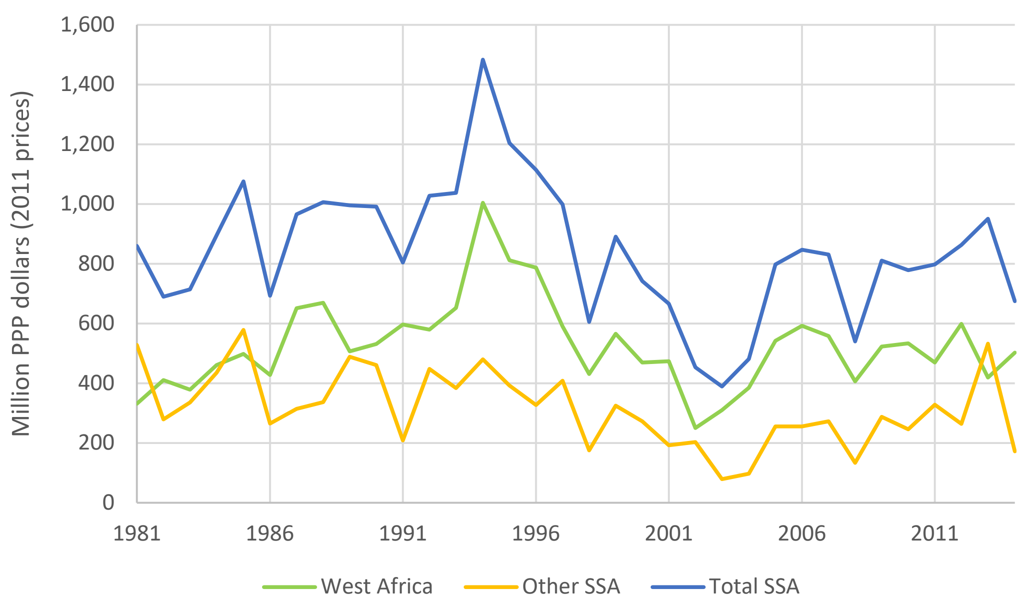
Note: For details of the underlying methodology, see Nin-Pratt (2016).

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 such as The Gambia, Ghana, and Senegal are deemed to be very close to the levels drawn from the index, 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 at present. Nonetheless—irrespective of which intensity measure is used—many countries in West Africa significantly underinvest in agricultural research.

The intensity index can also be used to provide a new perspective on the research investment gap. The research investment gap has in the past been conceived as the difference between present outlays and 1 percent of the value of AgGDP or, alternatively, as the difference between present outlays and the amounts required to meet growth targets. The latter concept is particularly difficult since many factors in addition to investment in research determine growth. The intensity index offers a third option that, if carefully interpreted, can be useful. The index allows standardization of heterogenous countries into one benchmark country and establishes an investment level actually observed (virtually) for the hypothetical benchmark country. Countries can express their own unique characteristics in terms of size, agroecological diversity, wealth, and other dimensions in standard terms using the index and measure where their investment levels fall compared with the benchmark country. If all are investing at the same level according to the index, then their investments are equal, even if they differ in absolute amounts. If countries fall short of the amount shown as the norm according to the index, that is their contribution to the regional investment gap. If all countries meet the amount shown by the intensity index, the burden of investment in regional research is equally shared. If some countries fall short, burden sharing is unequal.

As previously established, West Africa invested $948 million in agricultural research in 2014 (in 2011 PPP prices). If all countries had invested as much as indicated by the intensity index, subregional investment levels in 2014 would have totaled $1.4 billion (Figures 9.4 and 9.5). 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. Closing this gap would even the contributions to regional research effort across countries in West Africa. This is an attainable amount and could be accomplished through reallocation of budgets currently allocated to agriculture. Bringing research funding up to the level of $1.4 billion (in 2011 PPP prices) might not be sufficient to meet the ambitious growth targets set for the sector and would not necessarily fully meet the needs to rebuild staff numbers and improve research infrastructure, but it could nonetheless serve as an intermediate target consistent with absorptive capacity.

Figure 9.5 Gap between actual agricultural research investment and attainable agricultural research investment, 1981–2014



Source: Calculated by Nin-Pratt (IFPRI) based on ASTI (2017).

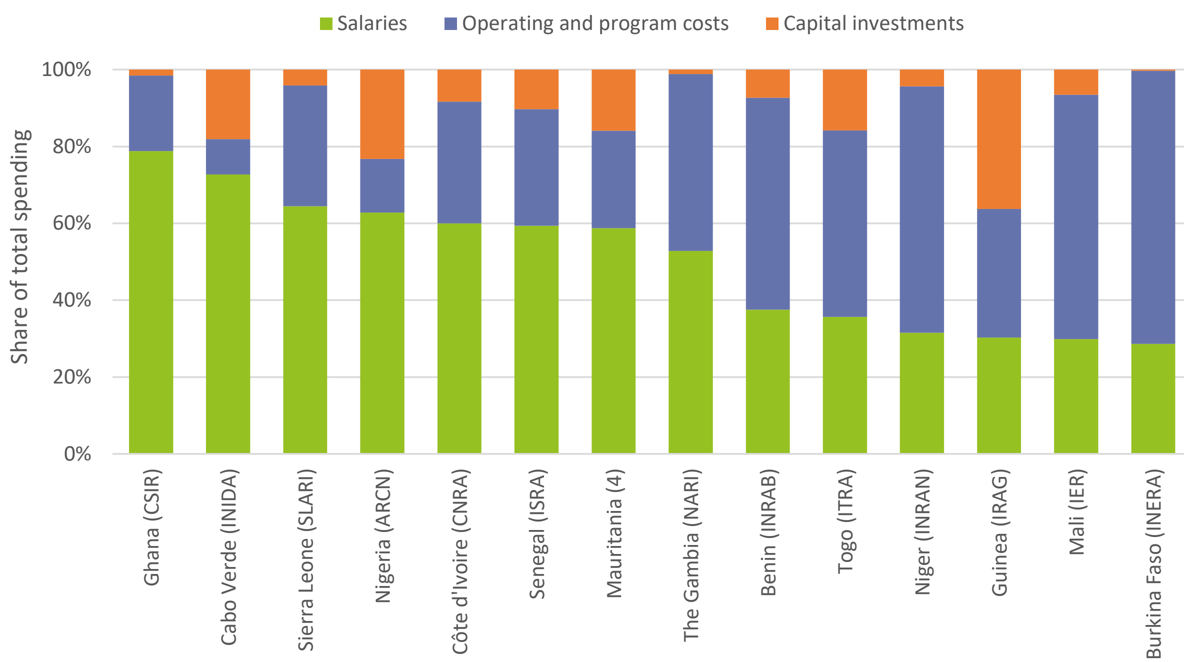
Note: For details of the underlying methodology, see Nin-Pratt (2016).

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 9.6). These regional averages mask a significant degree of cross-country variation. The NARIs 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 9.6 NARI expenditures by cost category, 2009–2014 average



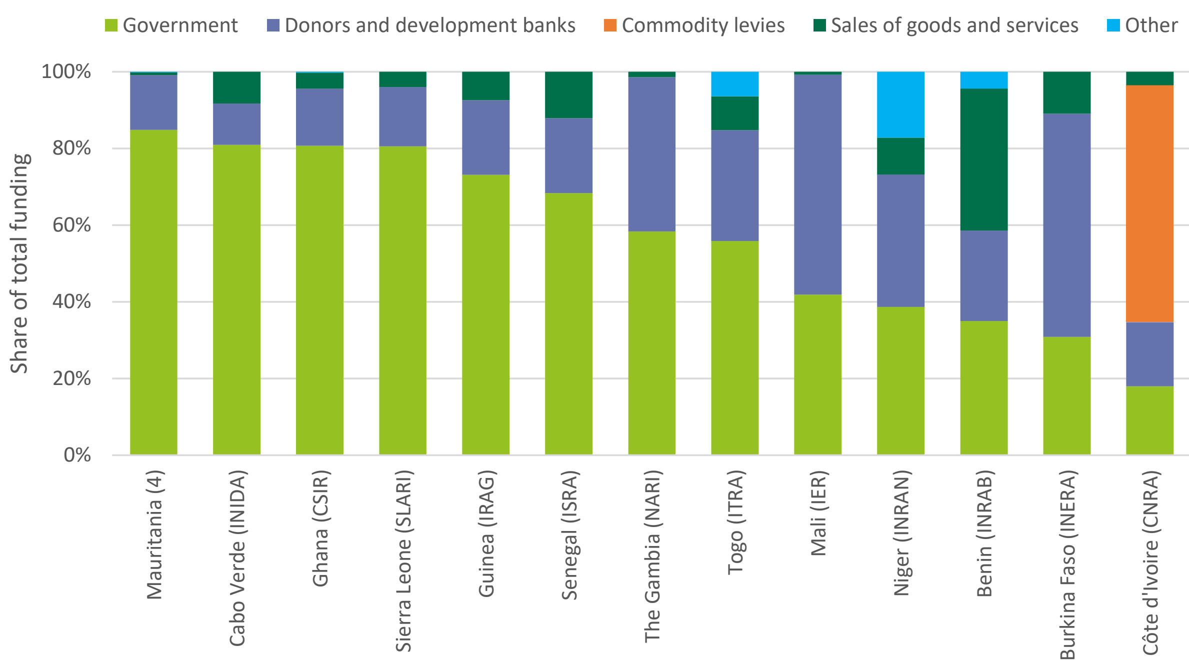
Source: Calculated by authors based on ASTI data and various secondary sources.

Note: The principal agencies included for Mauritania are the Mauritanian Institute of Oceanographic and Fisheries Research, the National Agricultural Research and Development Center, the National Livestock and Veterinary Research Center, and National Anti-Locust Center. 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 and Beintema 2015; Stads 2016; Stads et al. 2016). Overall, during 2009–2014, 54 percent of the funding to the NARIs 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 9.7). In many countries, the national government funds the salaries of researchers and support staff, but little else, leaving non-salary-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 and grants as part of WAAPP.

Figure 9.7 Funding sources of principal agricultural research agencies in West Africa, 2009–2014



Source: Calculated by authors based on ASTI data and various secondary sources.

Note: The principal agencies included for Mauritania are the Mauritanian Institute of Oceanographic and Fisheries Research, the National Agricultural Research and Development Center, the National Livestock and Veterinary Research Center, and National Anti-Locust Center. Data for Sierra Leone are for 2012–2014 only. Data for Guinea-Bissau, Liberia, and Nigeria were unavailable.

Although many governments have committed to fund agricultural research, 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 agencies under the Council for Scientific and Industrial Research (CSIR) and the Senegalese Agricultural Research Institute (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. Two-thirds of the program costs of the National Agricultural Research Institute of Benin (INRAB) 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 and lack of capacity at CSIR to generate funds internally, as well as patent issues. Funding diversification through the sale of goods and services is not encouraged in all West African countries, however. The Togolese Agricultural Research Institute (ITRA) 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, the Environment and Agricultural Research Institute (INERA) in Burkina Faso and the National Agricultural Research and Development Institute (INIDA) in Cabo Verde must transfer any funding they generate internally back to the Treasury. The Agricultural Research Council of Nigeria (ARCN) is allowed to keep 30 percent of its internally generated income. Neither excessive dependence on self-generated funds nor confiscation of earnings provide good incentives for high quality research.

The funding structure of National Center for Agricultural Research (CNRA) in Côte d'Ivoire is unique and exemplary in West Africa. The second National Agricultural Services Support Project, 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 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 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.

10. The West Africa Agricultural Productivity Program

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 generating and disseminating agricultural technologies, and to establish a more differentiated, yet regionally relevant, research agenda through the establishment of national centers of excellence. Because of the size of WAAPP and its influence on the institutional configuration of research, a summary of the structure and experience under WAAPP is helpful in identifying current and future needs of innovation systems. Such a summary follows below.

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 for the implementation of Pillar IV of CAADP. The program commenced in 2008 under the auspices of ECOWAS and is coordinated at the subregional level by CORAF/WECARD. WAAPP was initially designed as a 10-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 learned during the first phase, the second phase focused on intensifying 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, particularly in human training and infrastructure; the third focuses on funding 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 and evaluation level, as well as communication management level.

WAAPP’s financial arrangement truly reflects its regional scope. It is funded under the Adaptable Programmatic Loan formula at the regional desk of the International Development Association (IDA) of the World Bank. Funding is drawn from a blend of each country’s IDA allocation and from the World Bank’s funds for the financing of regional programs. 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 $45 million, known as WAAPP-1A, included three countries: Ghana, Senegal, and Mali (Table 10.1). These countries are working on the high-priority value chains identified in ECOWAS’s mobilizing programs, namely roots and tubers in Ghana, dryland 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 1A ended their first phase and are currently in their second phase. Moreover, additional financing was granted to four 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, building on WAAPP achievements and supporting multifunctional agricultural growth in the region.

Table 10.1 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 (2017b).

Note: This table includes WAAPP funding to research and nonresearch activities. It excludes country counterpart funding. WAAPP = West Africa Agricultural Productivity Program; IDA = International Development Association of the World Bank; PHRD = Policy and Human Resources Development; GFRP = Global Food Response Program.

WAAPP Funding Allocation to National Agricultural Research

In order to achieve its ambitious goals, WAAPP works with scientists, researchers, extension workers, and farmers to do the following:

- Generate, disseminate, and promote adoption of improved technologies.
- Create enabling conditions for regional cooperation.
- Build human and institutional capacity across the subregion.
- 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, nongovernmental organizations (NGOs), farmer organizations, and international research institutes.

In an effort to focus more directly on funding received by research agencies (in contrast to that received by nonresearch 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, such as Liberia and Sierra Leone, the NARIs turned out to be the only recipients of research-related WAAPP funding, whereas in 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 the Rural Economy Institute (IER, Mali) (Table 10.2). This is not surprising, given that WAAPP started much earlier in these countries and WAAPP 2A funding to these countries is four times higher than WAAPP 1A funding. The fact that IER received a considerably lower amount 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 million–$14 million (in 2011 PPP prices) of WAAPP funding each during 2012–2016. Most NARIs that are part of WAAPP 1C received around $6 million–$7 million each over this timeframe with the exception of INRAB in Benin (which received close to $17 million) and the National Agricultural Research Institute of Niger (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 CNRA, which coordinates agricultural research in the country, rather than INRAN, which carries out agricultural research.

Table 10.2 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
The Gambia (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 (2017b).

Note: WAAPP funding includes all IDA, GFRP, and PHRP allocations. The 2016 total excludes Nigeria. WAAPP = West Africa Agricultural Productivity Program; IDA = International Development Association of the World Bank; GFRP = Global Food Response Program; NARI = national agricultural research institute; INRAB = National Agricultural Research Institute of Benin; INERA = Environment and Agricultural Research Institute; CNRA = National Agricultural Research Center; NARI = National Agricultural Research Institute; CSIR = Council for Scientific and Industrial Research; IRAG = Guinean Agricultural Research

Institute; CARI = Central Agricultural Research Institute; IER = Institute of Rural Economy; INRAN = National Agricultural Research Institute of Niger; ARCN = Agricultural Research Council of Nigeria; ISRA = Senegalese Agricultural Research Institute; SLARI = Sierra Leone Agricultural Research Institute; ITRA = Togolese Agricultural Research Institute.

As previously mentioned, WAAPP funding targets not only 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 the National Center for Scientific and Technological Research (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 many higher education agencies combined received considerably more WAAPP funding than 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 10.3). In addition to in-country recipients, a very small proportion of WAAPP funding is disbursed to international research centers (for instance, 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 10.1).

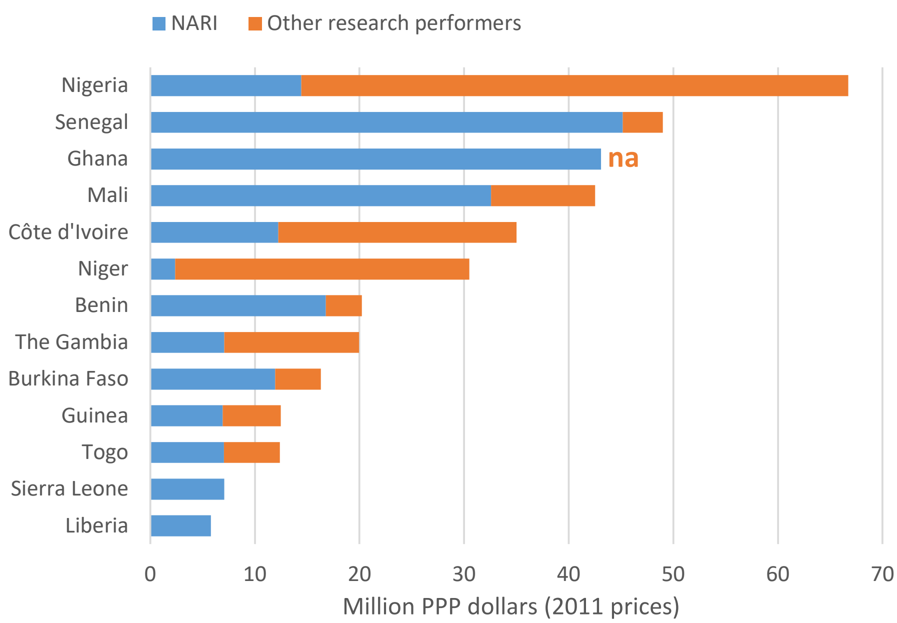
Table 10.3 WAAPP funding allocation to non-NARI research performers, 2008–2016

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
The Gambia	—	—	—	—	2.464	0.932	2.648	3.958	2.859	12.862
Ghana	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
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	n.a.	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 (2017b).

Note: "n.a." = not available; WAAPP funding includes all IDA, GFRP, and PHRP allocations. The 2016 total excludes Nigeria. WAAPP = West Africa Agricultural Productivity Program; IDA = International Development Association of the World Bank; GFRP = Global Food Response Program; NARI = national agricultural research institute.

Figure 10.1 Total research-related WAAPP funding to NARIs and other in-country research performers, 2008–2016



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

Note: na denotes that data were unavailable. WAAPP funding includes all IDA, GFRP, and PHRP allocations. The Nigeria data cover the period 2012–2015. IDA = International Development Association of the World Bank; GFRP = Global Food Response Program; NARI = national agricultural research institute; WAAPP = West Africa Agricultural Productivity Program.

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 10.4). WAAPP funding is mostly targeted toward research programs, infrastructure upgrades, and capacity building, as opposed to staff costs, which are usually covered by governments. 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.

Table 10.4 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%
The Gambia (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%	

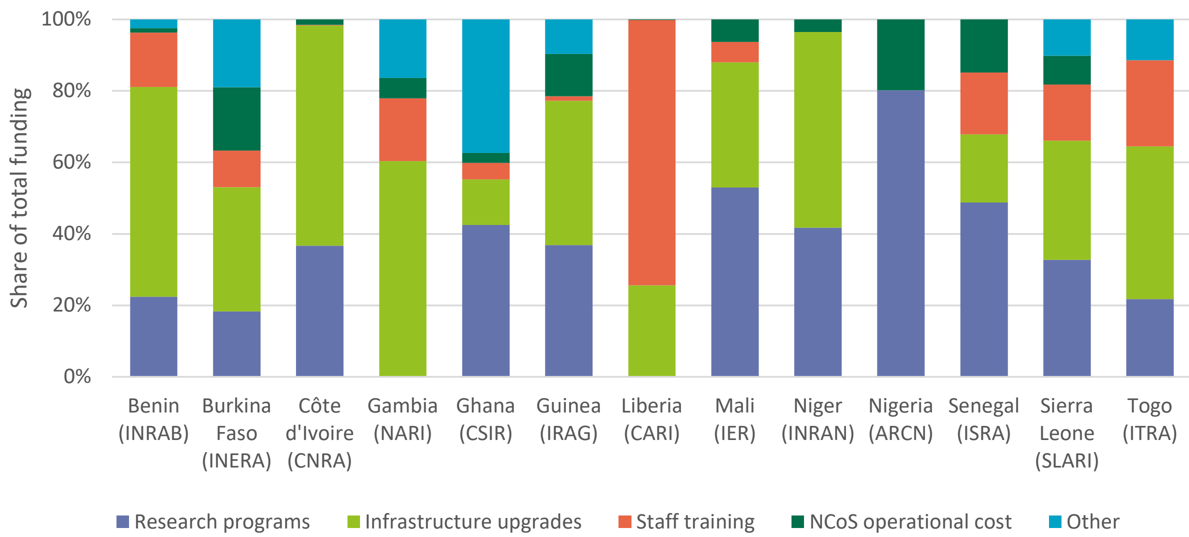
Source: Compiled by authors from World Bank (2017b).

Note: 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 for any years covered in the table. WAAPP = West Africa Agricultural Productivity Program; NARI = national agricultural research institute; INRAB = National Agricultural Research Institute of Benin; INERA = Environment and Agricultural Research Institute; CNRA = National Agricultural Research Center; NARI = National Agricultural Research Institute; CSIR = Council for Scientific and Industrial Research; IRAG = Guinean Agricultural Research Institute; IER = Institute of Rural Economy; INRAN = National Agricultural Research Institute of Niger; ARCN = Agricultural Research Council of Nigeria; ISRA = Senegalese Agricultural Research Institute; SLARI = Sierra Leone Agricultural Research Institute; ITRA = Togolese Agricultural Research Institute.

Regional averages mask 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 construction and 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 nonsalary costs were funded through WAAPP. Dependence on WAAPP to fund nonsalary costs is also relatively high (between 40 and 60 percent) at INRAB (Benin), CSIR (Ghana), and the Guinean Agricultural Research Institute (IRAG). 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.

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 and construction of research laboratories and investment in research equipment (Figure 10.2). 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 the Sierra Leone Agricultural Research Institute (SLARI), equal proportions were allocated to research programs and infrastructure upgrades, while at the Central Agricultural Research Institute (CARI) in Liberia, the bulk of WAAPP funding was spent on staff training.

Figure 10.2 Composition of WAAPP funding to NARIs, 2008–2016 averages



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

Note: WAAPP funding includes all IDA, GFRP, and PHRP allocations. WAAPP = West Africa Agricultural Productivity Program; IDA = International Development Association of the World Bank; GFRP = Global Food Response Program; NCoS = national centers of specialization; NARI = national agricultural research institute; INRAB = National Agricultural Research Institute of Benin; INERA = Environment and Agricultural Research Institute; CNRA = National Agricultural Research Center; NARI = National Agricultural Research Institute; CSIR = Council for Scientific and Industrial Research; IRAG = Guinean Agricultural Research Institute; CARI = Central Agricultural Research Institute; IER = Institute of Rural Economy; INRAN = National Agricultural Research Institute of Niger; ARCN = Agricultural Research Council of Nigeria; ISRA = Senegalese Agricultural Research Institute; SLARI = Sierra Leone Agricultural Research Institute; ITRA = Togolese Agricultural Research Institute

WAAPP-Funded Competitive Agricultural Research Grants

In addition to direct World Bank support to the countries, complementary funds are 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 seven regional competitive and/or commissioned projects financed within the WAAPP framework, four Integrated Land and Water Management (ILWAC) Trust Fund subgrant 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 many complementarities and synergies between WAAPP and MDTF projects, both at the country and the CORAF coordination levels.

Between 2013 and 2017, a total of $7.2 million of funding was channeled to the MDTF and allocated to the countries on a competitive or commissioned basis (Table 10.5). These seven projects cover a wide variety of research topics and themes. Benin and Senegal have been most successful in securing CARGS funding: six of the seven projects cover these two countries. In contrast, Guinea, Liberia, Sierra Leone, and Togo only received funding through two CARGS projects. Exact funding allocation amounts per country per year are unavailable.

Table 10.5 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 scaling up 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	Jul 2013—Jun 2016

Development of a seed program (ASPRODEB/ ROPPA)	Sustainable increase of the production of certified seeds in Benin, The 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	WAAPP-2A	Burkina Faso, Côte d'Ivoire, Ghana, Mali, Nigeria, and Senegal	600,000	2017-2018

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

Note: WAAPP = West Africa Agricultural Productivity Program; CARGS = Competitive Agricultural Research Grant Scheme.

In addition to the seven regional projects that are funded within the WAAPP framework, the government of Denmark has funded a series of ILWAC projects that were implemented under WAAPP. These projects, with a total cost of $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.

Contribution of WAAPP to Overall West African Agricultural Research Investment

A comprehensive analysis of the contribution of WAAPP in total (that is, 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 and 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 much of their time on nonresearch 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 10.6 provides an overview of total West African agricultural research investment and WAAPP funding during 2008–2015.

Table 10.6 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

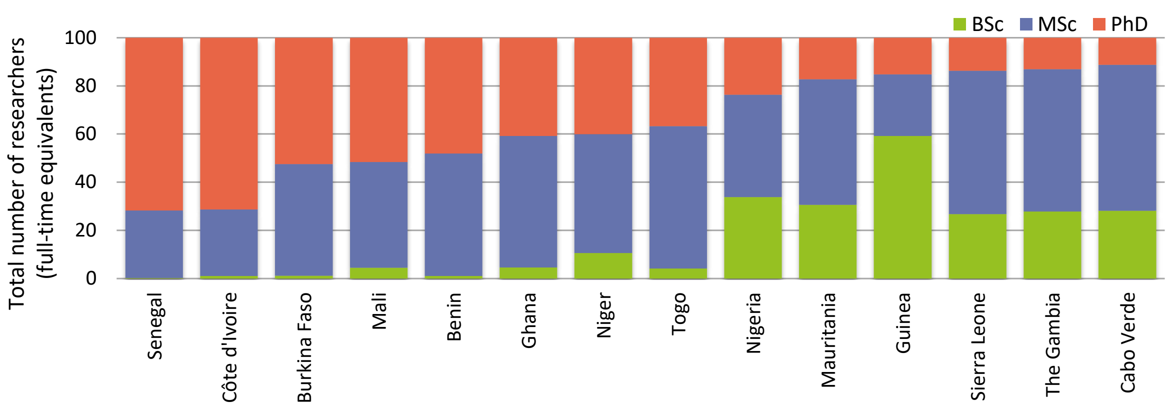
Sources: Total agricultural research spending from ASTI database; total WAAPP funding from World Bank (2017b).

Note: 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 10.5 were spread equally over time. WAAPP = West Africa Agricultural Productivity Program; CARGS = Competitive Agricultural Research Grant Scheme; n.a. = not available.

11. Qualification Level, Gender, and Age Composition 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 policy makers, 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 11.1). Cabo Verde, The Gambia, and Sierra Leone were the only countries with PhD shares below 15 percent.

Figure 11.1: Distribution of agricultural researchers by qualification level, 2014

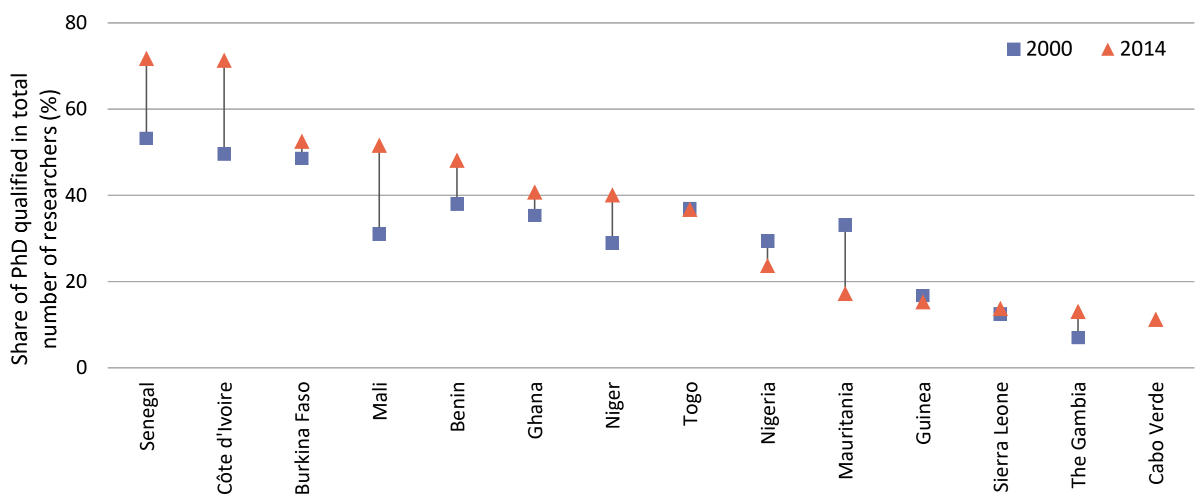


Source: Calculated by authors based on ASTI data and various secondary sources.

Note: Data for Guinea-Bissau and Liberia were unavailable. Data for Nigeria and Sierra Leone exclude the higher-education sector. This figure excludes technical and other support staff that held university degrees but did not hold official research positions.

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 in part 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 11.2). 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 11.2: Change in the share of PhD-qualified researchers by country, 2000–2014



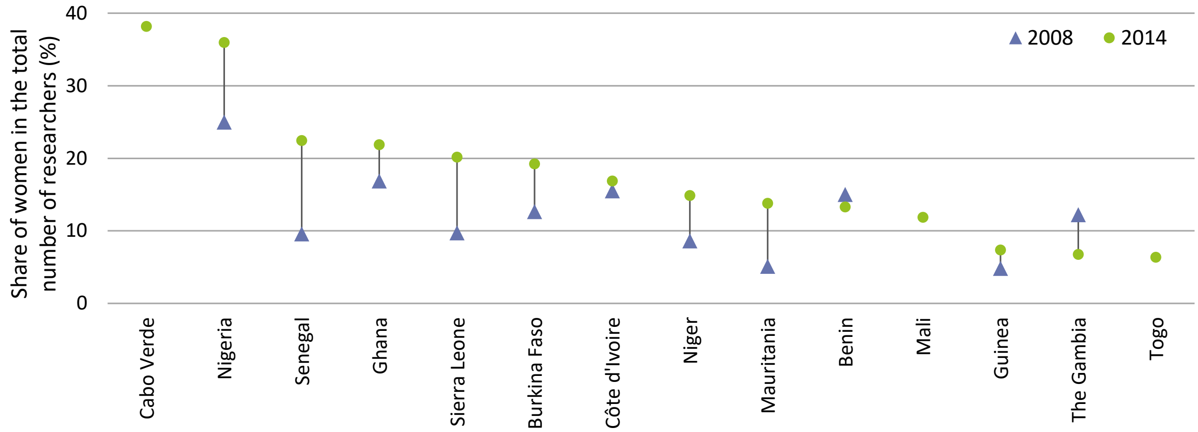
Source: Calculated by authors based on ASTI data and various secondary sources.

Note: Guinea-Bissau and Liberia data were unavailable, as were data for 2000 for Cabo Verde.

Female Participation in West African Agricultural Research

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) were female (Figure 11.3). 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 6–7 percent of agricultural researchers. With the increase in the number 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 lower than in other parts of Africa.

Figure 11.3 Change in share of female agricultural researchers by country, 2008–2014



Source: Calculated by authors based on ASTI data and various secondary sources.

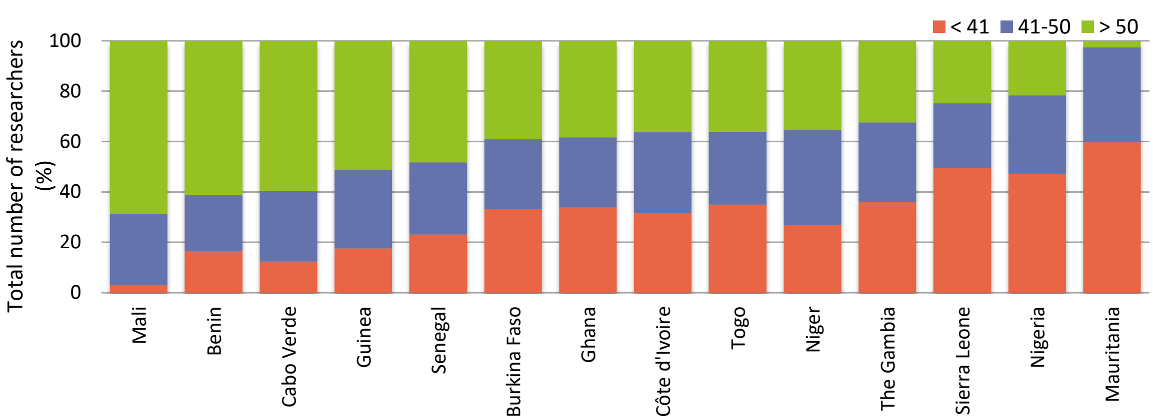
Note: Guinea-Bissau and Liberia data were unavailable, as were 2008 data for Cabo Verde, Mali, and Togo.

Female scientists are far less likely to hold PhD degrees than their male colleagues, which limits their contributions to research.

West Africa's Aging Pool of Agricultural Researchers

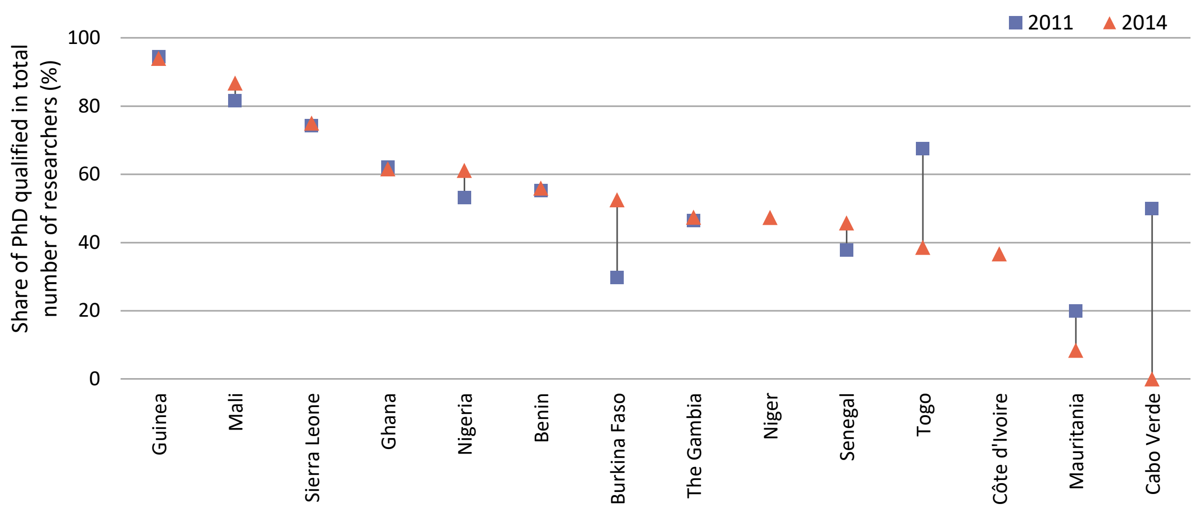
Long-term public-sector recruitment restrictions have left institutes in many countries with an aging pool of agricultural researchers, many of whom are set to retire within the next decade (Figure 11.4). In 2014, on average, more than half the agricultural scientists in West Africa with PhD degrees were older than 50 (Figure 11.5). In Guinea, Liberia, Mali, Sierra Leone, and Togo, more than 70 percent of PhD-qualified researchers are 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 11.1).

Figure 11.4 Distribution of researchers (including BS, MS, and PhD holders) by country and age bracket, 2014



Source: Calculated by authors based on ASTI data.

Figure 11.5 Change in the share of PhD-qualified researchers over the age of 50, 2011–2014



Source: Calculated by authors based on ASTI data.

Table 11.1 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 transferring, 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 promotion opportunities. The government of Ghana instituted the Single Spine Pay Policy, which introduced parity between the salaries of CSIR scientists and university-based scientists. Staff morale has improved considerably at both institutes, the supply of

Box 2. Motivation of NARI-based researchers

As part of an ASTI/IFPRI and CORAF project, a staff motivation survey was conducted during 2013–2014 in Benin, Burkina Faso, Ghana, Senegal, Sierra Leone, and Togo to gain a better understanding of the factors that 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.

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 NARIs and the university sector remain significant and hurt morale. A large percentage of researchers in all six countries indicated that a lack of research funding and inadequate research infrastructure and equipment negatively affected their level of motivation. Limited promotion 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 promotion 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.

candidates for vacant positions has increased, and staff turnover appears to have declined.

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 faces. In nearly all countries in West Africa, a majority of PhD-qualified researchers will retire by 2025, which creates a need for succession strategies and training to avoid impending capacity gaps. 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 (MS- and PhD-level) of more than 1,000 young scientists, 30 percent of whom are women, in various priority areas. Not all of the people in training 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 corps is being tackled at a large scale. A considerable number of NARI staff members have undergone or are currently undergoing PhD- or MS-level training as part of WAAPP (Table 11.2). 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, capacity lost due to retirement will to a large extent be offset by an influx of younger scientists who received WAAPP-funded postgraduate training. As capacity gaps are narrowed, more funding can be applied to research programs, thereby raising returns to resources invested in agricultural research.

Table 11.2 Number of staff receiving WAAPP-funded postgraduate training, by gender and location, 2008–2016

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

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

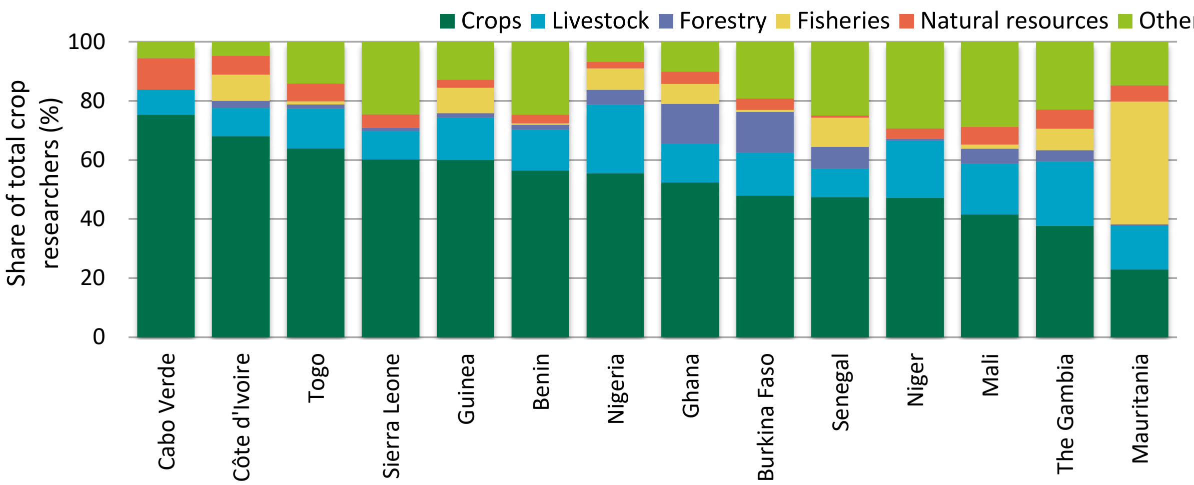
Note: This table focuses on the main agricultural research institutes. A large number of additional scientists at smaller government research agencies or universities have also received WAAPP-funded MS- and PhD-training.

12. Focus and Quality of Agricultural Research

As noted earlier in this report, meeting objectives of multifunctional agricultural development requires productivity growth across a broad spectrum of products and technologies, and regional integration to share costs and benefits. Improved regional integration of research effort can, in turn, be built from an understanding of the present distribution of research by commodity and among countries.

Crop research remains the dominant type of research conducted throughout West Africa (Figure 12.1). Livestock research is also 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) and focuses instead on fisheries research.

Figure 12.1: Agricultural research focus by components by country in West Africa, 2014

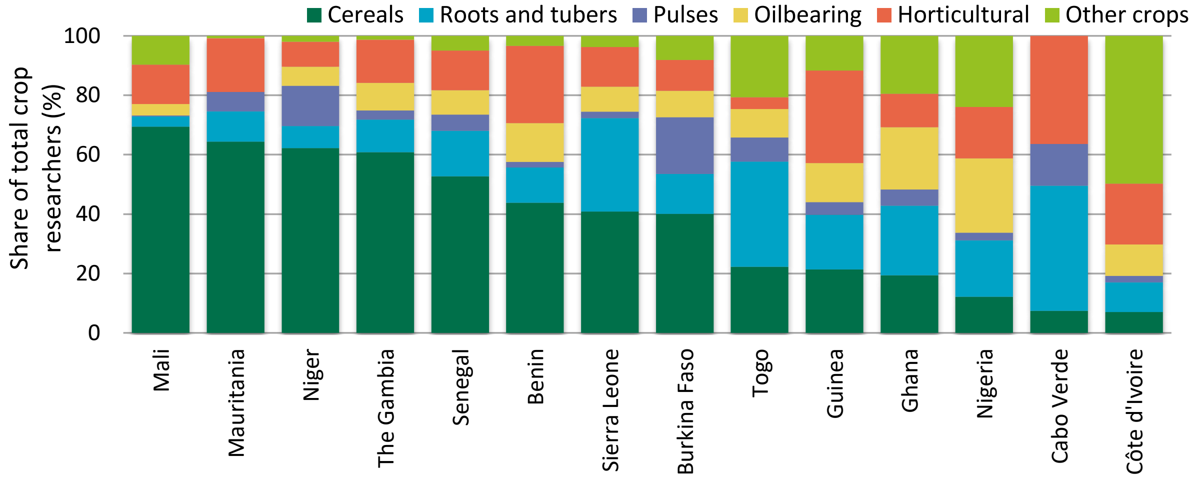


Source: Calculated by authors based on ASTI data.

Note: The category "Other" comprises socioeconomic research, on-farm postharvest research, agricultural engineering research, etc.

West Africa's agroclimatic diversity is clearly reflected in the type of crop research conducted across countries. The Sahel countries focus predominantly on cereal crops, while roots and tuber research is more important in the tropical zones (Figure 12.2). Horticultural research is conducted throughout the subregion. Research on pulses (mostly cowpeas) is particularly prominent in Burkina Faso and Niger.

Figure 12.2 Crop research focus by category by country, 2014



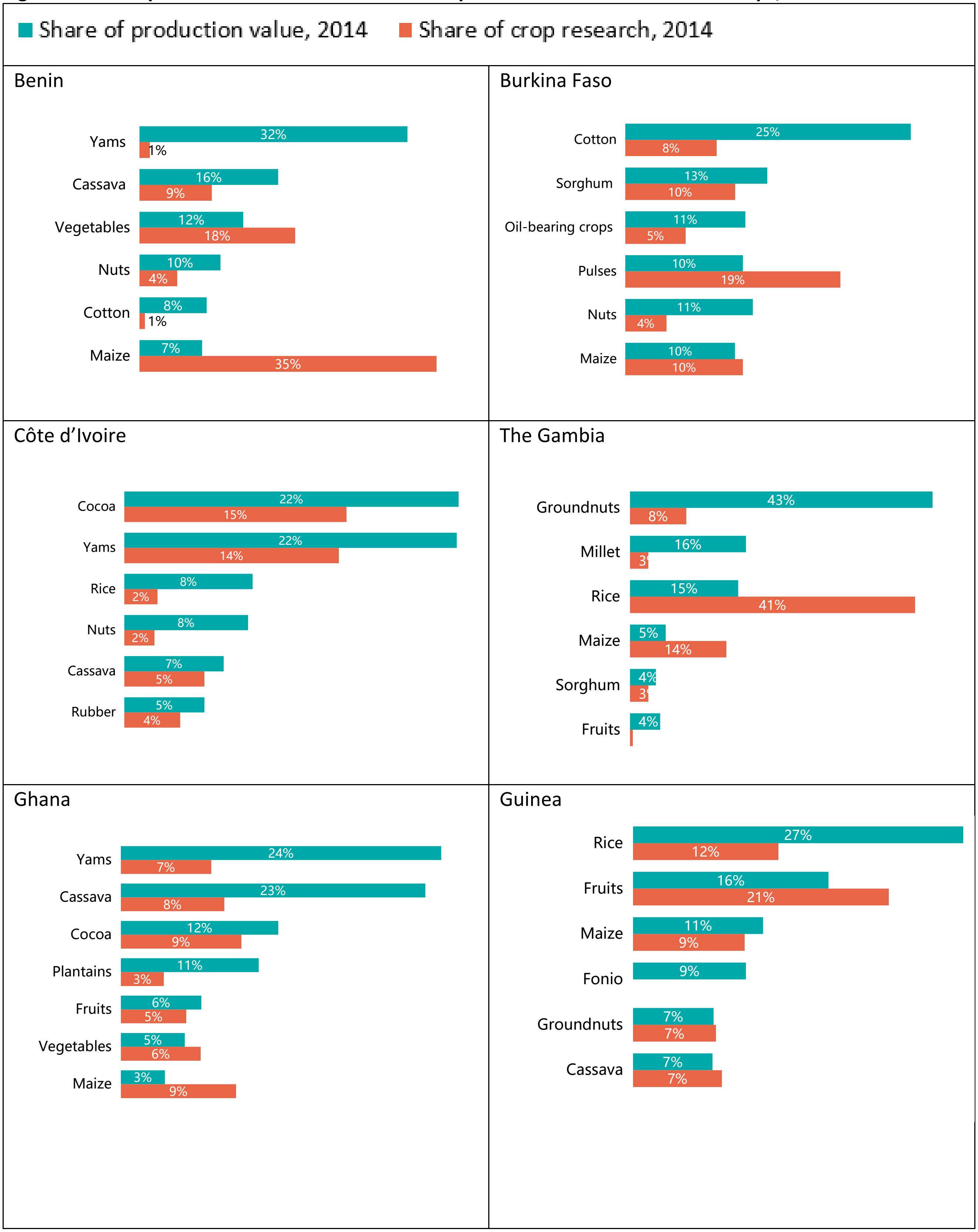
Source: Calculated by the authors based on ASTI data.

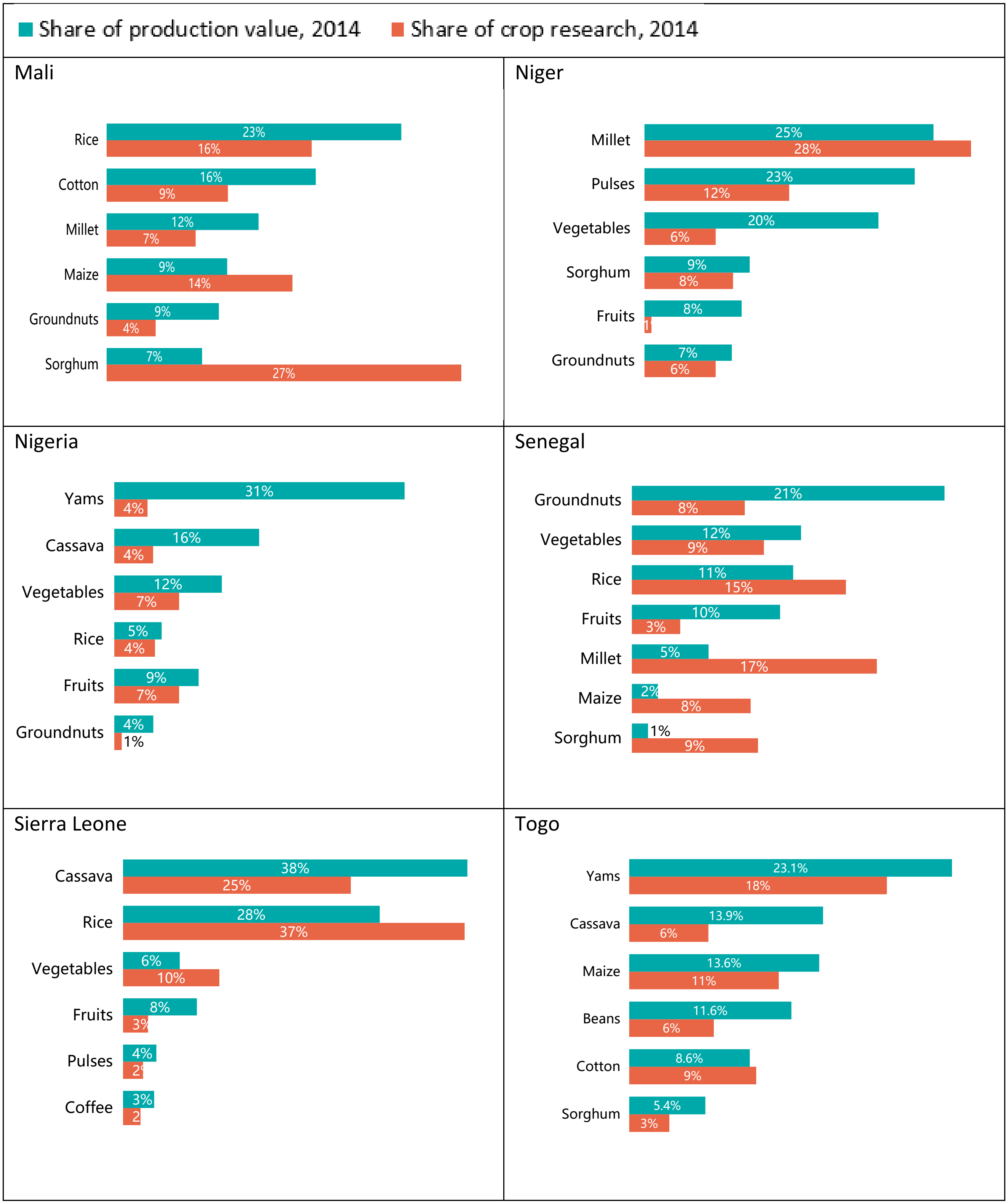
Note: The category "Other crops" comprises nuts, cotton, sugar, coffee, cocoa, rubber, etc.

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 12.3). For maize, this situation was reversed: more researcher time was allocated to this crop relative to its production value in five of the seven countries where maize is an important crop. 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.

Figure 12.3 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 (2017b).

Note: Data for Liberia are unavailable.

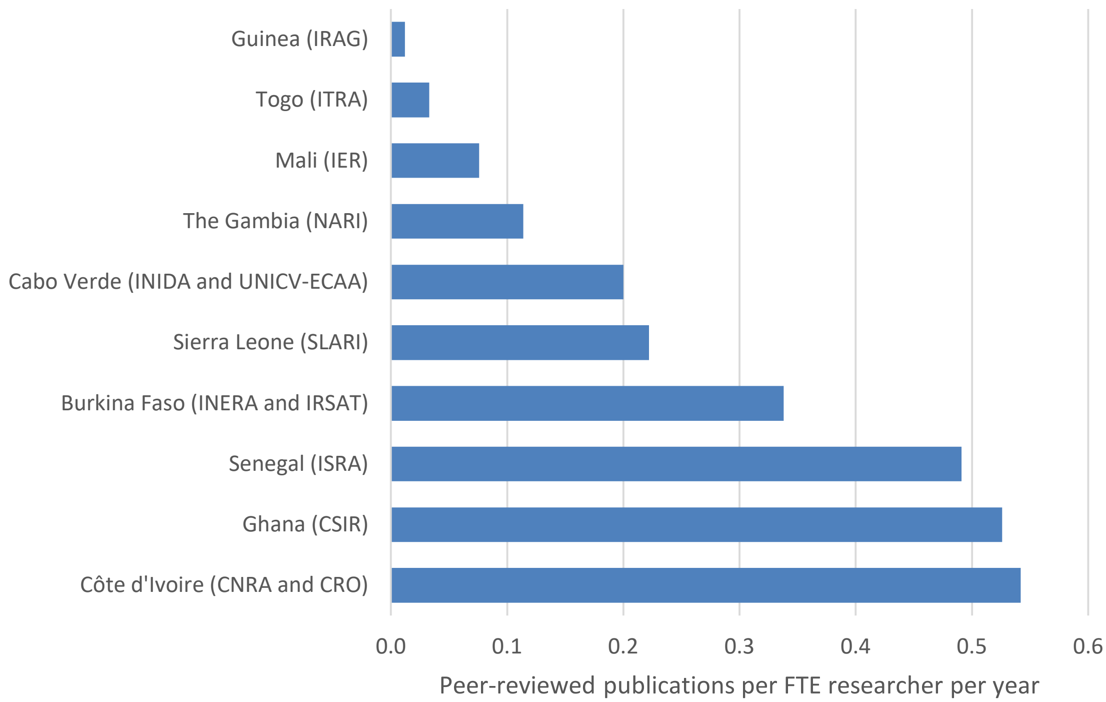
The data highlight the importance of viewing research support in a regional context and strengthening regional linkages. Countries show differing commodities of emphasis which, if seen only at the national level, can imply suboptimal allocation. Alternatively, if viewed at the regional level in a setting 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 assessment of the combined investment in specific crops and livestock products across countries compared with 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, as noted above in this report, 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 researchers with primary affiliation at institutions in 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 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 12.4), 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 opportunities to collaborate with international partners and to generate competitively sourced funding. Most NARIs provide insufficient incentives for their scientists to publish, and very few link the publication of results with performance appraisals. With low priority placed on publication, scientists do not develop the expertise to have their work accepted for publication in academic outlets and other forums.

Figure 12.4 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.

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 are incomplete, but those available indicate significant cross-country variation. 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 varieties of crops such as maize, vegetables, rice, sorghum, wheat, and cowpeas over time.

As part of this study, detailed information was collected on releases of new crop varieties 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 (for example, the release of 12 new New Rice for Africa (NERICA) rice varieties in Sierra Leone). The three WAAPP 1A countries have been the most productive in terms of variety releases, 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 12.1). WAAPP 1A support for roots and tuber research in Ghana has resulted in the release 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 specialized in rice under WAAPP and released five new rice varieties in 2012 and 2016 and disseminated many more. 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 12.1 Crop varieties that were registered and released, or adapted and diffused, with WAAPP funding or cofunding, 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 (2017b).

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. Few NARIs succeed in protecting improved varieties under the African Organization of Intellectual Property (OAPI) or the African Regional Intellectual Property Organization (ARIPO). 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, 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. Additional national funds are needed to upgrade equipment and facilities so that the funds spent on staff salaries can yield good results.

13. Conclusions and Implications for Action

The analysis presented above yields several conclusions and implications for action.

West African countries will need to build on and enhance the largely positive performance of agriculture in recent years to moderate or perhaps reverse projected higher prices and growth in imports. The effects of increased demand and climate change will be felt as early as 2030, and with greater force in 2050. Technologies are known at present and additional ones can be developed that will meet rising demand and perform well under projected changes in climate, but full preparation, release, and effective dissemination of the technologies will require investment and managerial engagement.

Complementary investment in research, water management, and infrastructure will be more effective than separate and uncoordinated investments. Different portfolios of investment carry different costs, payoffs, and trade-offs among objectives. In light of the resource constraints and multiple objectives, rigorous analysis to reveal costs and trade-offs will assist in decision making.

The composition of the agricultural research portfolio will affect the contribution of research to poverty reduction, nutrition, job creation, growth, and climate resilience. Research to raise productivity and yields of staples usually contributes most to poverty reduction. Research raising productivity of animal products, legumes, fruits and vegetables, and biofortified crops improves nutrition. Research raising the productivity and competitiveness of products requiring processing, whether for domestic, regional, or export markets, creates jobs. Research addressing the growing import gap contributes to growth and a manageable trade balance. Research on technologies for better management of natural resources addresses long-term sustainability. All of the research must take climate change into account. Important choices must be made in allocating resources among research programs. No single set of priorities is optimal, but analysis to clarify options and contributions to competing goals can be helpful in decision making.

The gap between current investment in agricultural research and levels reached if all countries contributed equally (once relevant heterogeneity is accounted for) is large, but within a range that is feasible to close. At around $500 million PPP per year, this sum can be mobilized by adjusting the composition of agricultural public spending within the commitments that governments have already made to CAADP spending targets. Closing a gap of $500 million PPP per year will not guarantee stable prices or zero hunger. Compositional effects and efficiency of research will also be very important. This is a level of investment, however, that is feasible, since some countries in the region are already investing at that level. It is also an amount consistent with absorptive capacity. Additional money will be required to fully rebuild staff numbers, construct needed infrastructure, and undertake the research required to meet ambitious growth targets.

At a level of funding corresponding to a closed gap (that is, $500 million PPP incremental per year), effective use of research money will require significant adjustment among institutions and research lines.

Investment in human capacity will need to continue at a high level for several years and then can settle to a steady state given the significant accomplishments in the last five years (including 1,000 young scientists trained under WAAPP—30 percent of whom are female). Mechanisms should be put in place to deploy staff regionally, instead of nationally.

To retain trained staff, NARIs will need to be able to set salaries and working conditions competitive with local universities and regional and international research organizations. This will in many cases require relaxing constraints of civil service human resources practices.

Sustained funding requires a commitment of national governments and regional bodies. It cannot depend largely on donors or external contributions. This, in turn, requires clear demonstration of the benefits of agricultural R&D and creation of national advocacy groups to assure vocal and visible support.

Regionalization of the research effort is at an early stage and must accelerate quickly if gains are to be realized. A monitoring system should be put in place to track regional effort. The system should include cross-national collaboration in research, counting of publications with authors from several national institutions, tracking of release and adoption of varieties and new technologies across borders, movement of staff among institutes, and collaboration with international partners, including CGIAR. The system should also include regular monitoring at the national level, using the ASTI methodology or a close correlate, to track allocations, release of funds, expenditure, and human resources by country and source of funding.

To support continued integration, a regional study of congruence should be undertaken to provide a baseline diagnostic of existing research programs and highlight links that should be strengthened now, and those that should be incorporated in research priorities for the future. To support the latter, the congruence study should be supplemented by foresight analysis and application of CGE models to incorporate considerations of poverty reduction, growth, job creation, nutrition, and climate resilience into regional deliberations on priorities for research.

Geospatial analysis should be used to target release of varieties and technologies and to estimate ex ante adoption rates. Where adoption either leads or lags projections, specific studies should be undertaken to assess barriers or identify accelerating factors.

The work described above as necessary analytical support can and should be led by experts from the region, with technical support from external partner organizations. The core models and data developed by IFPRI/CGIAR and described above are open-source and can be accessed by institutions or individuals from the region. West African scientists are already involved in the analytical effort and can lead in the future. Additional training is available upon request. Design of interventions to strengthen West African agriculture should include an analytical component, managed and coordinated by regional scientists, to assure feedback of new data and changes in the context into the decision calculus.

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Fax: +1-202-862-5606
Email: ifpri@cgiar.org