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Priorities for Realizing the Potential to Increase Agricultural Productivity and Growth in Western and Central Africa

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Contents

List of Tables

List of Figures

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ABSTRACT

We identify a set of development priorities for agriculture that cut across West Africa, at both the country and the regional level, to achieve economy-wide growth goals in the region. To do this, we adopt a modeling and analytical framework that involves the integration of spatial analysis to identify yield gaps determining growth potential of different agricultural activities for areas with similar conditions and an economy-wide multimarket model to simulate *ex ante* the economic effects of closing these yield gaps. Results indicate that the greatest agriculture-led growth opportunities in West Africa reside in staple crops (cereals as well as roots and tubers) and livestock production. Rice is the commodity with the highest potential for growth and the one that could generate the greatest benefits for many countries. Activities contributing the most to agricultural growth in the Sahel are livestock, rice, coarse grains, and groundnuts; in coastal countries, staple crops like cassava, yams, and cereals seem to be relatively more important than the contributions of other subsectors; and livestock and root crops are the sources of growth with highest potential in Central Africa. Our results also point toward an essential range of policies and investments that are needed to stimulate productivity growth of prioritized activities. These include the following: development of opportunities for regional cooperation on technology adaptation and diffusion, strengthening of regional agricultural markets exploiting opportunities for greater regional cooperation and harmonization, diversification of traditional markets, and enhancement of linkages between agricultural and nonagricultural sectors.

Keywords: agricultural growth, multi-market model, spatial analysis, staple crops, West Africa, yield gap.

1. INTRODUCTION

Many African countries have undergone a number of development initiatives over the past four decades to find ways to spur growth and development that will enhance welfare and provide a more humane lifestyle for their citizens. Key among these initiatives is the goal shared by many countries to halve poverty and hunger by 2015, a commitment that headlines the so-called Millenium Development Goals (MDGs). Countries in the western and central regions of Africa, like many other countries in Sub-Saharan Africa, have undergone a number of challenges and hurdles in achieving these goals. In fact, out of 16 countries in this region, only 1 (Ghana) is on track toward halving poverty and hunger by 2015 (Breisinger et al. 2008). To be sure, this is a goal of considerable difficulty, which requires consistent and broad-based growth accompanied by dramatic improvements in infrastructure, governance, and a host of social indicators. For most poor African countries faced with limited resource endowments, a harsh physical and socioeconomic environment, and a predominantly rural and agrarian population, being able to meet the challenges involved in generating so many improvements in various key areas is a daunting task. In West Africa, these challenges are especially pronounced given the region's poor overall economic performance compounded by periods of political instability and erosion in both physical and human capital. Moreover, the small size and isolation of many of the economies in the region, their fragile agro-ecologies and high dependency on rain-fed agriculture, and their frequent susceptibility to droughts and tropical diseases make generating any growth especially challenging (Abdulai, Diao, and Johnson 2005).

One of the key factors behind the overall weak performance of West African economies is poor growth in agriculture. While most of the economies in West Africa depend on agriculture for export revenues, employment, national income, and rural livelihoods, agricultural production has remained typically characterized by small family farms that still rely heavily on rain-fed production systems, natural methods for soil fertility maintenance, and infrequent year-long access to large market centers. Consequently, a majority of rural West African farmers continue to face low productivity and high production and marketing risks, which in turn increase the variability in production and income growth of the sector. Modern input use—such as fertilizer, improved seeds, and machinery—remains very limited, and therefore, agricultural productivity has remained far below its potential.

The significant amount of knowledge and technology generated since the green revolution to enhance productivity has clearly failed to reach much of Western and Central Africa. This is evidenced in a comprehensive database developed by CABI (2005) that shows that yield losses can average up to 60 percent in Western and Central Africa due to weeds, pests, viruses, and pathogens. Altogether, the losses contributed to a US$10 billion loss in output between 2000 and 2004 (Cohen et al. 2005; CABI, 2005). Moreover, a study by Fischer et al. (2001) shows that current crop yields have the potential to increase by two- to fivefold if the mix of existing technologies and best farming practices is used optimally within each of the major agro-ecological zones (AEZs) in West Africa. Our own estimates of potential productivity and productivity gaps for different crops and regions, using information from the study by Fischer et al. (see chapter 3), show that on average for West Africa there is potential to triple productivity of maize and coarse grain, double rice productivity, and boost cotton productivity by a factor of 2.6, while present productivity of other crops could be increased by 10 to 50 percent.

Even as current levels of production and productivity in West African agriculture are hardly encouraging, they offer West African countries the opportunity of rapid growth by closing the gap between current and regional potential productivity. Essentially, the larger the productivity gap, the greater the potential to make big leaps in productivity growth (Abramovitz 1986). Thus, productivity backwardness in West Africa could become a growth opportunity if countries in the region would target a reduction of this gap in an immediate strategy for improving the performance of agriculture in the region.

Considerable literature exists to back the argument that agriculture is a key tool for both growth and poverty reduction (see chapter 2). Hence, any strategy that aims to achieve the goals outlined by the MDGs inevitably has to incorporate growth in agriculture as one of its essential components. Doing so requires significant growth in levels of productivity and thereby reductions in the gap between actual and potential yields. For West and Central Africa reducing this gap has to be a top priority. In addition, increased collaboration among countries in the region, alongside with productivity growth, can pave the way to a regional approach for an agricultural-led growth strategy, which can be an effective tool in promoting agricultural-based growth. This occurs as there is a growing recognition among countries that share common borders and problems that there are potential gains to be had from greater regional cooperation and economic integration. In West Africa, this can be seen through the existence of several regional bodies such as the Economic Community of West Africa States (ECOWAS), Conseil Ouest et Centre Africain pour la Recherche et le Développement Agricoles/West and Central African Council for Agricultural Research and Development (CORAF/WECARD), and Comité permanent Inter-Etats de Lutte contre la Sécheresse dans le Sahel. The growing commitment to a shared vision for development across individual countries further supports this perspective, as is evident in the New Partnership for Africa's Development and the MDGs.

There are also strong economic and technical reasons that justify a regional approach to agricultural development. Critical among them is the agro-ecological diversity of the region. Most West African countries cover several ecogeographical zones, from the Sahara desert and the arid Sahelian zone with average annual rainfalls of less than 150 and 400 millimeters, respectively, to the humid zones on the coast with an annual rainfall ranging from 900 to over 1,500 millimeters. As a consequence of this diversity, significant gains might be achieved from regionally conceived and implemented R & D programs, given that the compartmentalization of some of these programs reduces opportunities for economies of scale and that national expertise, taken individually, is often insufficient to meet the scientific challenges of innovation and technical change. At the same time, certain natural resources, particularly many of the freshwater resources in the area (surface water but also underground water) are transboundary and are therefore not appropriately dealt with within the framework of strictly national strategies (Niasse 2007).

Another important economic reason for a regional, agricultural-led development strategy in West Africa is that given the scarcity of resources in the region, cost-sharing could be a necessity and ultimately the solution for one of the poorest regions in the world, with weak economies and high costs of capital. Joint regional investment projects in one country could benefit that country's neighbors through the generation of externalities leading to potential efficiency gains from regional rather than national investment strategies. Moreover, benefits from regional integration could be more powerful if key development policies were synchronized across countries, increasing economic linkages to allow stronger countries to act as regional growth centers, pulling neighboring countries along with them as they grow.

Finally, a strategy that facilitates and promotes the creation of regional markets could boost up the development of agricultural subsectors that are constrained by the small size of the domestic markets in individual countries. Production of staple food and in particular of cereals and maize is one of the areas that could be affected by regional integration, with obvious implications for rural poverty and food security. Regional integration offers the possibility of enlarged markets for increased production of cereals, and poor countries have the potential to dramatically increase output and farm sales if some of the intraregional trading barriers and transaction costs were to be removed.

Some of the reasons that suggest the need for a regional approach to development (part of the "How?" question in a development strategy) also point to the importance of correctly answering the "What?" question. In other words, which activities are going to be prioritized in the context of an agricultural-led development strategy? The need to make the most efficient use of regional agro-ecological diversity, economies of scale and regional expertise, and the fact that agricultural activities will differ in their contribution to growth and poverty alleviation, makes the evaluation and prioritization of these activities one of the focal components of a regional, agricultural-led growth strategy for West Africa. The impact of a particular agricultural activity will depend on its share in total agricultural output and the links between this subsector and the poor. Hazell (2005) argues that agricultural growth in Africa is not necessarily pro-poor when driven by high-value exports. The reasons for this are that the amount of additional agricultural income from high-value exports is too small to make much of a difference for most of the poor and that the main beneficiaries of this growth are commercial farms located in areas with good market access. According to Hazell, food staples production is much more pro-poor for two reasons: first, staples are grown by farmers across Africa, including those at most small farms and the poor. Second, increases in cereal yields, if based on inputs or technologies that can be used widely by farms of all sizes, can have an enormous impact on poor farmers' income while bringing down food prices for everyone else.

In recognizing the importance of defining priorities for a regional, agricultural-led strategy, the primary purpose of this report is to identify a set of alternative agricultural activities with the highest potential to achieve economy-wide growth and poverty-reduction goals across West Africa[1] when measures are put in place to reduce the existent productivity gap in those activities.

Under these considerations, the economic analysis in this report focuses on a disaggregated set of 32 crop and food products and 8 livestock activities plus fishing and forestry, covering the major staple, cash, high-value and export crops, and main livestock products in West and Central Africa.[2] The analysis was conceived, from the very beginning, as a series of integrated analytical steps that can explicitly capture the diversities within and across countries while analyzing national and regionwide options for attaining higher agricultural and economic growth rates. First, spatial analysis is used to define areas with similar growth potential across the region (development domains), with different productivity gaps for the agricultural activities associated with each of these areas.

Second, the spatial information is used together with secondary data to calibrate the two economic models used in the analysis (the multimarket and Dynamic Research Evaluation for Management [DREAM] models). By simulating the reduction of the productivity gap in crop and livestock activities, these models provide a regional and economy-wide analysis of the economic impact of enhancing productivity of these activities, allowing for a greater understanding of the response of regional agriculture to policy interventions that promote productivity growth.

Finally, our approach incorporates a *dynamic* perspective by being forward looking during the next decade. Growth in the different scenarios simulated by the economic models is compared to a business-as-usual scenario wherein it is assumed that productivity in all activities continues to grow at its historic rate. Every effort is made to maintain an *integrated* analytical approach by using the same agricultural activities and the same baseline information and growth scenarios to serve as key input into the modeling and economic analysis.

The report is organized as follows: chapter 2 provides a theoretical argument, together with supporting evidence, about why the agricultural sector is central for achieving growth and poverty reduction in the region. It also reviews the importance of agriculture in the region and its past performance. Chapter 3 focuses on the analysis of the potential to increase productivity within different agro-ecological and socioeconomic environments in West Africa, depending on the current yield gaps for each crop and unique environment and on the potential demand to absorb increased production resulting from increased productivity. Chapter 4 presents the integrated methodological approach developed in this study to assess regionwide strategic options for stimulating agricultural growth. Simulation results are presented in chapter 5, focusing attention on measuring the impact of each growth scenario on agricultural and overall economic growth. Based on these results, we assess how the different crop and livestock activities and growth scenarios compare across countries—in terms of their impact on growth and relative to the Comprehensive Africa Agricultural Development Programme's[3] 6 percent agricultural growth

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[1] The focus region of this study includes countries that are members of the Conseil Ouest et Centre Africain pour la Recherche et le Développement Agricoles/West and Central African Council for Agricultural Research and Development. These countries are Benin, Burkina Faso, Cameroon, Cape Verde, Central African Republic, Congo, Ivory Coast, Gabon, Gambia, Ghana, Guinea, Guinea Bissau, Mali, Mauritania, Niger, Nigeria, Democratic Republic of Congo, Senegal, Sierra Leone, Chad, and Togo.

[2] See the complete list of activities in appendix C.

[3] The Comprehensive Africa Agricultural Development Programme (CAADP) has been endorsed by the African Heads of State and Governments as a framework for the restoration of agriculture growth, food security, and rural development in Africa. The primary CAADP goal is agricultural development that eliminates hunger and reduces poverty and food insecurity, opening

target—to define priority subsectors and corresponding policy and investment options. The final chapter offers conclusions and policy implications.

the way for export expansion. CAADP has as one of its specific targets for achievement by 2015 improving the productivity of agriculture to attain an average annual growth rate of 6 percent.

2. THE ROLE OF AGRICULTURE - THE ECONOMY AND REGIONWIDE CONTEXT

The pivotal role that agriculture occupies today in promoting growth is the consequence of years of debate and empirical work. Over the years, agriculture has swung the full spectrum of possibilities when it comes to ascertaining its role in development, from a mere source of labor to the manufacturing sector to a key component of a poverty-reducing growth strategy. To reach its status as an integral part of a sustainable growth strategy, not only has the agricultural sector witnessed the rise of many theories concerning its role, but also it has been a laboratory of sorts in which policy experiments were conducted to test the new theories in vogue.

Two distinct stages in the perception of agriculture are worth describing: the first, encapsulated in the theory of dual models, represents a view that dominated the perception of economists for much of the past century, one in which agriculture was perceived as a backward sector whose main function was to provide surpluses to the industrial sector. The second is the switch in the perception of agriculture, brought forward by a combination of new research and lessons from failed policies that dismissed agriculture. We review these two stages below. We then look at the importance of the agricultural sector for West Africa's economy.

2.1. Theoretical Underpinnings

Dual models were used to analyze the economies of and to explain growth in the developing world, especially in countries where population densities were high and industrial development was incipient at best. Conceptualized in the 1950s (e.g., Lewis 1955), these models were largely based on Asian economies such as India (see Johnston and Mellor [1961] 1995; Self and Grabowski 2007 for details). Asian economies at the time were mostly agricultural, and hence much of the population was concentrated in agricultural areas, which suggests that a potentially enormous agricultural labor force was available. Lewis's (1955) intuition was that much of the labor force available for agriculture was largely underutilized and that the entire agricultural sector served mostly the purpose of subsistence. The large pool of laborers combined with a subsistence (unproductive) agriculture translated into a very low, practically zero, marginal product of agriculture. Hence, agriculture was stagnant and far from being a source of growth. At the same time, the "modern" sector, which essentially comprised industries and services, offered a very different outlook for two reasons. First, it was profit oriented, and as such, additional labor was desired only up to the point where the marginal product of the last worker equaled the wage rate; second, it offered many more possibilities of using new technology. By being wage based, the modern sector has a natural restriction on the number of workers to take because the wage is a reflection of the marginal product of labor. In the early days of industrialization, agriculture was not only the single source of labor but also home to a large surplus of laborers (Johnston and Mellor [1961] 1995). The essence of dual models is precisely this extracting of the labor surplus from agriculture into manufacturing (or services). The ability of the modern sector to attract labor was derived from the differences in marginal products, with a zero marginal product of labor in agriculture and relatively high marginal product in the modern sector. Thus, workers would be willing to take any wages that were higher than the mere subsistence level (Johnston 1970). This process was to continue until the marginal products of labor in the two sectors were equal. The logical consequence of this line of thinking is that to generate growth, governments need to promote rapid industrialization, and the way to do so was to extract the surpluses from agriculture, particularly labor. However, as economists and policy makers became more and more comfortable with the idea of extracting surpluses from agriculture, policies that were implemented in an attempt to promote industrial growth actually embodied a bias against agriculture.

Sub-Saharan Africa (SSA) was home to these policies, many of which had already been implemented during the postindependence period and directly targeted the development of industries by explicitly taxing agriculture (taxing the proceeds from exports was one of the ways it was done). The outcomes of these policies for SSA have generally been negative and have not spurred the development of an active industrial sector, let alone addressed other macroeconomic issues (Kherallah et al. 2002). This is in contrast with what happened in Asian countries, where similar policies were put in place and obtained a much greater level of success. In fact, part of the reason for the lack of success in SSA was that the policies made no adjustments to account for the significant differences in factors including demographics, production structure, and infrastructure present in SSA (Akyus and Gore 2001). Asian countries financed pro-industry policies by taxing agriculture but at the same time made investments in infrastructure that directly helped the growth of the agricultural sector (Karshenas 2001). In SSA resources taken away from agriculture applied mostly to urban sectors, and infrastructure investments were not made (see Karshenas 2001 for an excellent discussion).

At the same time that these policies were implemented in SSA, a new strand of research started reconsidering the role of agriculture. As a result, many of the premises about the backwardness of the agricultural sector have been proved wrong. Several factors have led to the change of hearts in the perception of agriculture. The first is that while agriculture is indeed a source of surplus for industry, the growth of a healthy industry depends on the growth of a strong agricultural sector. Thus, the link between agriculture and industry is indeed strong (Abdulai and Rieder 1996), but the relationship between the two has to be one of mutual growth.

A second factor that contributed to changing the perception of the role of agriculture derives from the ability of agricultural growth to promote overall GDP growth in developing countries, where agricultural growth has been found to be a causal variable of GDP growth (Tiffin and Irz 2006; Katircioglu 2006). Agricultural growth contributes to overall growth primarily through the transfer of financial surpluses to other sectors. These surpluses can be directly visible through taxes, transfers, and savings from agriculture invested in nonagricultural sectors or invisible through government interventions, overvalued exchange rates, and prices (Winters et al. 1998). In addition, as agriculture develops, incomes increase in both rural and urban areas, and in doing so increased incomes lead to more savings and more spending, which stimulate investments in other sectors (Stringer and Pingali 2004).

Third, technology developed to promote agricultural growth plays an essential role in overall growth (Self and Grabowski 2007). It does so through two main channels: (1) a direct one that relates to benefits obtained by technology adopters and (2) an indirect effect through gains in productivity, increased production, and lower prices (de Janvry and Sadoulet 2002). Given the linkages between agriculture and the rest of the economy, higher agricultural productivity releases workers from agriculture to other sectors (Gollin, Parente, and Rogerson 2002). In addition, higher productivity leads to higher production and lower food prices.

Finally, growth in agriculture is a powerful tool in poverty reduction (Datt and Ravallion 1998).

Poverty alleviation occurs as a consequence of agricultural growth for two main reasons: the effects of growth per se and the participation effect of agriculture. The first one relates to the well-known effects of overall growth on reducing poverty. The second relates to the fact that because a large number of the poor live in rural areas, the impact of investing in such areas can be significant (Christiansen, Demery, and Kühn 2006). A number of empirical studies that highlight the importance of agriculture have been conducted for individual countries or regions; see, for instance, Diao and Nin-Pratt (2007) on Ethiopia and Breisinger et al. (2008) on Ghana. By being home to a larger number of poor, the rural sector has the ability to have a greater impact on poverty than the urban sector. This is indeed supported by the findings of Datt and Ravallion (1998) and Christiansen, Demery, and Kühn (2006). In fact, the latter found that agricultural growth had an impact 13.8 times larger than nonagricultural growth on poverty (for a given poverty measure); for SSA countries and low-income countries, authors found a significant impact of agricultural growth on poverty, but impacts of nonagricultural growth[4] were not significant.

[4] It would be rather unusual to discuss agricultural growth and not mention productivity. Productivity is a key determinant of agricultural growth; thus, promoting agricultural growth means (at least in part) promoting productivity growth (see the next section for an extensive discussion of productivity).

2.2. The Evidence in Western and Central Africa: Importance and Past Performance

Although the agriculture sector is undoubtedly critical to development, its importance varies across countries in Western and Central Africa (see Table 1). With most West African countries classified as low-income countries,[5] agriculture constitutes a large share of their national economies. In 2000–2004, agriculture accounted for 28.7 percent of the region's total GDP and averaged 27.2 to 32.2 percent shares in the three major subregional zones identified by CORAF/WECARD:[6] coastal, the Sahel, and central. However, these subregional averages mask huge variances across countries. For example, agriculture accounts for 71 percent of the national GDP in Liberia, 57 percent in Guinea-Bissau, and 52 percent in the Democratic Republic of the Congo but less than 8 percent in oil-rich, middle-income countries like Gabon, the Republic of Congo, and Equatorial Guinea. These countries are among the four countries (the fourth being Senegal) in West Africa for which agriculture accounts for less than 20 percent of total GDP. For the rest of West Africa, agriculture shows strong potential to serve as a driver of growth and poverty reduction.

Most West African countries have large rural populations, accounting on average for 73 percent of the population in the Sahel, 54 percent in coastal countries, and 61 in central countries. Moreover, poverty rates are above SSA averages of 50 percent in 12 of the 18 countries for which information is available. Of these, 9 countries show poverty rates above 60 percent (Guinea, Nigeria, Sierra Leone, Togo, Chad, Guinea-Bissau, Mali, Niger, and the Central African Republic), and within this group, 6 countries have more than 70 percent of their population below the poverty line (Sierra Leone, Chad, Guinea-Bissau, Mali, Niger, and the Central African Republic). A large share of the poor in all countries lives in rural areas.

High and sustained rates of economic growth, driven in large part by the agricultural sector, will be necessary if West African countries are to accelerate poverty reduction. Although there is a burgeoning industrial sector in some West African countries rich in minerals or oil, agriculture constitutes an average of close to 30 percent of the region's GDP and contributes a considerable share to agricultural processing industries and the service sector.

In this context agriculture still provides the dominant livelihood for 70 percent or more of the population, and much of the continent's poverty remains concentrated in rural areas among smallholder farmers. Generating higher agricultural growth, particularly in the smallholder sector, would increase rural incomes and food supplies. It would also stimulate broad-based economic growth through linkages with the nonagricultural sector. By contrast, growth in the nonagricultural sector alone, especially in the mineral-based industrial sector, would not have a broad impact on poverty reduction (Fan, Chan-Kang, and Mukherjee 2005).

A common characteristic shared by most West African countries is that their agricultural sectors have not performed at the levels required to make meaningful contributions to growth, poverty reduction, and food security. West African countries saw deteriorating levels of per capita production from 1964 to 2003 (see Figure 1). Production performance was poor during the first half of the period, due in part to policies that were implemented in an attempt to promote industrial growth but that actually embodied a bias against agriculture. Policy changes in the mid-1980s resulted in a better performance of the agricultural sector, at least compared with previous years. This improved performance is explained by a significant increase in the rate of output growth in Coastal countries. Sahel countries showed only modest recoveries in the 1990s, while performance of countries in central West Africa still showed a declining trend in output per capita from 1994 to 2003.

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[5] The World Bank uses gross national income per capita to classify countries in terms of (1) low income, (2) middle income (lower and upper), and (3) high income. Almost all West African countries are classified as low-income countries (less than $905 of gross national income in 2006). Exceptions are Cameroon and the Republic of Congo (lower-middle income) and Equatorial Guinea and Gabon (upper-middle income).

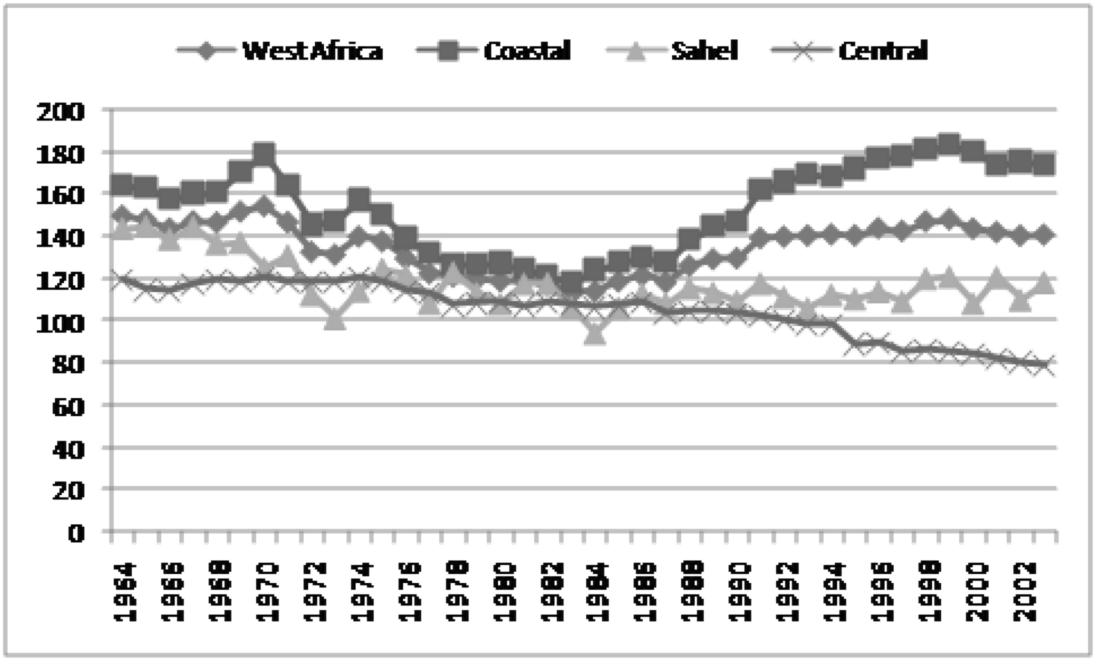
[6] The West and Central African Council for Agricultural Research and Development. Find information at http://www.coraf.org/English/en.php and in CORAF (2003).

Table 1. Income, agriculture, and poverty in West Africa (2004)

	GDP Per Capita	Rural Population Percentage	Share of Agricultural GDP in GDP	Share of Crops and Livestock in Agricultural Sector		Poverty Rate 2000[a]
				Crops	Livestock	
Coast						
Benin	495	60.2	34.0	93.3	6.7	30.7
Equatorial Guinea	6,572	61.1	7.8	96.4	3.6	n/a
Ghana	410	53.0	36.0	93.9	6.1	40.0
Guinea	440	67.4	24.1	86.1	13.9	64.0
Ivory Coast	866	55.4	24.7	93.1	6.9	33.6
Liberia	153	42.7	70.5	86.2	13.8	n/a
Nigeria	560	52.7	26.2	90.8	9.2	67.6
Sierra Leone	201	60.0	49.2	86.6	13.4	71.8
Togo	344	60.6	38.4	90.4	9.6	63.3
Sahel						
Burkina Faso	376	82.1	31.9	69.1	30.9	40.5
Chad	456	75.1	36.5	69.0	31.0	81.8
Gambia	271	47.1	32.8	88.2	11.8	37.8
Guinea-Bissau	175	70.4	57.0	80.3	19.7	84.2
Mali	371	70.0	37.9	61.3	38.7	71.7
Mauritania	519	59.7	26.7	14.6	85.4	50.5
Niger	226	83.3	39.3	71.2	28.8	74.5
Senegal	670	58.6	18.3	76.5	23.5	53.9
Central						
Cameroon	984	46.3	40.0	81.9	18.1	40.2
Central African Republic	328	62.1	55.7	55.6	44.4	81.5
Democratic Republic of the Congo	118	68.4	52.0	91.0	9.0	52.0
Republic of Congo	1,118	40.2	5.9	77.1	22.9	n/a
Gabon	5,306	17.1	7.6	75.3	24.7	n/a
Coast	540	54.2	27.2	91.3	8.7	60.0
Sahel	406	72.8	30.5	66.6	33.4	63.2
Central	434	61.5	32.2	82.9	17.1	50.5
West Africa	490	59.5	28.7	86.4	13.6	58.4

Source: Authors, based on information from World Bank (2007).
Note: n/a = not available.
a. Dollar a day poverty rate in percentage (year of the measure for different countries varies between 1998 and 2001.

Figure 1. Evolution of agricultural output per capita in West Africa and subregions (1964–2003)



Source: Authors' calculations, using data from Food and Agriculture Organization of the United Nations (2007).

For agriculture to grow in West Africa, it is going to be essential for agricultural productivity, or the growth of output per unit of resources used in the production process, to increase substantially. The region cannot afford to continue relying on its natural resource base under current population and income growth rates. Science-based solutions and improved resource-use practices will be required, including investments in rural infrastructure (e.g., roads, transportation, and storage systems), to ensure higher productivity growth rates can be maintained as population densities increase over time.[7] Our estimates of the evolution of total factor productivity (TFP) at the aggregate level for agriculture and the region in the past 40 years (1964–2003) are presented in Figure 2, while Table 2 presents average growth rates by country, region, and different periods.[8]

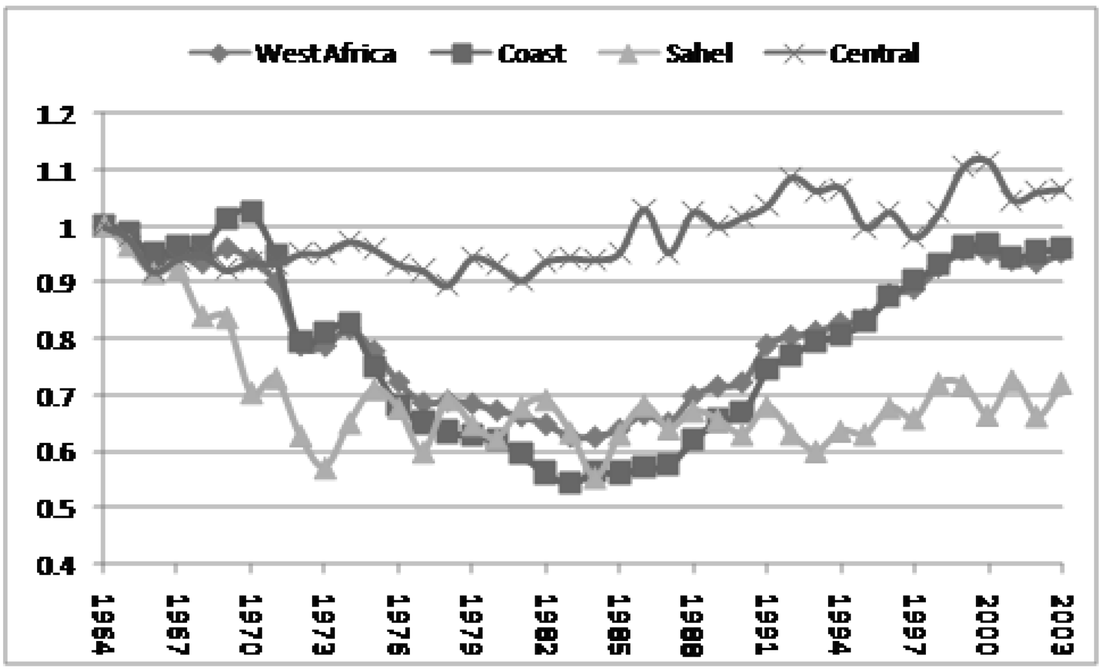
Figure 2 shows that the performance of the agricultural sector in West Africa in the past was poor. We calculate the average annual growth for the group of 20 West African countries for this period as –0.12 using annual growth estimates of the TFP index for each country. This growth rate means that on average, West Africa's agricultural TFP was 4.7 percent lower in 2003 than its level in 1964 (a growth of –0.12 percent during 40 years). This average, however, hides significant variations within the analyzed period, where two periods with contrasting results can be distinguished (see Figure 2). The first period, between 1964 and 1983, witnessed declining productivity growth rates of –2.12 percent per year. This was followed by a recovery period between 1984 and 2003 when TFP grew at an annual rate of about 1.9 percent per year, initially growing at a more rapid pace of 2.25 percent in the first half of this period (1984–1993), followed by 1.57 percent in the latter half. This is the general pattern within the coastal, Sahel, and central subregions of West Africa.

[7] Johnson et al. (2003) suggest that Africa did not enjoy the green revolution at the same time as Asia in part due to much lower population densities during the 1970s, which did not conduce to the pursuit of technical change. The authors add that now Africa has a better chance of enjoying a retarded green revolution given the higher densities and the new portfolio of crops being planted in Africa, though these would have to be accompanied with higher and better input use, particularly fertilizers.

[8] Changes in total factor productivity are estimated using a non-parametric Malmquist index. For details of the methodology used see Nin-Pratt and Yu (2008).

Among individual countries, there has been a general improvement in performance among a greater number of countries over time (see Table 2). Beginning in the first period (1964–1983), no country witnessed annual TFP growth rates of 1.5 percent or greater. But by the second period (1984–1993), 7 out of the 20 countries in our sample did. Ghana, with an average growth rate of 7.5 percent, appears to have been the most dynamic country during this period, followed by Benin and Nigeria, with growth rates well above 3 percent. In the more recent period (1994–2003), however, only 1 country (Niger) witnessed average TFP growth rates of above 3 percent. Yet more countries (10) grew at rates above 1.5 percent, signaling yet another improvement in the performance of countries that were not showing growth in previous periods. Nigeria and Ghana still show significant growth, but lower than the period before.

Figure 2. Cumulative total factor productivity[a] index for West Africa and regions and trends in total factor productivity growth (index = 1 in 1964)



Source: Authors' estimation.
Note: Aggregated values for regions are weighted averages of productivity growth measures of individual countries.
a. Measured as the change in total agricultural output relative to change in total inputs by estimating a nonparametric Malmquist index. Inputs are labor, arable and permanent cropland, fertilizer, tractors, and animal stock.

What are the implications of this past performance of the agricultural sector in West Africa in terms of its contribution to economic growth and poverty alleviation? To determine the degree to which agriculture contributes to economic growth within each country, we decomposed total GDP growth into the share and growth rates of the sectors. If agriculture has a dominant share in the economy and demonstrates high growth performance, the sector can become a key engine of growth. Conversely, a less dominant, poorly performing sector will contribute little to overall growth.

Table 2. Annual total factor productivity[a] growth rates for different periods (percentage)

	1964–1983	1984–1993	1994–2003	1964–2003
Coast	***–2.83***	***3.64***	***1.98***	***–0.10***
Benin	1.59	2.91	1.97	2.01
Ghana	–2.83	3.51	2.70	0.03
Guinea	–0.80	–1.32	1.07	–0.51
Ivory Coast	–1.12	0.11	1.80	–0.14
Nigeria	–3.65	4.72	2.02	–0.26
Sierra Leone	–0.87	2.59	–1.47	–0.14
Togo	–2.10	3.05	0.58	–0.18
Sahel	***–2.90***	***1.40***	***1.40***	***–0.83***
Burkina Faso	2.15	0.04	1.93	-0.66
Chad	–3.52	3.82	0.84	–0.68
Gambia	–1.92	–1.79	–1.09	–1.69
Guinea-Bissau	–0.23	0.34	0.43	0.07
Mali	–1.57	1.18	2.41	0.04
Mauritania	–0.82	–2.96	1.71	–0.80
Niger	–5.45	3.49	1.52	–1.64
Senegal	–2.83	1.17	–0.45	–1.27
Central	***–0.30***	***1.27***	***–0.02***	***0.16***
Cameroon	–1.55	1.56	2.11	0.08
Central African Republic	1.36	2.20	2.53	1.85
Democratic Republic of the Congo	0.28	1.02	–2.13	–0.09
Republic of Congo	–1.75	0.61	0.89	–0.54
Gabon	–2.00	1.60	2.21	–0.13
West Africa	–2.32	2.84	1.58	–0.12

Source: Authors' estimation.
Note: Aggregated values for regions are weighted averages of productivity growth measures of individual countries.
a. Measured as the change in total agricultural output relative to change in total inputs by estimating a nonparametric Malmquist index. Inputs are labor, arable and permanent cropland, fertilizer, tractors, and animal stock.

Between 1986 and 2005, agriculture contributed to about 32.0 percent of West Africa's overall GDP growth, about the same as its share in the economy in 1986 (see Table 3). In other words, of the 2.5 percent annual GDP growth between 1986 and 2005, 0.8 percent can be attributed to growth in the agriculture sector alone. Industry and services combined accounted for the remaining 1.7 percent. The highest agricultural growth occurred in the Coastal region, averaging 3.59 percent per year, almost 1 percentage point above growth in the Sahel and practically doubling the central region's 1.92 percent growth rate.

In the coastal and the Sahel subregions, agriculture contributed to 32.3 and 28.9 percent of overall economic growth, which was smaller than the sector's share in these regions' overall economy, indicating a poorly performing sector on the whole, with slower growth in agriculture than in the overall economy due to rapid growth in other sectors. In the central region, slow growth of nonagricultural sectors resulted in a major contribution of agriculture to growth (65 percent of total GDP growth where agriculture contributes only 20 percent of total GDP).

Regional averages mask large variances across countries. Benin, Ghana, Guinea, Nigeria, Chad, and Burkina Faso experienced relatively high agricultural GDP (AgGDP) growth rates (3.5 percent and over), while growth rates in the Democratic Republic of the Congo, Gabon, and Mauritania were close to zero. Many of the countries in the coastal region experiencing high agricultural growth rates (e.g., Benin, Guinea, and Nigeria) saw most of this growth come from crop production, whereas in the Sahelian region, we see a larger contribution of growth in the livestock sector (30 percent of output growth in the Sahel is explained by livestock compared to 7 percent of total growth in the coastal and 6 percent of growth in the central regions; see Table 3).

Table 3. Contribution of agriculture to overall economic growth in West Africa, 1986–2004 (percentage)

	GDP Growth Rate	Agricultural GDP Growth Rate	Share of Agriculture (1986)	Contribution to GDP Growth		
				Agriculture	Crops	Livestock
Coast						
Benin	3.51	4.71	33.7	39.8	100	0
Ghana	4.35	3.13	47.8	31.8	97	3
Guinea	3.64	3.98	23.9	24.2	83	17
Ivory Coast	1.30	2.82	28.5	40.5	92	8
Nigeria	3.99	3.88	38.7	25.6	93	7
Togo	2.25	3.04	34.8	40.4	90	10
Sahel						
Burkina Faso	3.51	3.69	28.4	34.3	70	30
Chad	5.05	3.77	32.6	23.9	80	20
Gambia	3.42	2.35	34.5	24.2	78	22
Guinea-Bissau	1.66	3.28	45.3	91.6	83	17
Mali	4.11	3.35	42.4	34.8	82	18
Mauritania	2.76	–0.46	26.6	–6.1	23	77
Niger	2.20	3.13	34.7	50.9	81	19
Senegal	3.22	2.26	22.3	14.4	35	65
Central						
Cameroon	0.66	2.97	22.4	109.1	74	26
Central African Republic	0.45	2.46	50.3	218.1	4	96
Democratic Republic of the Congo	–2.13	0.85	33.6	–9.0	134	–34
Republic of Congo	2.13	2.59	12.1	6.3	69	31
Gabon	1.94	0.73	9.2	3.6	77	23
Coast	3.17	3.59	37.8	32.3	93	7
Sahel	3.23	2.66	31.6	28.9	70	30
Central	0.60	1.92	28.6	65.0	94	6
West Africa	2.51	2.76	34.6	32.0	90	10

Source: Authors, based on information from World Bank (2007)

With these growth rates in agriculture only 1 percentage point higher than the region's average population growth rate, West Africa will reach the target of MDG One after 2020, many years later than the targeted 2015. Because of the great variation in growth performance, the growth rates required to attain MDG One will vary across countries in the region (see Table 4). For example, due to steady growth over the past 20 years and significant poverty reduction between 1990 and 2004, Ghana does not need a 6 percent agricultural growth rate to achieve MDG One. This country should be able to meet this poverty reduction target before 2015, even following its current growth path. Unfortunately, many other West African countries would not meet the goal at the national level. Ivory Coast, Guinea, Nigeria, Chad, Guinea-Bissau, and Niger, for example, could need 5 to 20 years to reach the MDG One target. Because of a lack of progressive growth in the 1990s, Guinea-Bissau and Niger will likely need rapid economic growth in the coming years to support a 7 to 10 percent annual poverty reduction and meet MDG One; as it stands they would need decades to meet the goal following business as usual.

Table 4. National poverty rate and a projection for reaching MDG One in West Africa

Country/Region	1990 Poverty Rate[a]	2004 Poverty Rate[a]	MDG One Poverty Rate	Years to Meet MDG One: Business as Usual	Years to Meet MDG One: 6% of Agricultural Growth[b]
AgGDP share below 35%					
Burkina Faso	44.5	40.5	33.7	2018	2015
Ivory Coast	33.6	32.3	17.8	n/a	2043
Gambia	81.6	60.8	40.8	2021	2012
Guinea	45.7	38.8	22.8	2031	2022
Mali	76.0	60.8	38.0	2024	2014
Nigeria	72.8	68.4	36.4	2032	2021
Senegal	57.9	53.9	29.0	2030	2015
AgGDP share above 35%					
Benin	34.9	30.7	17.5	2015	2015
Cameroon	53	34.9	26.5	2017	2009
Chad	80.8	82.4	40.4	2025	2017
Ghana	52.0	34.0	26.0	2010	2009
Guinea-Bissau	53.4	84.2	26.7	n/a	2027
Niger	70.8	76.6	35.4	2039	2019
West Africa	60.0	54.2	30.0	2022	2015
Africa	44.6	47.5	22.3	2027	2018

Source: Adapted from Table 2 in Fan et al. (2008, 12). Poverty rates are from available national household surveys. If no national poverty rate is available, data from United Nations Industrial Development Organization (2004) are used.

Note: MDG = Millenium Development Goal; AgGDP = agricultural GDP; n/a = data not available.

a. The years that the countries conducted the surveys may not be exactly 1990 and 2004, and surveys from close to these two years are used.

b. With business as usual in nonagricultural growth

Information presented in this chapter confirms the importance of the agricultural sector for West African economies but also shows that performance of agriculture in the past, although somehow improved in recent years, has been poor. While this is hardly an encouraging picture, we'll show in the next chapter that this poor past performance could become a growth opportunity for agriculture and the economy as a whole if countries in West Africa target a reduction in the difference between actual and potential productivity in an immediate strategy for improving the performance of agriculture in the region.

3. PRODUCTIVITY GAP AND AGRICULTURAL GROWTH POTENTIAL

In this chapter we focus on the potential to increase yields (or output per hectare of land) of individual crops, as a proxy for productivity, within different agro-ecological and socioeconomic environments in West Africa. Here, potential growth in productivity depends on the current yield gaps for each crop and unique environment on the supply side and on the potential demand to absorb increased production resulting from increased productivity.

In section 3.1 the focus is on the supply side for potential productivity growth. There the key concept is that of yield gaps, which are defined as the differences between actual observed yields and maximum obtainable yield levels if farmers adopt the most efficient combination of existing technologies and production systems. The technological frontier here is defined as the maximum attainable yield based on available knowledge on existing technologies and farming practices that may have yet to be adopted extensively at the country level. This information on potential yields will be a key input in the simulation scenarios defined in chapter 4.

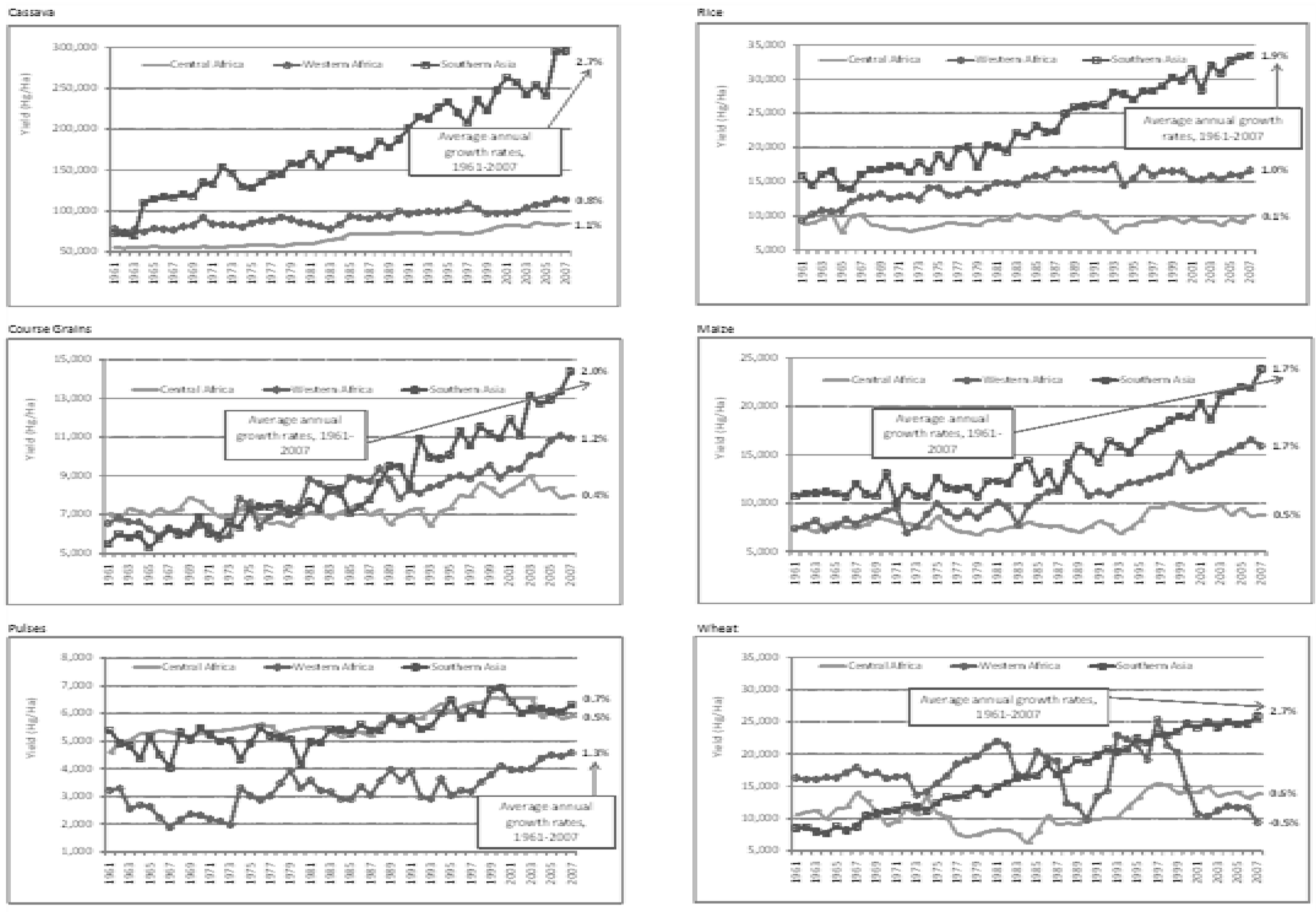
Growth in productivity leads to increased agricultural output, which in turn can be used either to increase the domestic supply of food or for exports. Over time, increased production resulting in higher productivity should also lead to cheaper food prices. There is, however, a catch to productivity growth: there needs to be a functional market structure to accommodate the growth in output generated by higher productivity. Section 3.2 presents an overview of general trade patterns of agricultural commodities in West Africa to show potential demand for agricultural commodities beyond domestic markets of the individual countries, given that without access to increased demand, the drop in prices of agricultural goods resulting from increased productivity and production will affect producers' incentives to invest in technical change and new production methods. Finally, section 3.3 simulates agricultural growth resulting from closing the productivity gap of main crops and brings into consideration information about trade patterns from section 3.2, concluding with the potential for productivity growth in West Africa.

3.1. Supply Side Considerations: Productivity Gaps

Current yield levels in West and Central African countries have remained significantly lower than elsewhere in the developing world, suggesting that there is still room to accelerate yield growth in the region. Figure 3 reports the general trend of aggregate yields over time for some select crops in Western and Central Africa compared with Southern Asia between 1961 and 2007. For cassava, growth has remained very low on average in Western and Central Africa, increasing steadily at barely 1 percent per year during the past four decades. In contrast, the yield of cassava in Southern Asia grew at a rate of 2.7 percent per year between 1961 and 2007. As a result, average yields in 2007 were almost three times those of Western and Central Africa, 30,000 kilograms per hectare compared to 10,000 kilograms per hectare, respectively.[9] This is partially because cassava production systems in West Africa are mostly for subsistence and human consumption; compare the degree of its commercial use in Asia for livestock feed and agroindustries. While improved varieties have been introduced in many African countries (see Nweke, Spencer, and Lyman 2002), production is still less intensified, and farmers typically intercrop it with other crops, especially in the more humid tropics.

[9] According to Nweke, Spencer, and Lyman (2002), however, yield estimates based on extensive village- and farm-level surveys undertaken by the International Institute of Tropical Agriculture in Nigeria show much higher gains in yields throughout the 1980s than what is captured by the Food and Agriculture Organization of the United Nations data. So the caveat is that these aggregate regionwide trends can easily mask successes witnessed on the ground in parts of Western and/or Central Africa.

Figure 3. Change in yields of major crops in Western and Central Africa relative to Southern Asia, 1961–2007



Note: Hg/ha = Hectograms per hectare

In the case of rice, not surprisingly, the wide use of irrigation and high-yielding varieties among rice farmers in the post–green revolution era of Southern Asia explains the current wide yield margin with Western and Central African rice producers. Over the long haul (between 1961 and 2007), rice yields grew by almost twice the rate in Southern Asia than they did in Western Africa: 1.9 percent compared to only 1 percent, respectively. On the other hand, they barely grew in Central Africa. For most countries, much of the improved performance in rice yields occurred between the 1970s and the 1980s. At the country level average annual growth rates of rice yield accelerate between 1976 and 1986 in countries such as Cameroon (10.8 percent), Niger (10.1 percent), Mauritania (8.5 percent), Gambia (8.5 percent), Guinea-Bissau (8.5 percent), and Burkina Faso (6.8 percent). While these high growth rates are impressive, they do not represent the bulk of the rice being produced in West Africa. Over 80 percent of the rice produced in the region comes from six countries: Nigeria, Ivory Coast, Mali, Ghana, Senegal, and Guinea. Among these, Ivory Coast, Mali, and Ghana have seen impressive growth rates of 3 percent or more per year during the more recent periods of the 1990s and 2000s.

Altogether, the analysis of yield growth in Western and Central Africa relative to the performance of other developing regions shows that there is still plenty of room to rapidly grow yields in the region—just by how much is limited by the factors that have inhibited large gains in the past. We review these next by examining the size of current yield gaps between actual (or realized) yields and maximum attainable yields given the existing stock of knowledge and technologies in the region.

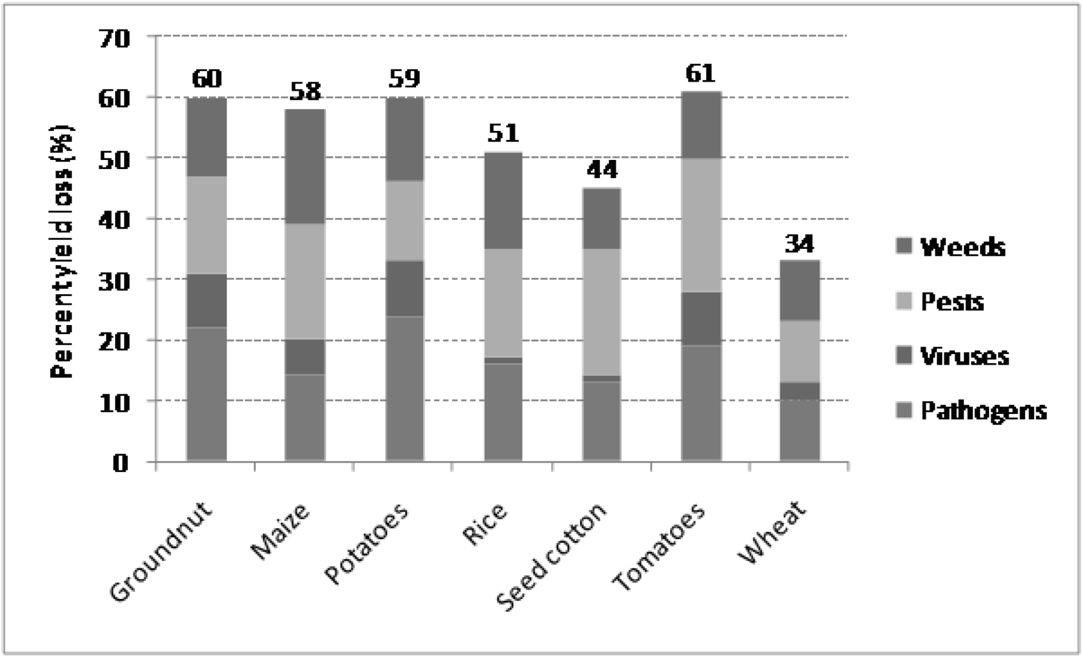
The potential to raise yields in West Africa can come from reducing yield losses or through the expanded use of yield-increasing technologies. One of the most cited works on reported crop losses in Africa is the study by Oerke, Schönbeck, and Weber (1994). The study in turn contributed to the development of a comprehensive CAB International database of yield losses due to biotic stress (CABI 2005). From this collection, yield losses can average up to 60 percent in Western and Central Africa, or 10 to 15 percent each from weeds, pests, viruses, and pathogens, respectively. Figure 4 illustrates the range of yield losses by crop. Altogether, the losses contributed to a US$10 billion loss in the value of output between 2000 and 2004 (Cohen et al. 2005; CABI 2005). Simply eliminating yield losses, therefore, could have a huge impact on agricultural performance and growth in the region.

Among cereals, maize yields in Western Africa have actually seen growth rates comparable with those in Southern Asia, recording a rate of 1.7 percent per year on average between 1961 and 2007 (see Figure 3). Much of the growth in Western Africa occurred between 1995 and 2006, growing at about 2.5 percent per year. The highest annual growth rates recorded include those of Guinea-Bissau (11.1 percent per year), Senegal (10.1 percent), and Ivory Coast (7.4 percent). In terms of long-term yield growth rates, Cameroon, Ivory Coast, Guinea-Bissau, and Burkina Faso led the way by growing at 3 percent per year between 1961 and 2007. Despite these positive growth rates, however, average yield levels for maize remain far below those of Southern Asia: 1,500 kilograms per hectare compared with the latter's 2,500 kilograms per hectare. In Central Africa, yields have barely increased above 1,000 kilograms per hectare on average. Yields for coarse grains (sorghum and millet) have also seen significant growth, but more so in recent years and in the countries of Niger, Guinea Bissau, Togo, Chad, and Nigeria.

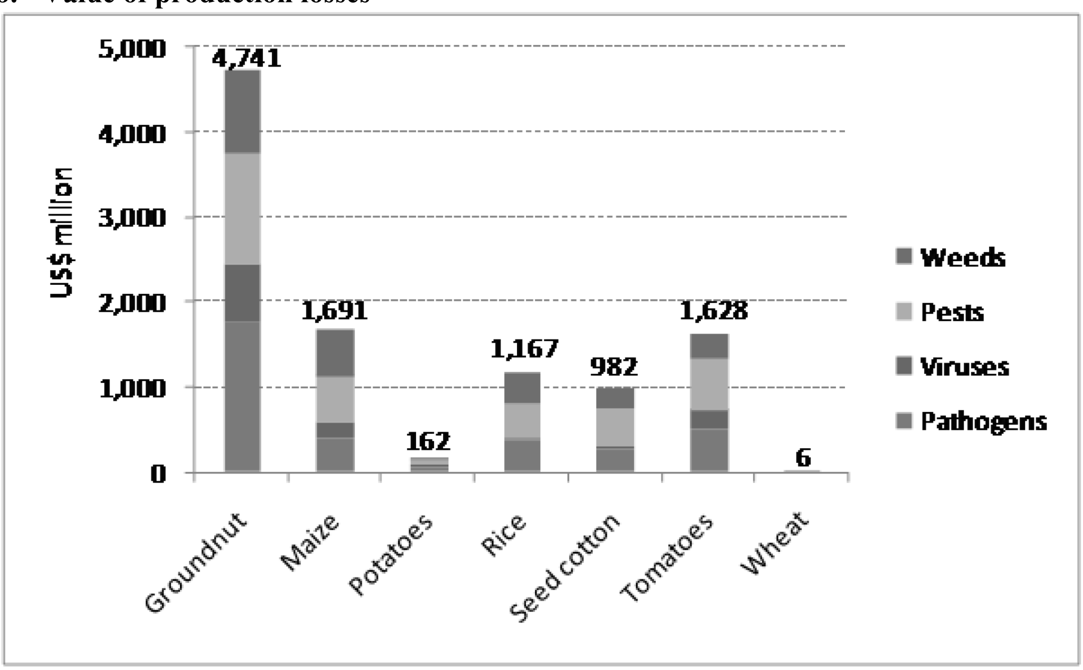
Aside from the elimination of yield losses, the potential to increase yields even further exists if farmers adopt more efficient farming practices and modern inputs. According to a study by Fischer et al. (2001), for example, current crop yields have the potential to increase by two- to fivefold if the mix of existing technologies and best farming practices are used optimally within each of the major AEZs in West Africa. This also accounts for a range of alternative farming systems, from traditional to modern practices. Closing the yield gaps, therefore, can be interpreted as catching up to a technology frontier (represented by the best performers) for each distinctive AEZ and farming system.

Figure 4. Simple average yield and production losses due to biotic stress in West Africa

a. Yield losses



b. Value of production losses



Source: Calculated by authors from CABI (2005).

Table 5 reports calculated average yield gaps based on the Fischer et al. (2001) assessment. Although we report averages only at the regional level, the standard deviations capture the variation in yields and yield gaps across countries, AEZs, and distinctive farming systems. Evidently, the potential to experience a two- to threefold yield increase among some of the basic food staples is possible if more farmers can access and efficiently utilize the available stock of knowledge and technologies. Among staple crops, coarse grains in particular have the potential to realize average yield gains of up to three times their current levels. Rice has the potential to experience a doubling of current yields. One study estimates that the yield advantage of simply adopting improved varieties (whether rain fed or irrigated) can be as high as 1.2 metric tonnes per hectare (see Dalton and Guei 2003). Cassava, another important staple in the region, can also realize significant gains, up to 50 percent on average—although this can be significantly higher in the less humid regions where intercropping is less intensive (see Nweke, Spencer, and Lyman 2002).

Table 5. Descriptive statistics of current and maximum potential yields among rain-fed cropping systems in Conseil Ouest et Centre Africain pour la Recherche et le Développement Agricoles/West and Central African Council for Agricultural Research and Development (CORAF/WECARD) region

Crop		Actual or Current Yield[a]		Maximum Potential Yield		Yield Gap (Potential/Current)
	n[b]	*M*	*SD*	*M*	*SD*	
Cereals						
Maize	39	1.24	0.6	3.40	1.1	2.7
Rice	31	1.49	0.6	2.78	0.6	1.9
Barley	4	0.85	0.2	3.23	0.9	3.8
Wheat	6	1.30	0.7	6.45	5.6	5.0
Coarse grains						
Millet	35	0.72	0.3	2.43	0.8	3.4
Sorghum	33	0.84	0.3	2.75	0.8	3.3
Root crops						
Cassava	32	9.15	5.4	14.0	5.4	1.5
Potato	20	6.11	3.3	28.4	10.6	4.7
Sweet potato	30	8.67	7.1	15.3	10.3	1.8
Pulses						
Beans	12	0.54	0.2	1.14	0.4	2.1
Oil crops						
Groundnut	32	0.83	0.3	1.35	0.6	1.6
Soybean	14	0.79	0.3	1.50	0.9	1.9
High-value products						
Banana	23	6.08	3.0	27.4	16.1	4.5
Cotton Lint	19	1.29	1.3	3.82	2.8	3.0

Source: Calculated by authors, using data from Fischer et al. (2001), averaged across the agro-ecological zones and farming systems among all CORAF/WECARD countries.
a. Yield is defined as crop output divided by land under that particular crop.
b. *n* is the number of farming systems/agro-ecological zones from which the average and standard deviation are calculated.

3.2. Food Demand, Overall Trade Patterns, and Growth Potential

In this section we present a brief overview of general trade patterns of agricultural commodities in West Africa. The overview has the purpose of providing substance to the argument for a regional approach in an agriculture-led strategy for the region, showing that staple crops and livestock can play a key role in increasing trade possibilities and providing food security for the region. Without a concomitant increase in demand and functioning markets to which to distribute and allocate increased production, the drop in prices of agricultural goods will certainly affect producers, who in turn will have reduced incentives to invest in ways to further increase productivity and production (Poulton, Kydd, and Dorward 2006).

One of the most directly observable phenomena that results from growth in poor countries is the increase in the demand for food. Two main factors help explain this increase: higher incomes derived from economic growth as well as higher population growth rates already observed in poor countries combined with the additional increase in birth rates spurred by growth. Both of these will vary in intensity depending on the level of pregrowth development. In the very early stages of growth, demand for food can increase up to 30 percent above its previous levels (Mellor 1983). Typically, countries have difficulties in generating enough production to meet the growth in demand and very often have to resort to food imports. In West Africa, we observe some of the stylized facts outlined above. First, as section 2.2 established, the region has been growing, though admittedly not enough. Second, this growth has led to a boost in demand for agricultural foods, though as we will show next, there is still room for considerable growth. The fact that the majority of countries in the region are net importers of most agricultural products suggests that the region was not able to accommodate growth in demand and therefore still resorts to food imports.

Trade profiles across countries vary by crop, food group, and trade destination. We have compiled estimates of trade flows (imports and exports) for four broad groups of commodities (staples and livestock, nontraditional, traditional, and other), each group containing a number of commodities (see Table 6). For each of these groups, data about exports and imports were also tabulated according to the source/destination of trade. For our purposes, three particular sources/destinations were used: world (includes the entire world minus SSA and West Africa), SSA, and West Africa (regional trade). The discussion below refers to these groups as world, SSA, and regional trade.

We begin our discussion with imports to and from the regions described above. In terms of imports from the world, other cereals, fish, and sugar are some of the most imported food items, accounting for over half of the region’s imports (relative to total world’s imports). Across food groups, staples and livestock products were the most imported commodities, accounting for 43 percent of the region’s imports. Nontraditional, traditional, and other crops accounted for 36, 15, and 7 percent, respectively. These figures change considerably when we look at import patterns from SSA and within the West African region. When the source of imports is SSA, the share of staples in total imports (from SSA) falls to 13 percent, while the share of nontraditional commodities increases to 62 percent. Import shares of traditional and other commodities remain almost unchanged. Fairly similar figures were observed for imports from the region.

On the export side, the most exported crops were cocoa and cotton. Relative to the region’s total exports to the world, these two crops combined accounted for nearly half of the region’s total exports. Across different destinations of exports, a very different pattern emerged. Staple crops played a very minimal role in the share of exports to the world, less than 1 percent, while traditional commodities played a major role, representing 57 percent of total exports. Patterns of exports with SSA and within West Africa also showed considerable changes. Most of the exports with SSA and within the region were composed of nontraditional commodities, accounting for 59 and 65 percent, respectively. Staples and livestock, traditional, and other commodities represented, respectively, 10, 21, and 11 percent of exports to SSA and 11, 14, and 10 percent of exports within West Africa. It is worth highlighting the fact that staple crops are to a large extent imported and play almost no role in the region’s exports. This disparity between imports and exports once again shows the wide gap between domestic production and consumption and the fact that the region has not been able to meet its internal demand for staples.

The dominance of imports in the region, however, does not translate into a lack of export potential especially within Africa. Between 1996 and 2000, the annual value of West Africa’s agricultural trade amounted to over US$7.1 billion per year (see Table 6). Total exports to the region (intraregional trade) yielded US$363 million per year. Within ECOWAS, intraregional exports equaled about 11.1 percent of total exports. Within the West African Economic and Monetary Union, trade equaled 12.6 percent of total exports (UN COMTRADE 2006). Trade in nontraditional goods has also grown, increasing from $26 million in 1993 to about $75 million by 2001 (UN COMTRADE 2006). These statistics capture only formal trade within the region.

Table 6. Composition of imports and exports for different sources and destinations (percentage)

	Import				Export			
	World	SSA	West Africa	Share of Intraregional Trade[a]	World	SSA	West Africa	Share of Intraregional Trade[a]
	Percentage							
Staples								
Other cereals	29.4	5.8	5.1	2.0	0.3	4.5	5.1	82.3
Meat	12.2	3.5	2.5	2.8	0.2	2.2	2.5	64.9
Livestock	0.5	1.1	0.5	23.0	0.1	2.2	2.6	98.3
Maize	0.3	2.2	2.6	64.4	0.0	0.5	0.5	88.7
Cassava	0.3	0.3	0.2	10.2	0.0	0.0	0.0	0.4
Beans	0.0	0.0	0.0	90.0	0.0	0.2	0.2	67.2
Subtotal	*42.8*	*12.8*	*11.0*	*3.0*	0.7	9.6	11.0	79.8
Nontraditional								
Fish	12.3	35.3	37.1	28.8	15.8	31.5	37.1	12.1
Vegetables and fruits	7.8	10.3	12.2	13.2	7.8	2.6	3.0	2.0
Oils and fat	6.5	7.7	8.6	11.9	2.8	10.4	12.2	23.0
Miscellaneous	3.9	3.9	3.0	10.1	2.4	3.5	0.4	8.9
Oilseeds	3.4	2.3	1.9	6.7	1.2	1.5	1.4	7.7
Processed food	1.6	0.7	0.4	4.4	0.9	7.4	8.6	51.5
Beverages	0.3	1.2	1.4	44.4	0.2	1.7	1.9	59.6
Subtotal	*35.8*	*61.5*	*64.5*	*17.2*	31.0	58.6	64.5	11.5
Traditional								
Cocoa bean	10.9	4.4	3.0	4.0	32.8	2.0	0.4	0.4
Cotton	1.3	0.8	0.3	6.2	14.5	13.2	8.1	5.5
Coffee green	1.1	0.9	0.4	8.3	7.5	0.6	0.4	0.5
Cashew nuts	0.9	6.8	8.1	76.2	1.4	0.1	0.1	0.6
Sugar	0.2	1.5	0.4	65.7	0.8	2.7	3.0	21.5
Other nuts	0.2	0.1	0.1	4.3	0.3	1.3	1.4	25.2
Tobacco	0.1	1.1	1.4	89.0	0.1	0.3	0.4	17.4
Tea	0.1	0.3	0.4	31.1	0.0	0.3	0.3	49.1
Other fibers	0.0	0.1	0.1	80.5	0.0	0.0	0.1	14.2
Subtotal	*14.9*	*16.1*	*14.1*	*10.8*	57.5	20.6	14.1	2.2
Others								
Processed cocoa	4.1	3.4	3.3	8.3	6.3	2.4	0.5	2.3
Animal skin	1.1	3.9	4.6	35.9	2.0	0.4	0.5	1.2
Coffee roasted	0.6	1.3	1.3	20.2	1.1	4.0	4.6	22.1
Feed stuffs	0.3	0.5	0.5	19.4	1.0	1.5	1.3	9.2
Cigarettes	0.2	0.1	0.1	4.8	0.3	2.9	3.3	68.1
Spices	0.2	0.4	0.5	20.1	0.1	0.1	0.1	7.6
Subtotal	*6.5*	*9.6*	*10.4*	*14.8*	10.8	11.2	10.4	6.3
Total (US$ million)	**4,437.0**	**444.0**	**363.0**	**10.0**	**7,084.0**	**430.0**	**363.0**	**6.1**

Source: Authors' calculation, using UN COMTRADE (2006) data.
Note: SSA = sub-Saharan Africa.
a. Calculated as the share of West African value of imports (exports) from (to) SSA in total West African value of imports (exports) from (to) the world.

These figures suggest that there is significant potential for agricultural growth in West Africa if countries can successfully tap domestic and regional market opportunities for staples and livestock products, especially given rapid urbanization trends in the region and the growing import of these commodities. This is because domestic demand for food staples (including farmers' own consumption levels) is valued at US$20 billion or more (see Hazell and Diao 2005). This is more than 3 times the level of West Africa's international exports and 50 times the level of intraregional trade captured by official statistics. Strengthening regional linkages and increasing intraregional commodity exchanges as productivity increases has, therefore, the potential to provide enormous gains to the region.

3.3. Potential for Agricultural Growth

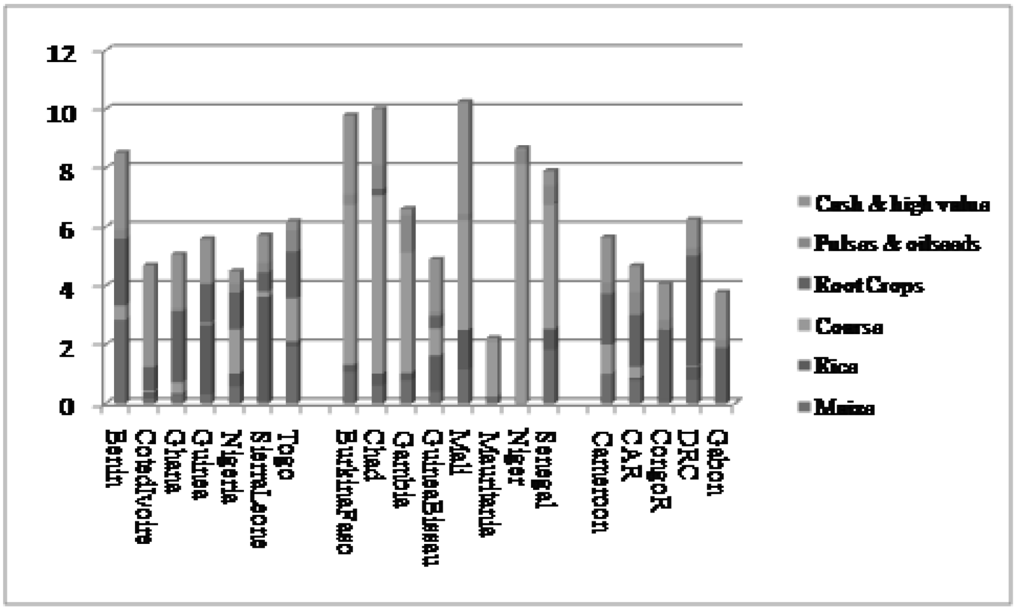
Based on our overview of the current performance and potential for productivity growth, and especially for crop yields, many countries in Western and Central Africa have the potential to experience sharp increases in (and in most cases a more than doubling of) current yields. This of course depends on how well farmers can access and adopt more efficient and intensive production practices to rapidly close current yields gaps over time. If these yield gaps can be closed, what sort of impact could this have on overall AgGDP growth? Assuming that the yield potential targets can be reached during the next 10 years, we calculate the annual growth rates of crop yields for each domain within each country. A summary of average agricultural growth rates and the contribution to agricultural growth of different groups of crops are reported in Figure 5. Given wider yield gaps for cereals, especially coarse grains, and combined with their larger contributions to value-added agriculture, the agricultural sector in Sahelian countries has the potential to grow faster from productivity improvements in cereals. Coastal countries also gain from productivity improvements in cereals as well as roots and tubers, while roots and tubers offer the biggest gains in central countries. Increased productivity of export and high-value crops could significantly contribute to agricultural growth in Benin, Ivory Coast, Ghana, and Guinea (among the coastal countries) and in Mali, Burkina Faso, Chad, and Guinea-Bissau (among Sahelian countries).

Results in Figure 5 are obtained by simply calculating the growth rate necessary to close the yield gap in the next 10 years. However, it does not take into consideration the effect that this growth would eventually have in domestic markets and prices. For this growth to be sustainable, West African countries need to expand markets for increased production.

We conclude that if the technical potential to expand output from productivity gaps is paired with a strategy that facilitates access to regional markets, there is significant potential for agricultural growth in West Africa, especially if countries can successfully tap domestic and regional market opportunities for staples and livestock products, given rapid urbanization trends in the region and the growing import of these commodities. We reach this conclusion by using data that allow us to compare actual yields with those that could be achieved using more efficient farming practices and modern inputs in different AEZs and the pattern of imports and the possibilities for regional trade and import substitution of staples and livestock products from the demand side. The analysis shows a high potential to rapidly expand output given the large yield gaps that have yet to be exploited considering the current stock of knowledge and technologies in the region. Countries in the Sahel can benefit from high growth in agriculture if the yield gap in cereal production is reduced in the next 10 years. Similarly, coastal and central countries could also benefit from increased productivity of cereals as well as roots and tubers.

Acceleration of agricultural growth can be accomplished through wider dissemination of the existing stock of knowledge and technologies associated with improving agronomic practices, adopting stress-resistant crop varieties, and appropriate use of chemicals for pest, disease, and weed control. Expanding and improving the efficiency of adaptive research and extension services is therefore going to be critical. There is definitely scope for greater regional cooperation in research and extension given the extent to which technologies and farming practices are applicable across national boundaries, leading to the greater likelihood of widespread adoption and impact in the region.

Figure 5. Annual agricultural output growth that results from eliminating the yield gap in 10 years and contribution of different crops to total agricultural growth



Source: Authors' calculations.

Note: CAR = Central African Republic; DRC = Democratic Republic of the Congo.

4. METHODOLOGICAL APPROACH

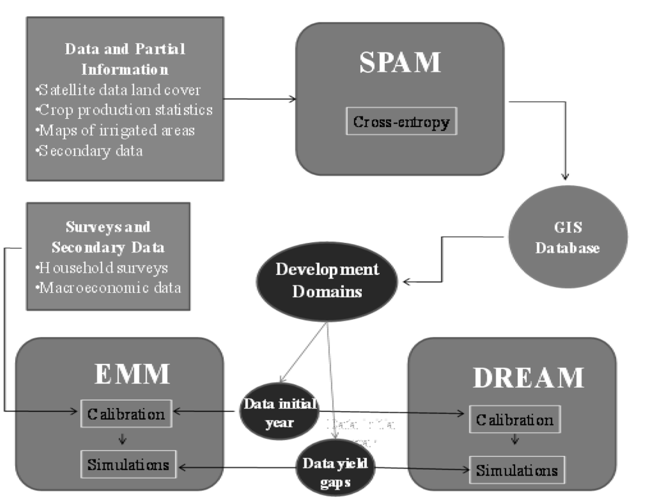
4.1. Overall Framework

In chapter 2 we discussed the importance of agriculture for West African economies and evaluated past performance and growth of the agricultural sector. The central conclusion drawn from the analysis is that West African agriculture is not performing as well as it could. Agriculture in the region has been growing only 1 percentage point above the region's average population growth rate, while agricultural productivity has had stagnant growth during 20 of the last 40 years and started to recover only in the mid-1980s in coastal countries and during the 1990s in the Sahel. However, in chapter 3 we looked at the potential to increase crop yields within different agro-ecological and socioeconomic environments in West Africa, and we found that there is high potential to rapidly expand output given the large yield gaps that have yet to be exploited considering the current stock of knowledge and technologies in the region.

In this chapter we present the methodology used to further analyze opportunities faced by West African countries to improve their performance in agricultural production, accelerate agricultural growth, and meet the MDG goals. Our approach links different data sets and models and uses detailed spatial information about crop production and production systems, spatial distribution and quality of natural resources, population, and infrastructure within the framework of an *ex ante* economic model simulation. By feeding this spatial information into an economic model, we can simulate different growth scenarios and determine the production possibilities and potential contribution to economic growth of different crops and agricultural activities. We can also quantify economic criteria useful for ranking future alternative priorities for agricultural investments, and by applying this economic analysis at the regional and multicountry level, both regional and country-specific priorities can be emphasized. A distinctive feature of this approach is the use of specific information about biotic constraints and yield potential for crops in different AEZs in West Africa to determine the productivity gaps and simulate productivity growth scenarios based on the reduction of these gaps.

Figure 6 presents a diagram of the overall framework of the methodological approach adopted in this study, showing how detailed spatial data are processed and transformed into input of both an economy-wide multimarket model and a single-market model specifically designed for the economic analysis of the impact of technical change. In what follows, we briefly describe the different components of our framework and present the simulation scenarios defining alternative productivity shocks to different crop and livestock activities.

Figure 6. Methodological approach, data sources, and links between models



Note: SPAM = spatial allocation model; GIS = Geographic Information Systems; EMM = economy-wide, multimarket; DREAM = Dynamic Research Evaluation for Management.

4.2.The Spatial Allocation Model (SPAM)

Achieving growth and poverty reduction in Western and Central Africa through accelerated growth in agricultural productivity, to begin with, requires an understanding of the potential for raising yields and performance at the crop level. As chapter 3 illustrated, crop yields currently are not realizing their full potential. They have the potential to increase by two- to fivefold if the right mix of existing technologies and best farming practices are used optimally within each of the major AEZs in the region. In this chapter, we show how we incorporate this information into an economic model to simulate different growth scenarios and determine the production possibilities and potential contributions to economic growth and poverty alleviation by closing the yield gaps, or the difference between maximum attainable yields and current yields.

To estimate yield gaps we employ a sophisticated SPAM developed by the International Food Policy Research Institute (IFPRI) to help allocate crop production data from coarser to finer spatial units (see You and Wood 2006; You et al. 2007; You, Wood, and Wood-Sichra 2007). This allows us to calculate yields based on different geographic scales than the administrative regions by which most statistics on yields and production are reported. The SPAM essentially downscales the spatial information to the lowest possible consistent scale, a "pixel" that is typically 1 to 100 square kilometers in size—in the terminology of Geographic Information Systems. These pixel-level results easily can be aggregated into the geographic specifications of choice.

A primary objective of adopting the SPAM approach is enabling the calculation of yields based on shared characteristics with respect to biophysical and socioeconomic factors (see appendix B). By nature, the agronomic performance of agriculture is fundamentally dependent on biophysical factors (agro-ecology and climate)—and thus is a measure of the absolute advantage of agriculture. On the other hand, socioeconomic factors (e.g., population density and access to markets) are equally important as they measure the comparative advantage of agriculture—influencing such outcomes as the choice of cropping systems, resource allocation, and degree of commercialization (Pender, Place, and Ehui 1999). Finally, the combination of all these helps determine current and maximum attainable yields based on the local agronomic suitability, profitability, and performance of particular crops and production systems, as well as the incidence and severity of crop pests, disease, and weeds.

Using available information on agro-ecological and climatic conditions, as well as socioeconomic factors such as population and distance to markets, we initially define an aggregated set of "development domains" that describe unique geographic areas similarly endowed in three key attributes:[10]

Agricultural potential: central, coastal, and Sahel;

Market access: high access to ports/domestic markets and low access to ports/domestic markets; and

Population density: high and low.

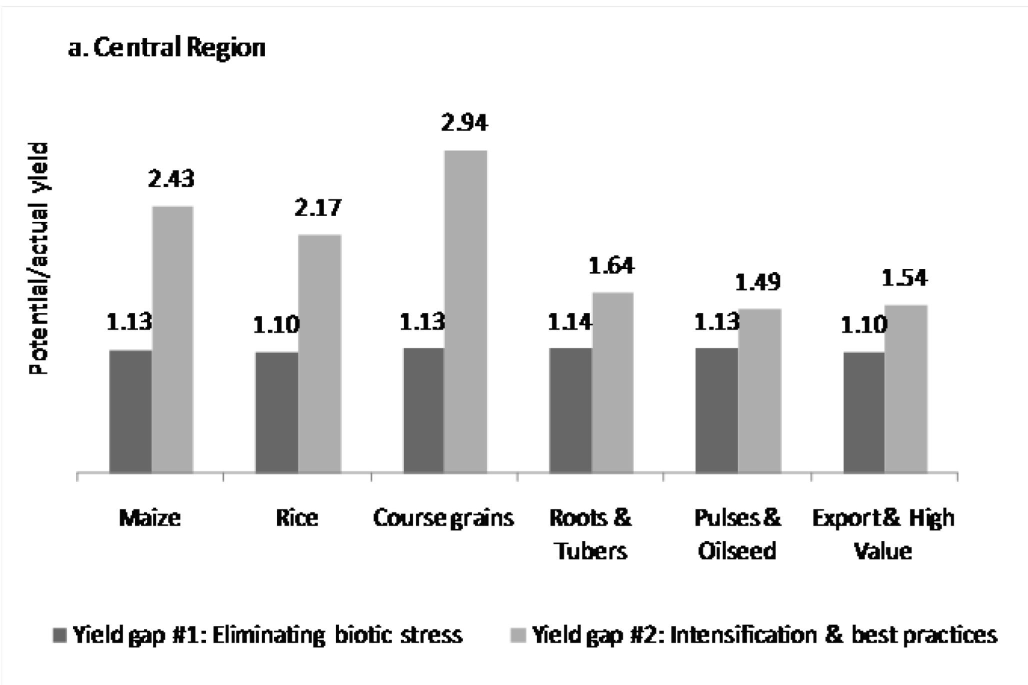
The result is 12 unique domains: central/high/high; central/high/low; central/low/high; central/low/low; coastal/high/high; coastal/high/low; coastal/low/high; coastal/low/low; Sahel/high/high; Sahel/high/low; Sahel/low/high; Sahel/low/low. Within each of these development domains, we calculate current and maximum attainable yields to determine yield gaps for individual crops using SPAM. Estimates of potentially attainable yields draw on two extensive sources of information mentioned in chapter 3: the Oerke, Schönbeck, and Weber (1994) and CABI (2005) databases regarding yield losses

[10] Details of the development domain concept and analysis used for this study are presented in appendix B. An initial comparison of actual and potential yields using some earlier development domain specifications showed that the difference in the length of the growing period was a main factor determining agricultural potential. As this factor dominates the agro-ecological contrasts between the Sahel, coastal, and central regions, we chose to use these two regions as a fair generalization of agricultural potential. We found that in general, agricultural potential for the different crops were similar for countries in the same region (i.e., Sahel, coastal, or central), and the within-country variation was minimal. For this reason, and to maintain a manageable regional economic model, we chose to simplify the development domain specification in this manner.

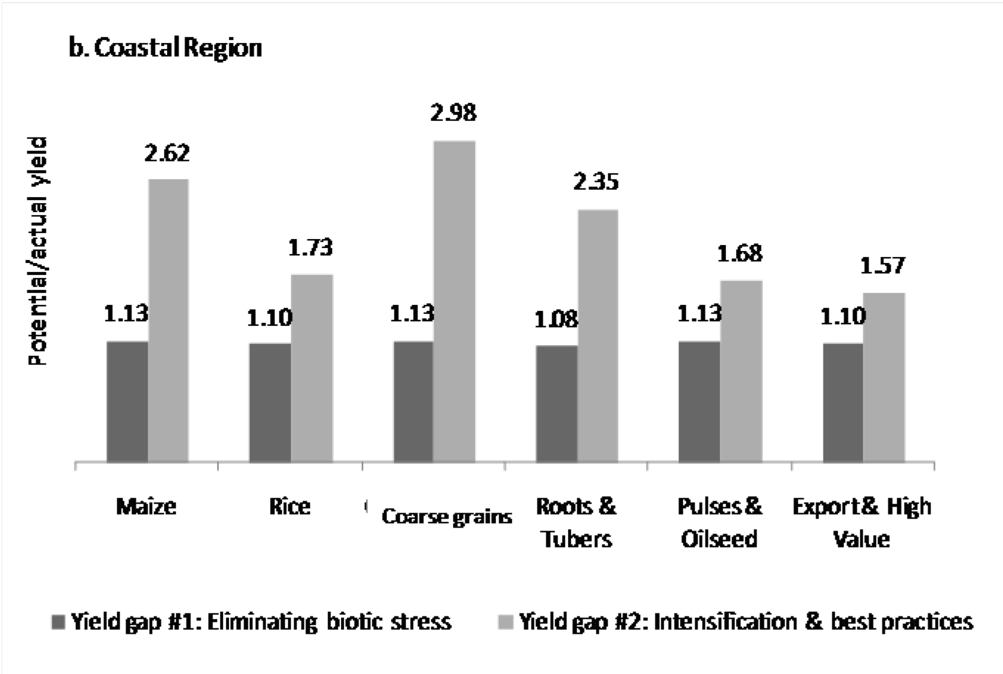
due to biotic stress and the global AEZ assessment by Fischer et al. (2001) to estimate maximum attainable yields by major AEZ and farming system.[11]

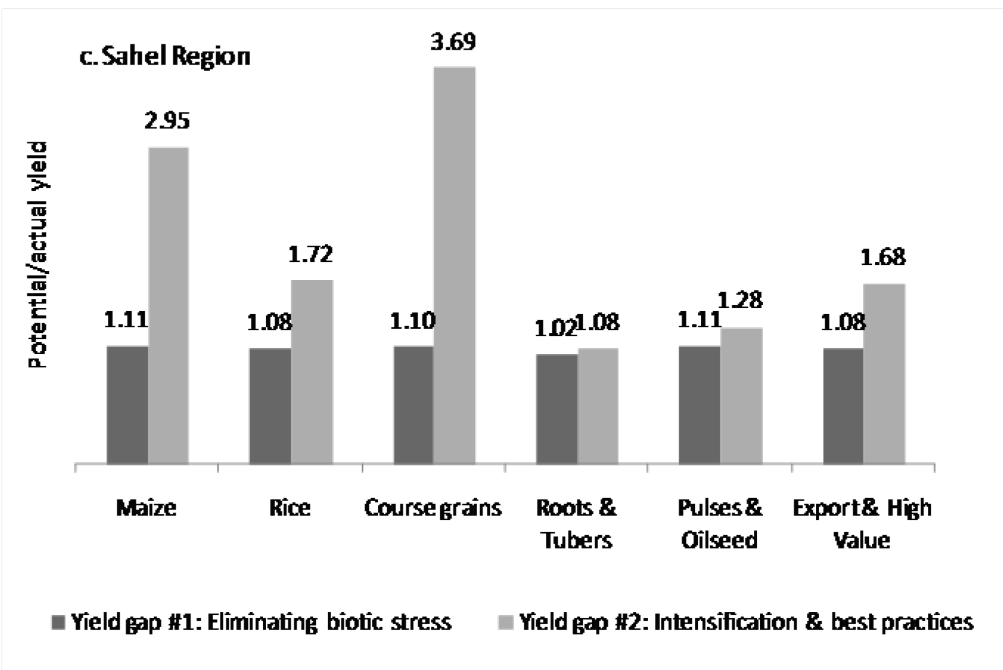
Figure 7 summarizes the resulting series of yield gaps for rain-fed crops, aggregated across the development domains except for the major agroclimatic subregions (i.e., irrespective of population density and market access). Not surprisingly, the yield gaps associated with eliminating biotic stress are much smaller than those associated with maximizing potential yields under more intensified farming systems. Nevertheless, simply eliminating constraints from biotic stress can increase yields by more than 10 percent among all crops, especially in the central and coastal regions. On the other hand, yields have the potential to rise even more sharply, in most cases more than doubling current yields, if farmers adopt more efficient and intensive production practices using current knowledge and technologies. For coarse grains, for example, gains can be three to four times the level of actual yields.

Figure 7. Simple average yield gaps between actual and potential



[11] To estimate the yield gaps using the first set of data we initially match the yield loss parameters by the agro-ecological zones identified by Oerke, Schönbeck, and Weber (1994) and CABI (2005) with the parameters defining our development domains and spatially allocate actual and potential yields at the pixel level using the spatial allocation model. These are then averaged at the domain level to define a yield gap for each crop and within each major development domain. We assume that 5 to 35 percent of yield losses would be regained by simply adopting improved technologies and farming practices (see Cohen et al. 2005). For the yield gaps associated with the Fischer et al. (2001) database, we use Fischer et al.'s estimates of maximum attainable yields by major agro-ecological zone. As in the first case, the yield gaps are initially calculated at the pixel level using the spatial allocation model, this time also accounting for farming system by assuming higher input use in areas with high market access and high population densities. These are then further aggregated at the domain level to come up with a single and production weighted average yield gap for each crop, separately for rain-fed and irrigated systems. In both cases, the yield gaps are adjusted to maintain reasonable estimates based on what has been achieved in the past.





Source: Authors' calculations, using data from CABI (2005) and Fischer et al. (2001).

Having calculated the yield gaps, we introduce the two scenarios for closing the yield gaps among different crops as alternative policy interventions within a multimarket simulation model. This allows us to simulate a range of growth scenarios to determine their production possibilities and potential contribution to and impact on overall agricultural and economic growth.

4.3. The Multimarket Model

An economy-wide, multimarket (EMM) model based on neoclassical microeconomic theory is developed for this study with the fundamental aim of quantifying the economic implications of alternative policy decisions or scenarios. This model has special features that differentiate it from other multimarket models found in the literature (see Croppenstedt et al. 2007 for a recent survey of the use of multimarket models for the analysis of agricultural policy impact). One of these features is the economy-wide nature of the model. The model focuses on agriculture but puts the agricultural sector in an economy-wide context by including two nonagricultural sectors, allowing also for the endogenous determination of regional- and national-level GDP and AgGDP.

A second characteristic that differentiates the EMM developed for this study is the spatially explicit approach used to calibrate the production side of the model allowing analysis at multiple levels: regional, national, and subnational. Subnational information on the spatial distribution of production for 40 commodities (see appendix C) is used to define supply for each commodity at the development domain level (zone), integrating biophysical and socioeconomic information. Supply functions calibrated at the zonal level for different technologies (production systems) are used to capture each representative producer's response to market. These supply functions have two components. The first component is a yield function that is used to capture supply response to own prices given farm area allocated to this crop:

$$Y^q_{R,Z,i,t} = \psi^q_{\mathrm{R,Z,i,t}} P^{\alpha^q_{R,Z,i}}_{R,Z,i,t}, \tag{4.1}$$

where $Y^q_{R,Z,i,t}$ is the yield for crop *i* with technology *q* in country *R* and zone *Z* (representing development domain), $P_{R,Z,i}$ is the producer price for *i,* and $\psi^q_{R,Z,i,t}$ is the productivity shift parameter, which varies according to different technologies (*q*).

The second component is a land allocation function that is a function of all prices and hence is responsive to changing profitability across different crops given the total available land:[12]

$$A^q_{R,Z,i,t} = \xi^q_{\mathrm{R,Z,i,t}} \prod_j P^{\beta_{R,Z,j}}_{R,Z,j,t} \text{ and } \sum_j^J \beta_{R,Z,j} = 0, \tag{4.2}$$

where $A^q_{R,Z,i,t}$ is the area for crop *i* with technology *q, P* is the vector of producer prices, and $\xi^q_{R,Z,i,t}$ is the shift parameter.

Both yields and land can change over time. Yields can grow as a function of the annual productivity growth rate in yield $g_{Y_{R,Z,i}}$ acting on the productivity shift parameter $\psi^q_{R,Z,i,t+1} = \psi^r_{\mathrm{R,Z,i,t}}\left(1 + g_{Y_{R,Z,i}}\right)$, while crop area varies across years as a function of an annual area expansion rate. Shocks to the model to simulate improved production performance are introduced through changes in the productivity growth rate at the zonal level.

For each West African country, 12 potential subnational areas are defined based on combinations of the presence or absence of irrigation, the market access condition (easy access to ports for exports, easy access to domestic markets, and difficult access to domestic markets), and population density (high and low). Moreover, each of the 20 West African countries included in the model is further classified into Sahelian, coastal, and central regions to partially capture different agro-ecological conditions across countries.

The consumption side of the model is based on national-level information on demand for key commodities related to population and income levels and disaggregated to the development domain level. The model does not capture bilateral trade flows across subnational regions, although it does identify

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[12] Supply of livestock products is defined in a similar way, with an equation defining livestock output per head of animal stock instead of yields and an equation defining the number of animals of different species in total animal stock.

subnational regions as being food surplus or deficit by comparing regional-level demand and supply for total food commodities. Similarly, while the model cannot specifically capture trade flows among countries within the region, it can identify total regional demand and supply and net trade flows at the regional level, based on national exports and imports of traded commodities. Prices can vary across regions due to differences in transportation and market costs, while perfect substitution between domestically and internationally produced commodities is assumed. However, transportation and other market costs distinguish trade in the domestic market from imports and exports.

Several data sources are used to calibrate the model. National-level agricultural production, consumption, and trade data are from the country, when available, or from Food and Agriculture Organization of the United Nations (2007); nonagricultural data are from World Bank (2007). As mentioned above, a range of economic data are further disaggregated using Geographic Information Systems information. The model therefore permits analysis at multiple levels: regional, national, and subnational (see appendix B for a detailed presentation of the model).

4.4. The DREAM Model

The regional EMM model of West African agriculture lacks information about the dynamics of the technological adoption process and the scope of agricultural technology development and dissemination. This information is introduced in our analysis through the use of the DREAM model. This model can account for details about research and technology adoption: time lags, technology-induced supply shifts, and diffusion over time. In addition, DREAM allows technologies themselves to spill over from one region or country to another and to be adopted in recipient regions/countries,[13] allowing the examination of potential subnational, national, and regional benefits and costs of alternative technology development and deployment strategies as well as the estimation of the distribution of economic gains across countries from greater regional cooperation in agricultural research.

To capture the specific dynamics of the technical change process not captured by the EMM model, we use DREAM, closely linked to the EMM model, to measure the impact that growth in production of different agricultural activities has on the producer's welfare. With this information we define a ranking of activities according to their potential contribution to the producer's welfare that can help to prioritize allocation of R & D investment. To make the analysis using DREAM and EEM consistent and comparable, we calibrate both models using development domains as the basic spatial unit and the same values of the common parameters. These common parameters include crop production and consumption, crop prices, demand, supply, and income elasticities. We also use the same growth scenarios in both models and use the consumption projections from EMM in DREAM to account for the consumption growth for the crop. This is important because DREAM is a single-market, partial equilibrium model, and it does not capture the substitution effect in consumption that results from price changes in close substitute crops.

4.5. Alternative Growth Scenarios

To further build on the understanding of strategic opportunities for agricultural development in West Africa, this section considers alternative scenarios of agricultural growth implemented using the EMM and DREAM models and focusing on the subsequent implications they have for overall economic growth and poverty reduction.

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[13] Technology spillover benefits have been shown to account for half, and sometimes more, of the total benefits of agricultural research (Alston 2002).

Business as Usual

The business-as-usual scenario uses recent trends of growth in crop and livestock production to project agricultural growth into the future. This scenario serves as a marker against which we evaluate the alternative agricultural growth scenarios defined below.

One of the most prominent indicators of the challenge currently facing West African agriculture is the low growth rates within key agricultural subsectors. Consider the growth rates for three agricultural commodity groups: staples, cash crops, and livestock products. These commodity groups combined account for at least three-quarters of AgGDP of the majority of countries in West Africa. Table 7 reports growth rates of key agricultural subsectors during the past five to eight years for countries in the three subregions (coastal, central, and Sahel). Given current constraints on West African agriculture, what becomes clear from the growth rates in Table 7 is that a business-as-usual path will not lead to significant growth or reduction of poverty.

Table 7. Production growth rate employed in the base run (based on the trends of 1998–2004)[a]

	Cereals	Roots	Pulses and Oilseeds	Vegetables and Fruits	Cocoa	Cotton	Other High-value Products	Livestock	Processed Food
Coastal									
Guinea	2.27	2.88	3.93	2.61	3.38	3.03	2.36	3.78	4.17
Sierra Leone	1.85	3.33	3.42	4.98	2.56	0.00	3.68	2.31	3.65
Ivory Coast	1.81	2.67	4.08	4.81	2.43	3.84	2.76	2.23	5.08
Ghana	3.09	3.74	4.87	3.68	3.26	2.64	3.14	4.26	5.52
Togo	3.21	3.12	4.49	3.41	5.73	2.65	4.03	2.26	3.72
Benin	4.03	4.29	3.92	6.41	2.08	3.17	2.22	2.83	5.93
Nigeria	3.09	4.01	3.03	2.95	2.17	5.04	7.10	2.95	4.69
Sahel									
Burkina Faso	3.07	3.26	3.17	3.38	—	4.24	2.92	3.99	4.72
Chad	3.42	3.21	3.17	2.85	—	2.28	2.68	2.19	3.58
Gambia	3.16	2.92	2.55	4.32	—	3.35	2.84	4.17	4.78
Guinea-Bissau	2.41	3.10	2.54	3.31	—	3.75	3.13	3.21	3.91
Mali	3.57	3.45	3.41	3.69	—	4.56	2.95	4.31	4.68
Mauritania	2.59	2.26	4.07	3.61	—	0.00	2.88	2.70	6.28
Niger	3.18	2.00	3.75	2.74	—	2.00	0.00	3.01	4.97
Senegal	3.07	3.10	2.41	5.93	—	3.97	0.00	1.96	2.67
Central									
Cameroon	2.92	3.05	3.06	3.48	3.62	2.62	3.60	3.52	3.92
Central African Republic	3.08	2.08	4.02	2.48	2.59	3.12	2.91	2.40	4.11
Gabon	2.47	2.96	2.44	2.70	3.47	0.00	2.43	2.48	3.64
Republic of Congo	2.18	2.68	2.75	2.77	2.28	0.00	2.65	2.01	2.50
Democratic Republic of the Congo	2.27	2.54	2.74	3.08	2.68	2.53	3.80	2.20	2.54

Source: Authors' estimation.

Note: Dashes indicate no production of cocoa.

a. These growth rates represent the weighted average of national average growth rates of the 40 individual crops and livestock activities represented in the model and included in each group and development domain and are incremental yield growth rates with respect to base-run rates.

Yield Gap and Potential Productivity Growth

For the purpose of our study, we adopt two alternative scenarios for closing the calculated yield gaps within each development domain. The first one focuses on simply reducing yield losses due to biotic stress as a shorter-run and least ambitious policy alternative for accelerating agricultural productivity in the region. The second alternative introduces a longer-run and more ambitious strategy, one that requires significant investments to achieve maximum attainable yields. This goes beyond simply eliminating stress-induced yield losses and considers the efficient use of existing technology inputs (e.g., improved high-yielding varieties, application of fertilizers and chemicals, and mechanization) within each development domain.

Figure 8 illustrates the two scenarios for closing yield gaps and how they are derived conceptually at the development domain level. The calculation of both types of yield gaps is based on the corresponding actual and maximum attainable yield levels as discussed in section 3.2.

We complement these two scenarios with a third and final scenario, the most optimistic and ambitious of the three, wherein we assume the same higher-yield growth rates in the second scenario together with improvements in market access. This is intended to help absorb a rapid increase in output by integrating markets more fully within and across countries in the region.

Growth Scenario 1: Recovering Yield Loss due to Biotic Constraints. This scenario estimates the yield loss due to biotic constraints by crop and development domain as discussed in section 3.2. Assuming that the yield targets will eventually be reached within the next 10 years, we calculate the annual growth rates of crop yields for each domain within each country by comparing the yield target with the projected yield in 2015 in the business-as-usual scenario. A summary of average national growth rates for different groups of crops are reported in Table 8. It is important to notice that these growth rates represent the weighted average of national average growth rates of the 40 individual crops and livestock activities included in each group and development domain and represented in the model and are incremental yield growth rates with respect to base-run rates.

Growth Scenario 2: Catching up to Maximum Yield Potential. Targeted annual growth rates for this scenario are presented in Table 9. These growth rates are defined by the yield gaps calculated from the SPAM analysis as described in section 3.2. Like in the first growth scenario, the target yield in growth scenario 2 is assumed to be reached in the next 10 years, which allows us to define the annual growth rate of each crop's yield at the domain level within each country.

In the case of livestock, adequate data for growth projections are not available. To capture the growth contribution of the livestock sector, an important source of growth in many West African countries, we estimate growth in the livestock sector based on a comparative assessment of its performance in different countries. Growth in agriculture must be supported by income increases in both agricultural and nonagricultural sectors. Thus, additional growth in nonagriculture is also estimated in the growth scenarios.

Figure 8. Alternative scenarios for determining yield gaps

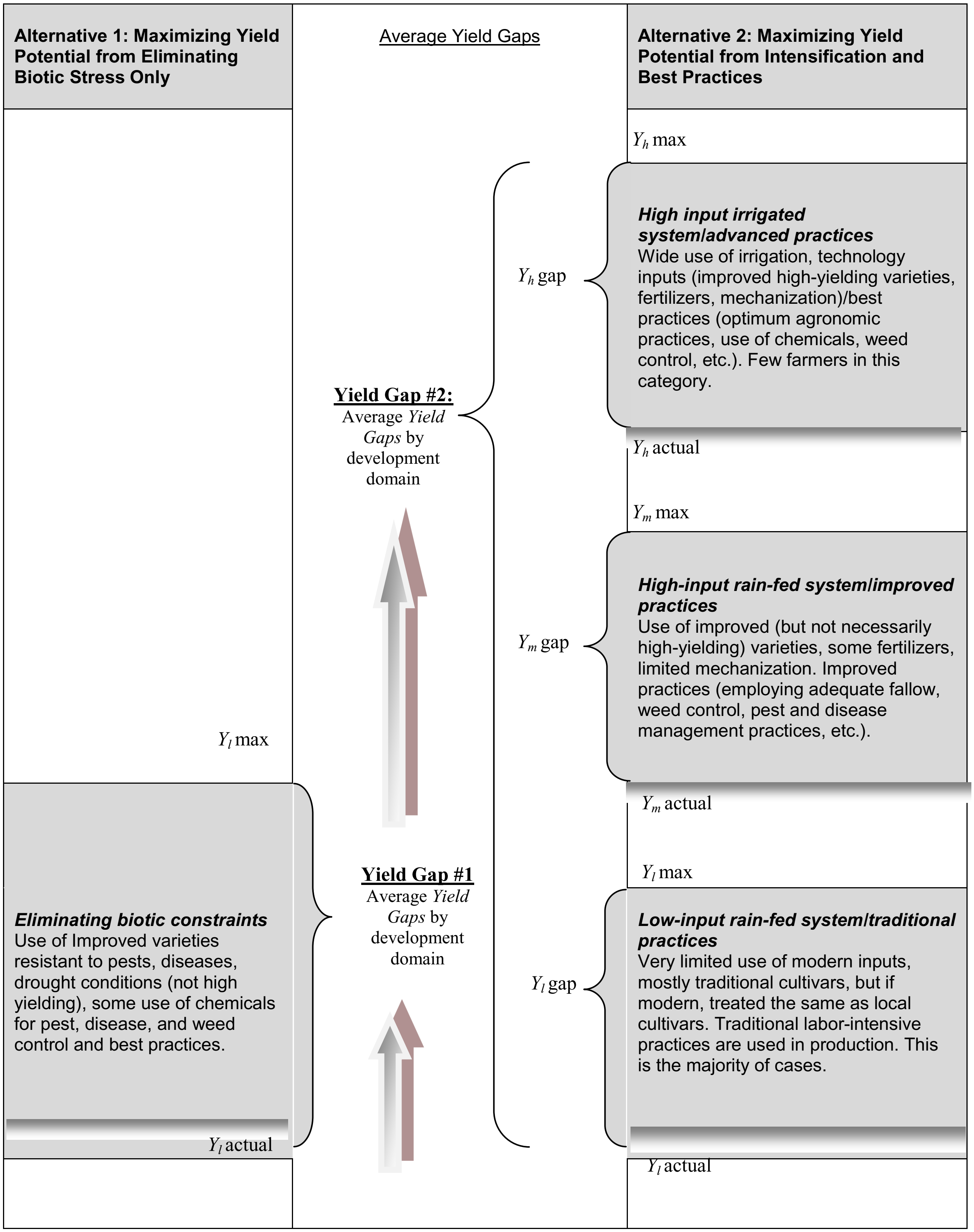


Table 8. Targeted annual growth rate (percentage) in crop yield in yield-loss recovering scenario, (2006–2015)[a]

	Cereals	Roots	Pulses and Oilseeds	Vegetables and Fruits	Cocoa	Cotton	Other High-value Products	Livestock	Processed Food
Coastal									
Guinea	3.65	3.44	5.03	3.18	3.75	4.08	2.83	4.93	5.28
Sierra Leone	3.16	3.92	4.30	5.72	3.49	0.00	4.61	3.57	4.66
Ivory Coast	3.10	3.19	5.33	6.57	2.45	5.21	0.00	3.42	6.06
Ghana	3.85	4.29	5.90	4.46	3.48	3.88	3.82	5.54	6.51
Togo	4.00	3.59	5.65	4.45	6.49	3.14	3.89	3.46	4.84
Benin	4.85	5.01	4.96	7.45	2.13	4.38	0.00	3.98	6.96
Nigeria	4.07	4.71	4.19	3.45	2.52	6.04	4.27	4.13	5.72
Sahel									
Burkina Faso	3.82	3.84	4.19	4.34	—	5.35	4.82	4.96	5.72
Chad	3.83	3.67	4.17	3.87	—	3.50	4.85	3.58	4.93
Gambia	4.12	3.47	4.07	6.04	—	4.48	0.00	5.47	6.10
Guinea-Bissau	3.63	3.51	3.58	3.93	—	4.87	3.46	4.30	5.04
Mali	4.85	3.76	4.33	4.35	—	5.44	5.05	5.74	6.12
Mauritania	4.24	2.45	4.44	4.03	—	0.00	0.00	3.38	6.91
Niger	3.65	2.52	4.55	3.14	—	2.78	4.84	4.55	6.13
Senegal	4.06	3.54	3.86	6.69	—	5.09	4.63	2.97	3.57
Central									
Cameroon	3.68	3.89	4.27	4.59	3.86	3.77	4.19	4.94	5.21
Central African Republic	3.91	2.53	5.09	3.08	2.67	4.31	3.30	3.87	5.48
Gabon	3.75	3.64	4.11	3.30	3.51	0.00	3.13	3.95	4.93
Republic of Congo	3.73	3.32	3.89	3.30	2.72	0.00	3.22	3.63	4.09
Democratic Republic of the Congo	3.63	3.19	3.86	3.80	3.43	3.81	4.29	3.56	3.91

Source: Authors' estimation.

Note: Dashes indicate no production of cocoa.

a. These growth rates represent the weighted average of national average growth rates of the 40 individual crops and livestock activities included in each group and development domain and represented in the model and are incremental yield growth rates with respect to base-run rates.Growth Scenario 3: Catching up to Maximum Yield Potential with Improved Market Access. Despite the significant gains that can be achieved from reducing biotic constraints and catching up to the maximum yield potential, West African agriculture still faces considerable barriers based on market and trade access. The first two alternative growth options are based on an assumption that current trade policies and market conditions will not significantly change. But without improvements in market conditions and reductions in intraregional trade barriers, the increased supply of agricultural products may depress prices and reduce farm incomes. Thus, we use the multimarket model to further simulate a situation in which trade barriers from inefficient trade policies and inadequate infrastructure are reduced. Productivity growth assumptions for the agricultural sector are the same as those employed in the second growth scenario; that is, growth in agriculture is mainly realized through catching up to the yield potential. Reduced price gaps due to improved market and trade conditions are modeled by exogenously lowering trade margins between domestic producer prices and border prices. Reductions in trade margins also indicate the potential for improvements in trade-sector productivity. To capture this, we exogenously increase the service sector's productivity to match reductions in trade margins.

Table 9. Targeted annual growth rate (percentage) in crop yield in catch up to potential yield scenario (2006–2015 average)[a]

	Cereals	Roots	Pulses and Oilseeds	Vegetables and Fruits	Cocoa	Cotton	Other High-value Products	Livestock	Processed Food
Coastal									
Guinea	6.21	4.24	6.21	4.22	5.40	5.69	5.15	5.10	5.78
Sierra Leone	7.47	6.24	6.81	8.73	7.12	0.00	9.39	4.26	6.01
Ivory Coast	5.73	4.39	7.27	10.00	4.08	6.75	0.00	3.73	6.58
Ghana	5.28	5.43	6.91	6.58	5.47	8.10	6.29	6.46	7.53
Togo	4.98	4.16	7.44	7.01	9.75	5.54	7.53	3.75	5.18
Benin	5.70	5.83	6.07	9.87	2.40	6.04	0.00	4.87	7.41
Nigeria	6.29	5.58	6.28	4.79	4.46	6.89	5.38	4.77	6.64
Sahel									
Burkina Faso	5.03	5.44	5.04	6.49	—	6.54	8.87	5.38	6.06
Chad	4.07	3.83	4.48	5.86	—	3.76	9.33	3.70	5.11
Gambia	5.25	4.47	6.19	9.85	—	7.87	0.00	5.57	6.40
Guinea-Bissau	5.75	3.56	3.59	4.04	—	4.87	3.44	4.26	5.05
Mali	6.76	4.34	5.09	5.95	—	6.65	9.62	5.80	6.46
Mauritania	7.34	2.84	4.97	5.07	—	0.00	0.00	3.42	7.04
Niger	4.23	3.93	5.47	4.69	—	4.21	9.26	5.01	6.65
Senegal	6.40	5.26	7.50	9.19	—	10.96	8.67	3.82	3.81
Central									
Cameroon	3.68	3.89	4.27	4.59	3.86	3.77	4.19	4.94	5.21
Central African Republic	3.91	2.53	5.09	3.08	2.67	4.31	3.30	3.87	5.48
Gabon	3.75	3.64	4.11	3.30	3.51	0.00	3.13	3.95	4.93
Republic of Congo	3.73	3.32	3.89	3.30	2.72	0.00	3.22	3.63	4.09
Democratic Republic of the Congo	3.63	3.19	3.86	3.80	3.43	3.81	4.29	3.56	3.91

Source: Authors' estimation.

Note: Dashes indicate no production of cocoa.

a. These growth rates represent the weighted average of national average growth rates of the 40 individual crops and livestock activities represented in the model and included in each group and development domain and are incremental yield growth rates with respect to base-run rates.

5. GROWTH POTENTIAL FOR WESTERN AND CENTRAL AFRICA

According to the discussion in previous chapters, there exists the potential for West African agriculture to attain higher yields simply from adopting existing technologies and farmer best practices. In the absence of any other data that are comparable across countries in the entire region, and assuming the estimates are closest approximations to realities on the ground, average yields are consistently below the maximum potential. This yield gap is quite large for a majority of countries in West Africa and signals an important opportunity for the region to realize even greater productivity growth in the future with new and improved technologies.

In this chapter, we delve deeper into examining and comparing the potential and variable effects of narrowing these yield gaps on overall economic growth and farm income within the framework of an *ex ante* economic model simulation. The model provides a way to quantify certain economic criteria useful for ranking future alternative priorities for agricultural investments, including the contribution to overall growth and poverty alleviation and economic benefits by crop. Finally, by employing the economic analysis at the regional and multicountry levels, both regional and country-specific priorities can be emphasized.

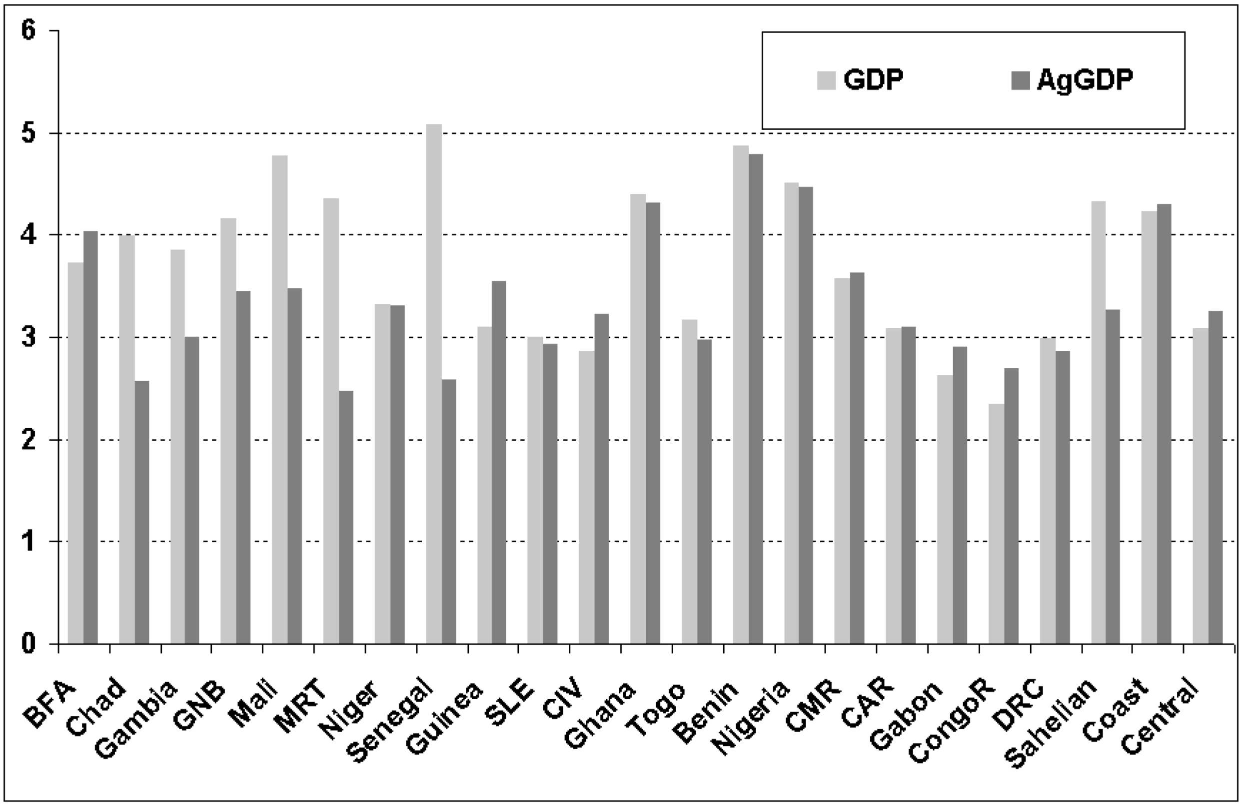
The analysis proceeds as follows. First, an EMM model for West Africa is used to quantify the economic implications of alternative growth scenarios on African agriculture beyond a business-as-usual scenario. It is also used to prioritize both agricultural and nonagricultural subsectors by evaluating the potential contributions that 32 crops and 8 livestock activities have in driving future AgGDP and GDP growth rates. This multimarket model is then integrated with IFPRI's DREAM model to further assess the major gainers at the commodity level (focusing on crop production) by quantifying the impacts of productivity-enhancing investments in agricultural R & D across spatial development domains.

5.1. Business as Usual

Using past growth rates along with recent growth rates in agricultural processing sectors and two nonagricultural subsectors, we use the multimarket model to project economic growth forward to 2015. The projected annual growth rates for AgGDP and overall GDP are reported in Figure 9. These business-as-usual outcomes suggest that in all countries, AgGDP growth rates would fall below the six percent target required to attain the MDG goals. Overall economic growth would stay at a similarly low level. Because most West African countries have experienced two to three percent population growth rates, per capita AgGDP growth rates would fall below 1 percent (or even decline) in 13 of the 20 West African countries. Ghana and Nigeria have the highest per capita AgGDP growth rates at close to 2.0 percent per year, and only 3 other countries could potentially reach a 1.5 percent AgGDP growth rate.

What does this analysis tell us about different subsectors' projected contributions to total AgGDP in a business-as-usual scenario? The EMM model simulates these results (see Figure 10). Results from the EMM model at the individual crop or livestock activity levels from attaining yield potential from intensification and best practices are aggregated at the subsector level to present an overall view of the contribution to growth of major groups of activities. Each subsector's contribution varies across countries depending on the size of the subsector in the economy as well as its past growth rate. For example, the livestock subsector has quite a large impact on total agricultural growth in most Sahelian countries, while it is of much less importance in the coastal and central regions. While cotton and cocoa are the most important export crops and sources of foreign exchange earnings in the region, their contribution to total AgGDP growth is not as large as expected in a business-as-usual scenario. This holds true even when considering cotton's contribution to AgGDP in Mali and Benin and cocoa's contribution in Ivory Coast and Ghana. The shares of these traditional export commodities in total agricultural income become modest when domestic markets' and farmers' own consumption are taken into account. The low shares of these export commodities suggest there is not much room for them to significantly affect growth in a business-as-usual scenario. If West Africa continues along the current growth path there will be a widening gap between the supply and demand of major food crops. For cereals, the shortfall in supply would increase to 22 million metric tons by 2015—80 percent more than what it was in 2003. This would represent 27 percent of the total regional demand. This widening gap between supply and demand would make it impossible for most countries to meet the MDGs focused on increased nutrition and food security.

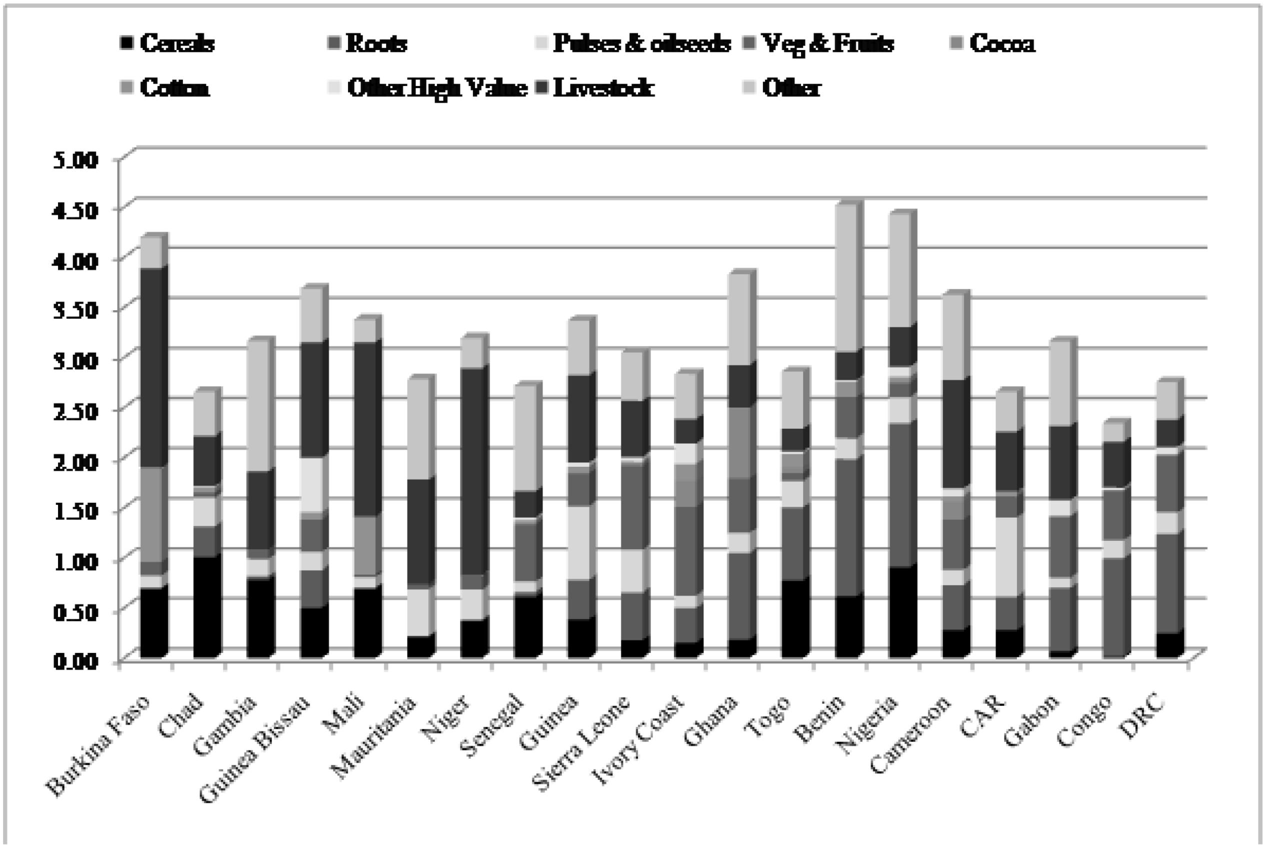
Figure 9. Projected agricultural GDP (AgGDP) and overall economic growth in the base run (2006–2015 average)



Source: Economy-wide, multimarket model simulation results.

Note: BFA = Burkina Faso; GNB = Guinea-Bissau; MRT = Mauritania; SLE = Sierra Leone; CIV = Ivory Coast; CMR = Cameroon; CAR = Central African Republic; CongoR = Republic of Congo; DRC = Democratic Republic of the Congo.

Figure 10. Subsector's contribution[a] to agricultural GDP growth rate in the base run (2006–2015 average)



Source: Economy-wide, multimarket model simulation results.

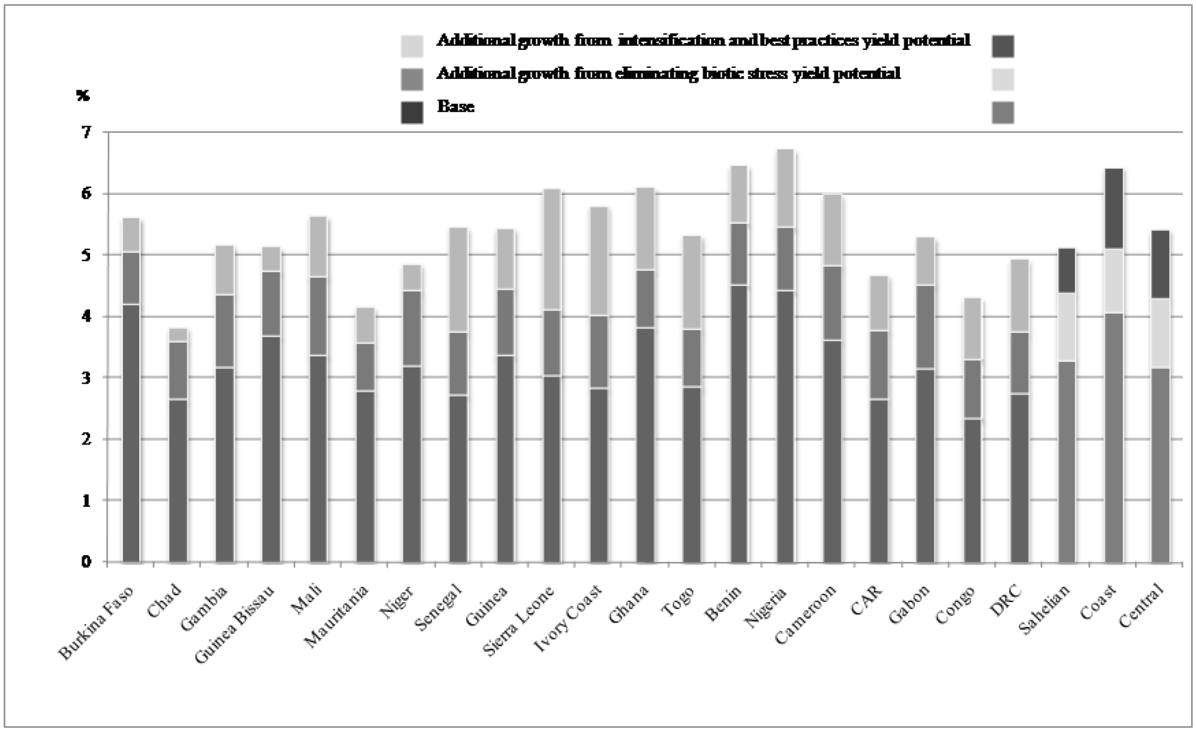
Note: Veg&fruit = vegetables and fruits; Other high-value = other high-value products; CAR = Central African Republic; DRC = Democratic Republic of the Congo.

a. Contributions represent the weighted average of national average contributions of the 40 individual crops and livestock activities represented in the model and included in each group and development domain.

5.2. Growth Impact of Closing the Yield Gap in Agriculture Productivity

Based on the aforementioned description of the three growth simulations, and using the multimarket model to project these growth rates forward to 2015, the annual growth rates for AgGDP and overall GDP in the first two growth scenarios are reported in Figure 11, which also illustrates the clear differences these three scenarios show in terms of agricultural growth. Growth from recovering current yield losses (by overcoming biotic constraints) contributes to an additional one percent annual AgGDP growth in the next 10 years for many West African countries. Even with this additional growth, rates in most West African countries are still far below the six percent target. However, by catching up to the agroclimatically attainable yield potential from intensification and best practices, eight of the 20 West African countries included in the study (Benin, Nigeria, Ghana, Guinea, Ivory Coast, Sierra Leone, Cameroon, and Mali) can come close to reaching the six percent target. Among these eight countries, six are located within the Coastal region, while Mali is in the Sahel and Cameroon is in the central region. There are also 10 countries in which the annual AgGDP will grow at close to 5 percent or greater, while there are only two Sahelian countries, Chad and Mauritania, for which projected annual growth in AgGDP is below four percent.

Figure 11. Projected average annual growth rate of agricultural GDP in different scenarios (2006–2015)

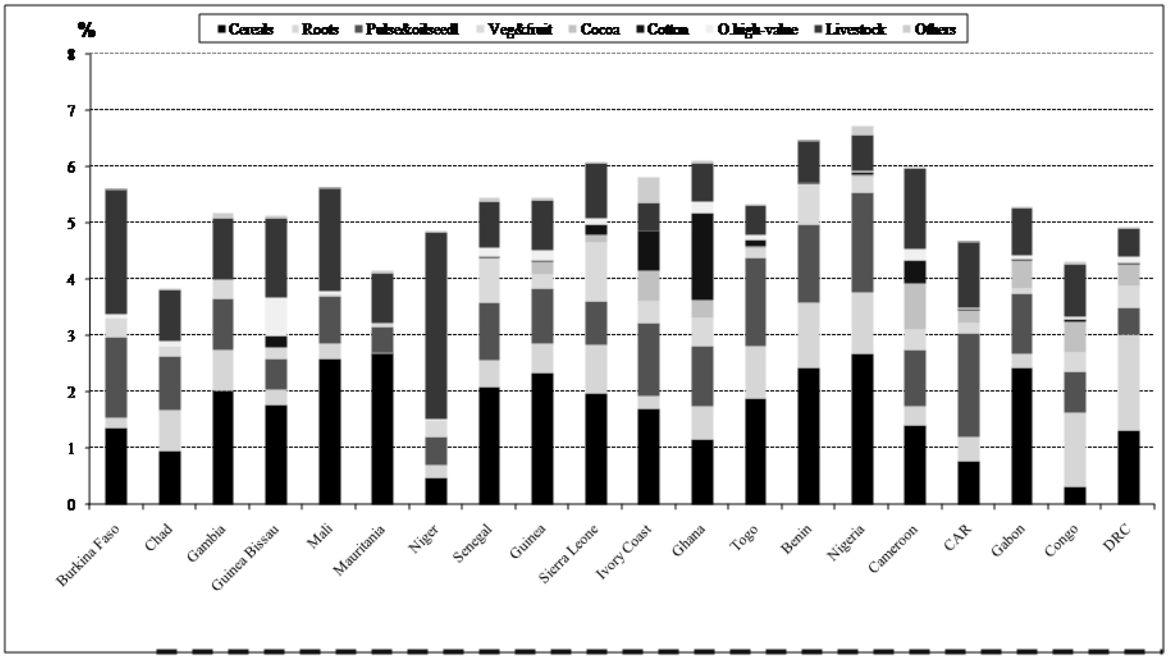


Source: Economy-wide, multimarket model simulation results.
Note: CAR = Central African Republic; DRC = Democratic Republic of the Congo.

As in Figure 11, results at the individual crop or livestock activity levels are aggregated at the subsector level to present an overall view of the contribution of major groups of activities. Results vary across countries and major regions due to social and economic conditions, agro-ecological potential, and different agricultural production structures (see Figures 12 and 13). There are underlying dynamics to the relatively high impact that the growth in livestock and cereal subsectors has on AgGDP in most Sahelian countries. Demand for these items tends to grow as incomes rise, and at proportionately greater rates. Such growth in demand allows for sustained productivity growth without significantly negative price effects and thus higher overall real income levels. In most Sahelian countries, livestock contributes more than 28 percent (36 percent in the Sahel as a whole). In only three countries (Chad, Gambia, and Senegal), livestock contribution is below these values. The cereal subsector's contributions to total agricultural growth are in the range of 24 to 41 percent for seven of the eight Sahelian countries, except for Niger, in which cereal growth contributes 13 percent of total agricultural growth.

In the coastal countries, the subsectors that contribute significantly to total growth are much more varied than those in most of the Sahelian countries discussed above. Despite this diversity, the contribution to total growth from root crops seems to be relatively more important than other subsectors. For example, root crops contribute to about 23 to 30 percent of agricultural growth in Ghana, Benin, Togo, and Nigeria and 9 to 10 percent of growth in Sierra Leone and Ivory Coast. Countries in the central subregion have relatively low agricultural potential (at the national aggregated level), except for Cameroon. Four Central African countries have the potential to reach levels of 5 percent agricultural growth while Cameroon could reach a growth rate of 6 percent. Given such relatively low agricultural growth rates, livestock and root crops seem to be the most important sources of growth in the region. Livestock contributes to 19 to 23 percent of agricultural growth in four of the five central region countries, except for Democratic Republic of the Congo, while root crops contribute to 10 to 35 percent of total agricultural growth in the five central region countries.

Figure 12. Subsector's contribution[a] to agricultural GDP growth varies by sector and across countries from three different scenarios (base scenario and scenarios 1 and 2)

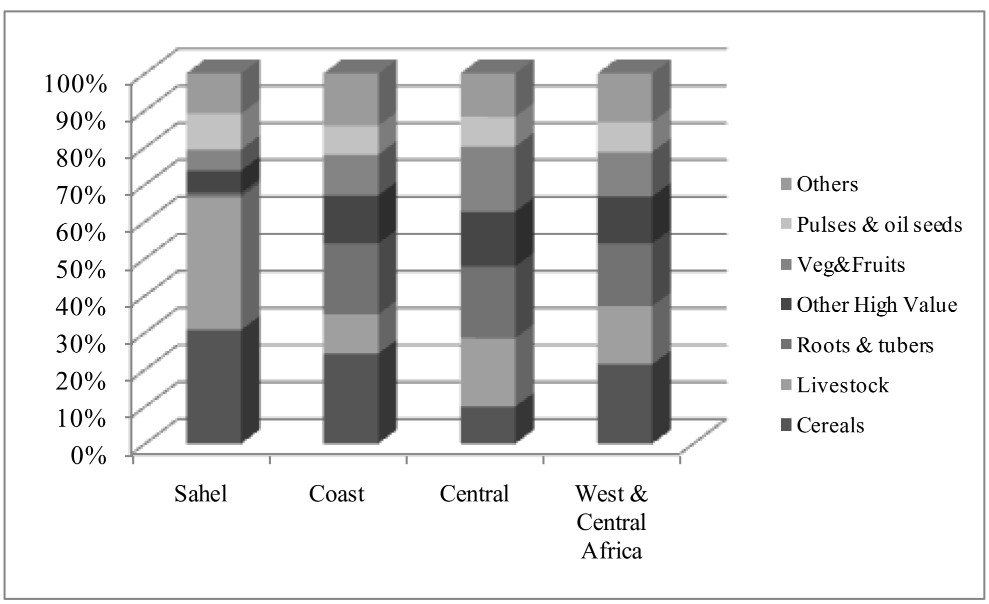


Source: Economy-wide, multimarket model simulation results.

Note: Veg&fruit = vegetables and fruits; O. high-value = other high-value products; CAR = Central African Republic; DRC = Democratic Republic of the Congo.

a. Contributions represent the weighted average of national average contributions of the 40 individual crops and livestock activities represented in the model and included in each group and development domain.

Figure 13. Subsector's contribution[a] to agricultural GDP growth by sector and across major regions (from scenario 2)



Source: Economy-wide, multimarket model simulation results.

Note: Veg&Fruits = vegetables and fruits; Other High Value = other high-value products.

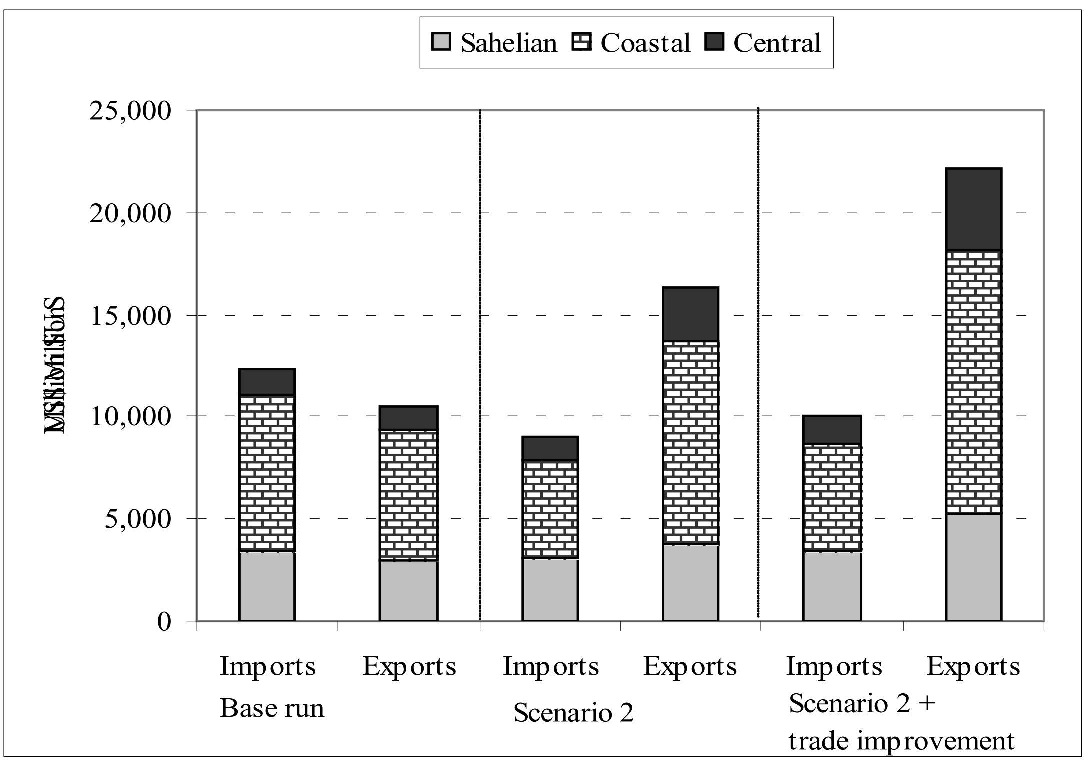
a. Contributions represent the weighted average of national average contributions of the 40 individual crops and livestock activities represented in the model and included in each group and development domain.

Traditional export crops, such as cotton and cocoa, contribute to around 10 percent of total agricultural growth in the major exporting countries (cotton in Mali and cocoa in Ivory Coast and Ghana). This share is close to their current contribution to the AgGDP. Nontraditional exports and other high-value crops seem to be an important growth source in some coastal countries. Their contribution to AgGDP growth is more than 17 percent in Ghana and more than 35 percent in Ivory Coast.
When considered collectively, livestock, cereal, and root crop subsectors result in relatively large AgGDPs. Results discussed here suggest that the greatest agriculture-led growth opportunities in West Africa reside in commodities for which (1) there is a relatively large production base to start with, (2) there is a large growth potential agroclimatically, and (3) there is a large and growing demand within the region. In the next section, contributions by crops such as maize, rice, cassava, yam, and pulses will be further analyzed.

5.3. Agricultural Growth and the Impact on Trade

Figure 14 summarizes potential agricultural export and import outcomes by 2015 as projected by the model. Compared to the business-as-usual scenario, catching up to yield potential in agriculture (scenario 2) results in US$6 billion more of agricultural exports for the region as a whole. In other words, total regional agricultural exports will rise to US$16.4 billion. This is significantly higher than the projected US$10.6 billion gained in the business-as-usual scenario by 2015. Looking at agricultural imports, the model projects that by 2015, agricultural imports will fall from US$12.4 billion in the base run to US$9.0 billion in growth scenario 2. If agricultural productivity growth is further supported by improved market conditions and trade policies (scenario 3), West Africa's total agricultural exports would rise to US$22.1 billion while total agricultural imports would only increase modestly to US$10.1 billion by 2015.

Figure 14. Projected total agricultural exports and imports by 2015 (US$ million)



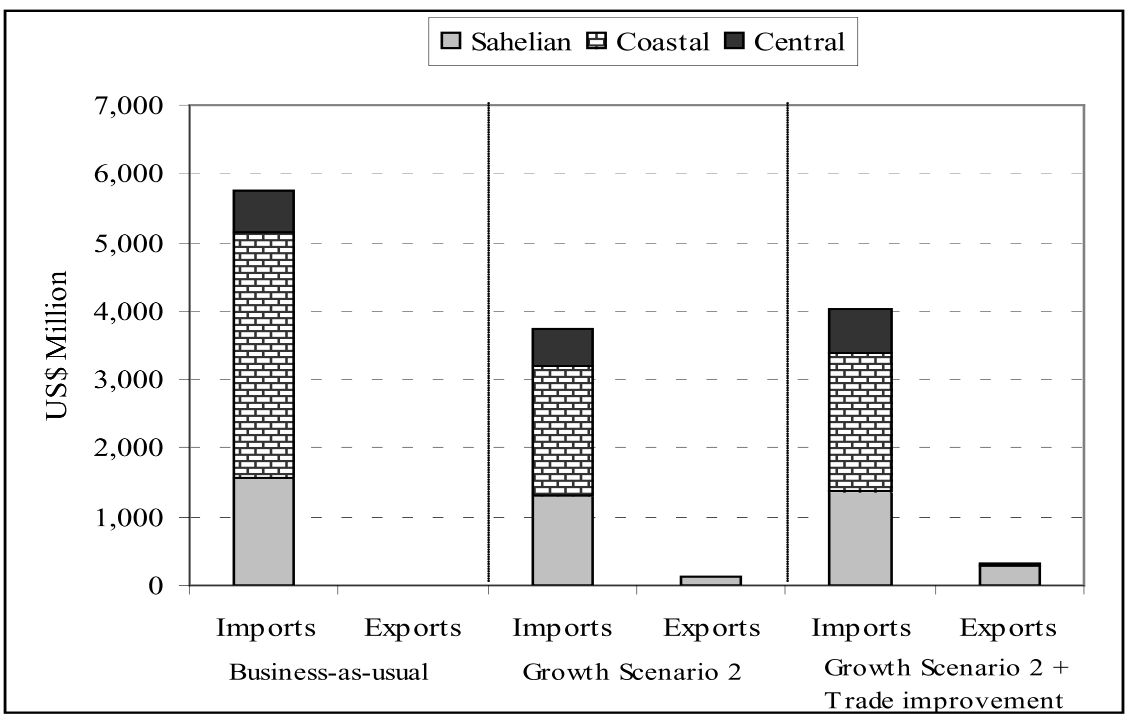
Source: Economy-wide, multimarket model simulation results.

Improved market conditions, along with increased agricultural productivity, can increase West African countries' competitiveness in both global and regional markets. Constrained by the lack of intraregional, bilateral trade data among West African countries, our analysis cannot distinguish intraregional trade from interregional trade. However, increasing trade and improvements in the region's international competitiveness would likely result in the substitution of global imports with intraregional imports. We focus on trade in cereals and livestock, the two subsectors with the highest intraregional trade potential, to illustrate this argument (see Figure 15).

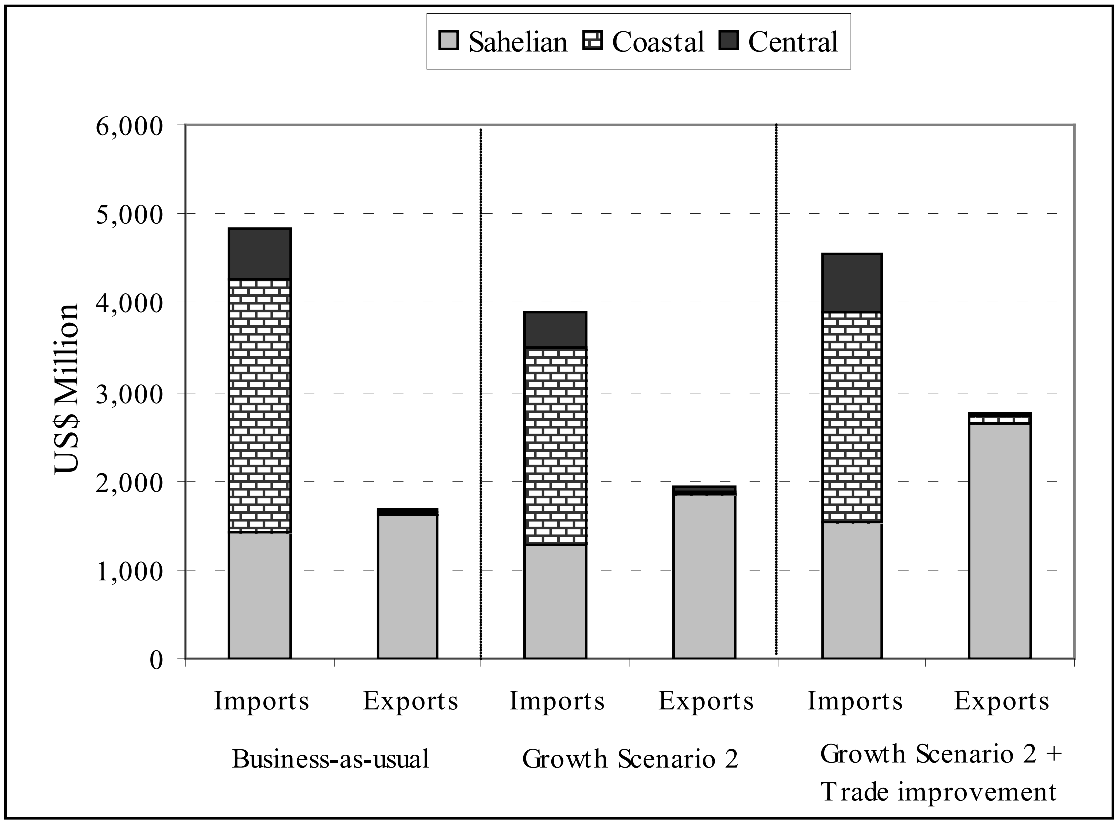
If growth follows a business-as-usual path, cereal imports will reach US$5.7 billion by 2015, and the three subregions in West Africa will continue to be cereal-deficient regions with low numbers of cereal exports (see Figure 15a). While livestock exports are significant in the base run (US$1.7 billion), imports (US$4.8 billion) will total more than exports by 2015. Among the three subregions, the Sahelian region is a net exporter, while the other two regions are net importers. With enhanced productivity growth in agriculture, cereal imports are projected to fall in West Africa, even though demand will significantly increase with income growth. While livestock imports will also decline, livestock exports will increase only modestly, indicating certain market constraints in the livestock-exporting countries (see Figure 15b). However, when productivity growth is supported by improvements in market and trade conditions, livestock exports increase to US$2.8 billion, of which US$1.8 billion is exported from Sahelian countries. While livestock imports fall slightly to US$4.6 billion, imports are still higher than exports for the region, due to the more than US$1.4 billion in imports by Nigeria. About US$280 million cereal exports are generated through improving market and trade conditions in the region, but cereal imports also increase, compared to the import levels in a growth scenario without market improvements. Thus, it is reasonable to believe that cereal exports could easily find markets in the region given that Nigeria will import US$2 billion in cereals in the same scenarios.

Figure 15. Projected cereal and livestock exports and imports by 2015 (US$ million)

a. Cereals



b. Livestock



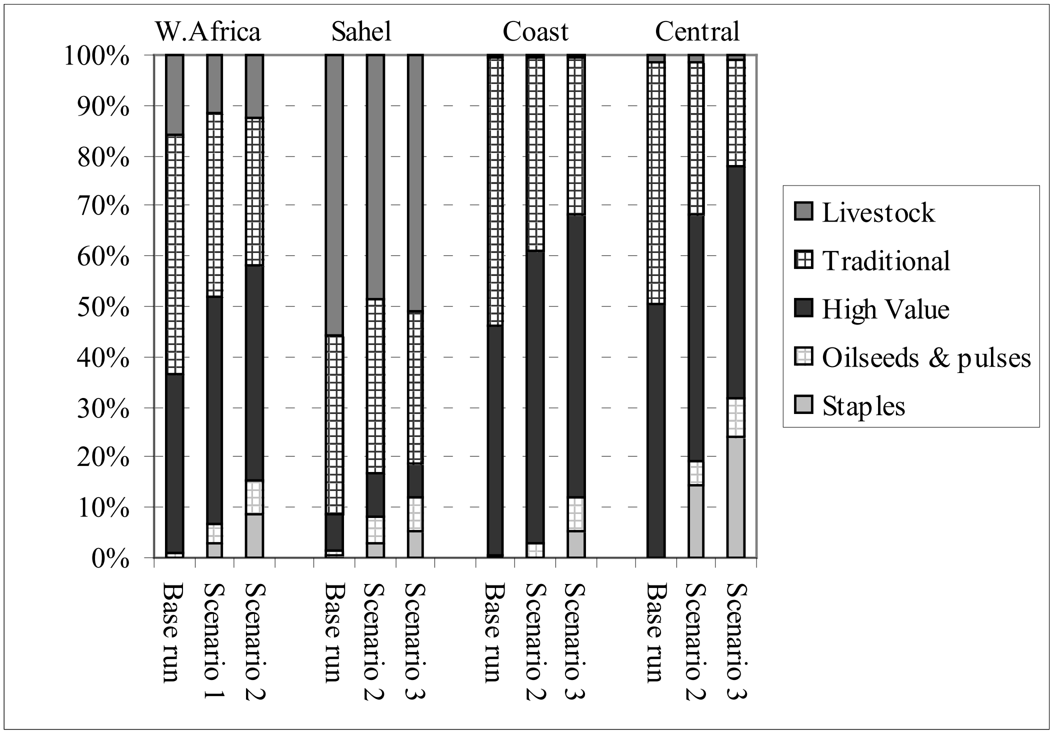
Source: Economy-wide, multimarket model simulation results.

Figure 16 summarizes the export and import structure of the three subregions as well as West Africa as a whole. West Africa's export structure appears to become more diversified with growth in agricultural productivity and improvements in market and trade conditions. In the base run, traditional exports including cocoa and cotton account for 47.8 percent of West Africa's total agricultural exports, a structure similar to that found in current trade. Agricultural productivity growth, together with improvements in market and trade conditions, increases export opportunities of other commodities. Thus, as observed in Figure 16, exports of cocoa and cotton in total agricultural exports fall to 29 percent, while exports of high-value products (fruits, vegetables, and processed food) increase from 36 to 43 percent of total exports. Also, staple crops, including cereals, roots and tubers, and oilseeds and staples, increased their share in exports from 0.1 and 0.7 percent to 6.6 and 8.9 percent, respectively. On the import side, improved productivity and reduced transaction costs result in a reduction of the importance of cereals and in an increased share of livestock products in total imports.

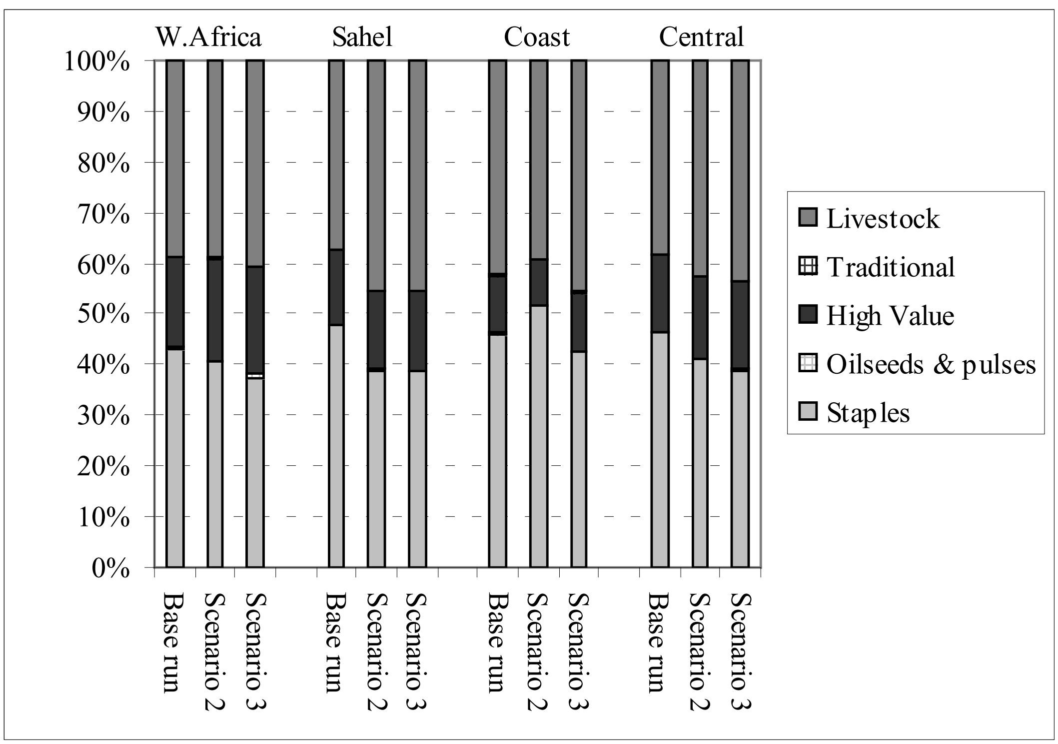
Changes in the structure of exports in subregions show a similar pattern. However, changes in coastal and central regions are more pronounced than in the Sahel, reflecting the higher agricultural potential of these regions. With increased productivity, high-value products will displace traditional exports and become the major agricultural export item on the coast. The central region can become an exporter of staple crops with a substantial reduction in the share of traditional export crops.

Figure 16. West Africa's agricultural export and import share in different scenarios (percentage, 2015)

a. Exports



b. Imports



Source: Economy-wide, multimarket model simulation results.

5.4. Producer Benefits by Agricultural Commodity

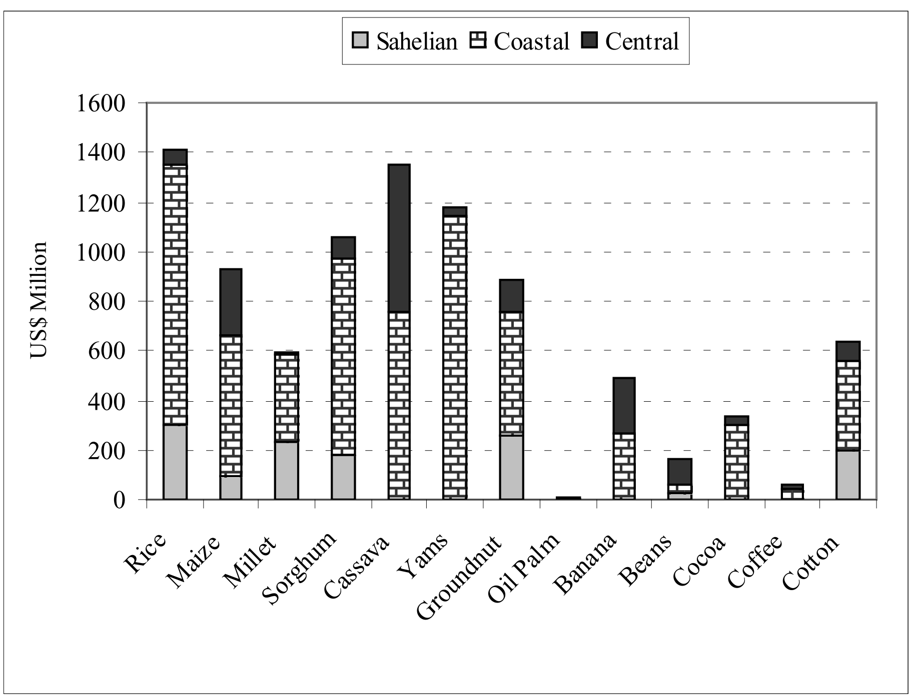
The impact of alternative growth options at the commodity level is evaluated using IFPRI's DREAM model. Such analysis can help set priorities for commodity-level R & D investment. The baseline in the DREAM model is the same as the multimarket model's business-as-usual scenario discussed above. Specifically, we focus on 15 crops including major staple crops (cereals, root crops, pulses, and oilseeds), 2 tree crops (bananas and coffee), and 2 major traditional export crops (cocoa and cotton) for the analysis. The actual productivity shocks are the same as those used in the EMM model and defined in chapter 4.

The first scenario simulates the overall benefits to producers adopting technology to overcome biotic constraints. Results are shown in Figure 17a. The producer gains in rice and cassava production are the highest, both reaching more than $1.3 billion. Cereal crops such as maize, millet, and sorghum; root crops like yams; and oil crops like groundnuts would also generate gains to farmers in this scenario, reaching $594 million to $1.2 billion for each of these crops in the West African region as a whole. There are also gains to be had from export crops (such as cotton and cocoa), though these are smaller than the gains from many staple crops.

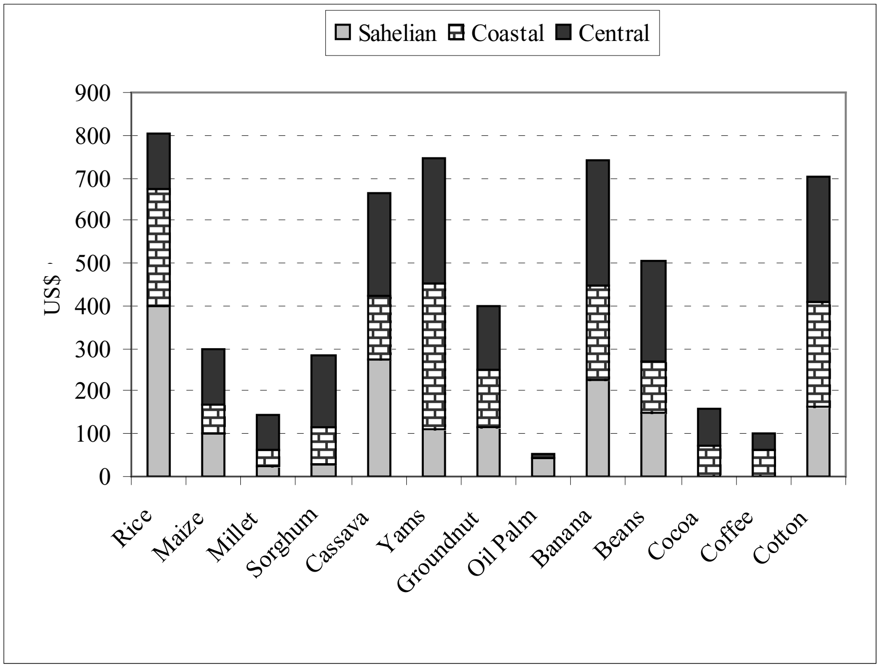
Total producer benefits at the country or commodity level depend on the size of the country and the size of the sector in each country's agricultural economy. To make investments in each sector comparable in terms of their return, we must normalize gains using a commonly measured denominator. Here we choose crop area as a denominator and report producer benefits per hectare in Figure 17b. Producer gains from rice growth are the highest gains among all crops for the region, ranging from $130/hectare in the central region to $400/hectare in the Sahelian region. In fact, such gains are extremely high in some countries, (e.g., $1,470/hectare in Mauritania and $1,040/hectare in Cameroon), implicating that there is a relatively large yield loss due to environmental constraints under the current situation. The next top gainer at the per-hectare level is yams, reaching $342/hectare in the coastal region and $291/hectare in the central region. It is important to note that such gains are measured in terms of current prices. Increases in rice production might encounter domestic market constraints if there are no additional export opportunities. Producer prices may be lowered with such market constraints, which would reduce the gains from such technological improvements.

Figure 17. Cumulative producer benefits in growth scenario 1: yield-loss recovery, 2006–2015

a. Total (US$ million)



b. Per hectare (US$/hectare)



Source: Dynamic Research Evaluation for Management model results.

The second growth scenario focuses on potential yield gaps identified at a geographical pixel level in West Africa. We assume that the agroclimatically attainable yield potential will eventually be realized in those domains with better agroclimatic conditions for growing such crops. Figure 18a presents the total producer benefits from such a growth option. The total benefits to West African farmers in this scenario are far greater than those from yield-loss recovery. For West Africa as a whole, catching up to the rice yield potential generates the greatest gains to farmers, totaling $6.8 billion during the next 10 years (2006–2015).

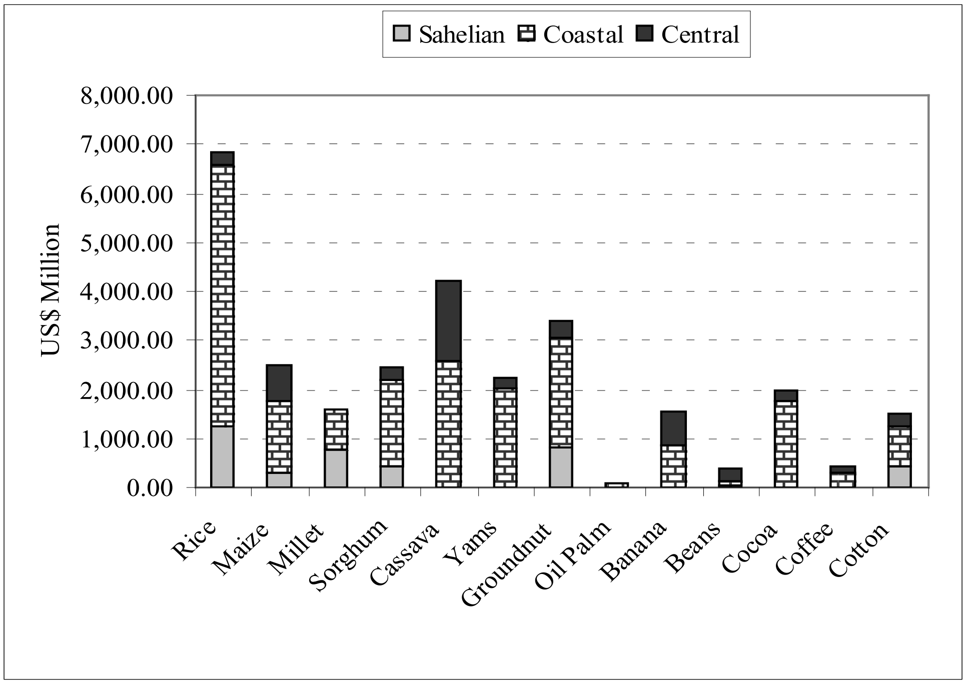
While the three subregions all gain, the coastal subregion gains the most at $5.3 billion. Rice, cassava, groundnut, maize, sorghum, and yams generate $2.2 to $6.8 billion of producer gains. Three export crops—cocoa, cotton, and bananas—each generate more than $1.5 billion of producer gains.

At the per-hectare level (see Figure 18b), gains from each crop vary across the three subregions. In the Sahel, per-hectare gains are the highest for rice ($1.6 thousand/hectare), followed by cassava and yams ($890/hectare and $846/hectare), while in the coastal region, the gains from sweet rice and groundnut growth are the highest, $1.4 thousand/hectare and $611/hectare, respectively. For the central region, per-hectare gains are the highest for root crops and export crops, ranging from $1.7 thousand for yams to $981/hectare for cotton. The size of the gains at the per-hectare level depends on the captured yield gap and the current price levels. Obviously, differences in market opportunities can significantly affect such projections. In the next section, such market opportunities are further assessed.

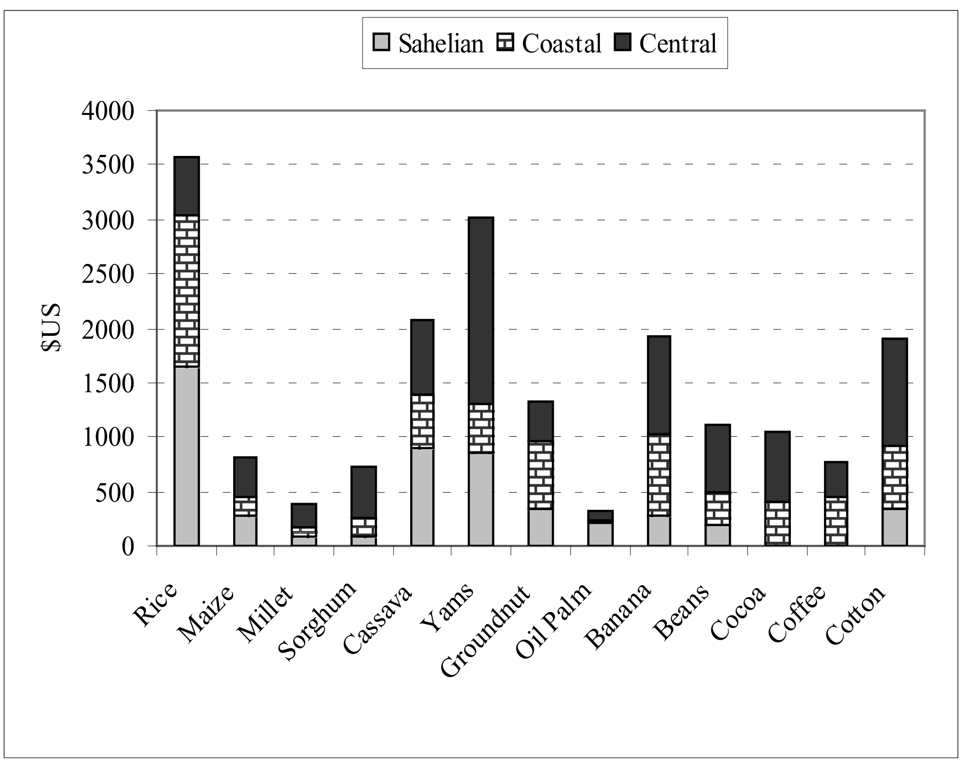
Given the size of the region, spatial scales (national, zonal, and regional) are important for evaluating priority crops. To get a regional perspective, we aggregate the subregional results into the aggregated West African region. In addition, we put the two growth scenarios together for an overall picture. Figure 19 shows relative producer benefits normalized by base year value of production (see Figure 19a) and producer benefits per hectare (see Figure 19b) for West Africa as a whole. While these two figures show different priorities among the 13 crops, there is some consensus between them as rice, groundnut, and cotton rank high in both figures. From a regional standpoint, technology investment in these three crops deserves to be a priority.

Figure 18. Cumulative producer benefits in growth scenario 2: catching up to yield potential, 2006–2015

a. Total (US$ million)



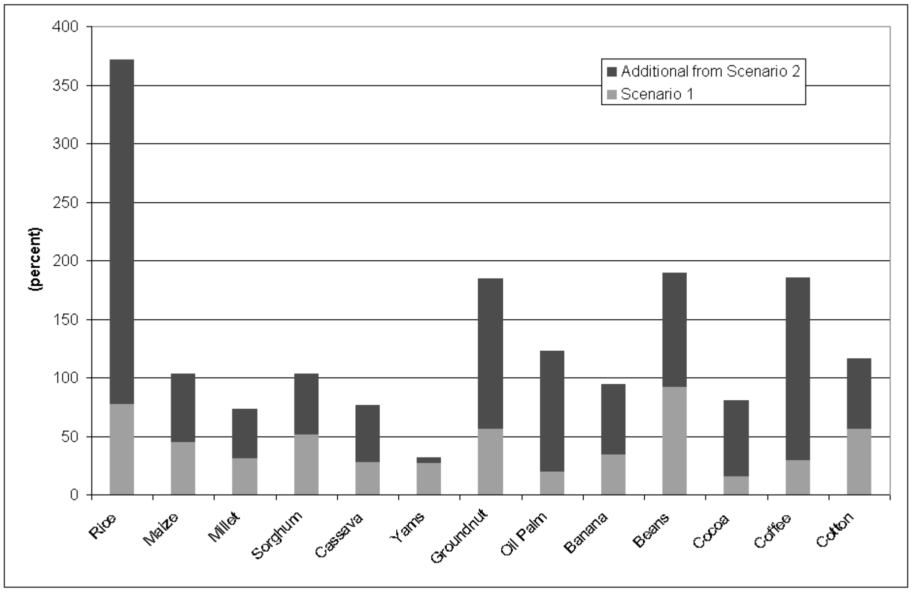
b. Per hectare (US$/hectare)



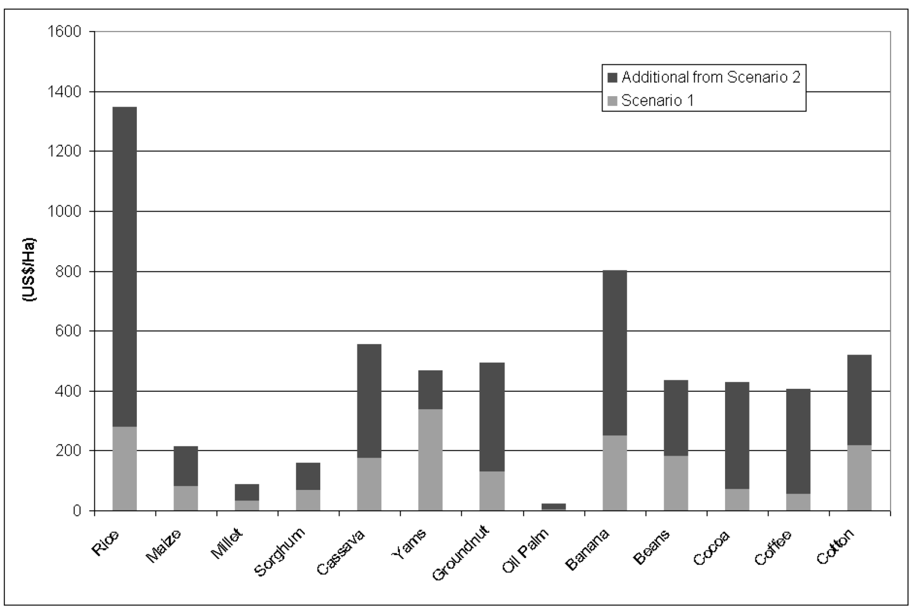
Source: Dynamic Research Evaluation for Management model results.

Figure 19. Producer benefits under scenarios 1 and 2 for West Africa

a. Relative to base year value of production



b. Relative to harvested areas



Source: Dynamic Research Evaluation for Management model results.
Note: US$/Ha = US$/hectare.

Our subsector analysis strongly indicates that West African countries sharing similar agro-ecological conditions could greatly benefit by pooling resources to find common technological solutions. Also, while priority crops vary from country to country and from zone to zone, rice can be thought of as a regional strategic commodity as it seems to have the highest producer benefits across the board. To a lesser extent, groundnuts, coffee, and cotton could also become regional priorities for the coastal and central regions.[14]

[14] As pointed out by a reviewer, the evaluation of each activity should bring into consideration the relative costs to farmers

6. CONCLUSIONS AND POLICY IMPLICATIONS

The primary purpose of this report is to identify a set of alternative development priorities that tap into the potential for agricultural productivity growth in crop and livestock production and that cut across West and Central Africa to achieve economy-wide growth goals in the region. To identify these priorities, we adopt a modeling and analytical framework that involves the integration of various economic and statistical tools, which results in a number of unique advantages. First, our approach is *spatial* and differentiates areas that are similar with respect to different agro-ecological and market conditions within West Africa. This allows us to properly identify yield gaps, which determine growth potential of different agricultural activities for areas with similar conditions. This approach then provides an increased level of confidence in the elaboration of strategies or policies that may be developed to close or reduce these yield gaps. Second, our approach maintains an *economy-wide and dynamic* perspective through the use of a multimarket model complemented by a single-commodity, multiple-region partial equilibrium model. These models incorporate information about yield gaps defined in the spatial analysis together with information about agriculture and nonagriculture production, consumption, prices, and trade to simulate *ex ante* the economic effects of closing these yield gaps. Model simulations allow us to estimate the contributions to overall economic growth of different agricultural activities and the benefits they bring about for producers.

The results that emerge from this integrated spatial and economy-wide approach point to a rank of production activities at the country and regional levels that must be prioritized to stimulate productivity growth and achieve overall growth and poverty reduction goals in West Africa. These results indicate that the greatest agriculture-led growth opportunities in West Africa reside in staple crops (cereals as well as roots and tubers) and livestock production. The impact of these activities is explained mainly by their relatively large share in total agricultural production, their large growth potential as suggested by the analysis of yield gaps in particular for staple crops, and a large and growing demand for these commodities within the region.

The contribution of different staple crops and livestock production to agricultural growth and to the income of agriculture producers varies across countries and major zones due to different agro-ecological, physical, and socioeconomic conditions. Despite these variations, rice appears to be the commodity with the highest potential for growth and subsequently the one that could generate the greatest producer benefits for many countries. Livestock production is the activity contributing the most to total agricultural growth in the Sahel. This is primarily because of the sheer size of this sector in the economies of most Sahelian countries, the comparative advantage of the Sahel for livestock production in West Africa, and the fact that demand for livestock products tends to grow at proportionately greater rates as incomes rises. Countries in this region can also benefit from high growth in agriculture if the yield gap in production of rice, coarse grains, and groundnuts is reduced in the next 10 years.

In the coastal countries, the subsectors with a significant contribution to total growth are much more varied than those in the Sahel. Despite this diversity, the contribution to total growth from staple crops like cassava, yams, and cereals seems to be relatively more important than that of other subsectors. In the case of Central Africa, livestock and root crops are the most important sources of growth in the region. Traditional export crops, such as cotton and cocoa, could have a significant contribution to growth in their major exporting countries (cotton in Mali and cocoa in Ivory Coast and Ghana), while nontraditional exports and other high-value crops seem to be an important growth source in some coastal countries.

Our results also point toward an essential range of policies and investments that are needed to stimulate productivity growth of prioritized activities. These include the following: development of

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of adopting the different technologies since the costs associated with the different strategies are not necessarily the same. As we are evaluating here technologies that are already being generated but not yet adopted, we are assuming that the cost of adopting these technologies is similar for the different crops and livestock activities.

opportunities for regional cooperation on technology adaptation and diffusion, strengthening of regional agricultural markets exploiting opportunities for greater regional cooperation and harmonization, diversification of traditional markets, and enhancement of linkages between agricultural and nonagricultural sectors.

Our subsector analysis strongly indicates that West African countries sharing similar agro-ecological conditions could greatly benefit by pooling resources to find common solutions regarding technology adaptation and diffusion. According to the ranking of priority activities, there is scope for greater regional cooperation in research and extension given the extent to which technologies and farming practices are applicable across national boundaries, leading to the greater likelihood of widespread adoption and impact in the region. Increased growth in the production of commodities in the list of regional priorities can be accomplished through a wider and more effective dissemination across country borders of the existing stock of knowledge and technologies associated with improving agronomic practices, adopting stress-resistant crop varieties, and appropriately using chemicals for pest, disease, and weed control. Expanding investment in adaptive research and extension services and increasing the efficiency of these activities investing at a regional scale is therefore going to be critical.

Regional markets would play a strategic role in expanding demand opportunities for producers of staple crops and livestock in different countries, facilitating subregional production specialization and contributing to export diversification. West Africa as a whole is a net importer of cereals and livestock products, and our analysis shows that if agricultural productivity growth is further supported by improved policies and market conditions, trade of these products are projected to increase in the region. These changes would likely result in the substitution of global imports with intraregional trade and could contribute to diversifying agricultural exports of some West African countries. The creation of such trade, and its diversification, would help agricultural growth and could also reduce the risk from concentrating on a very small number of agricultural export commodities.

Finally, a regional strategy to promote agricultural growth will need to enhance linkages between agricultural and nonagricultural sectors. In areas where transport costs and other structural factors prevent local economies from reaching outside sources of demand for local products, the strongest links between agricultural and nonagricultural sectors spring from the production and consumption of nontradable commodities. These areas would play an important role in the expansion of production of rice and coarse grains given that higher growth potential for these crops is in areas with low market access and low population density. In these areas, availability of processing technologies and improved varieties suited for feed appear to be important to strengthening links between production and consumption, complementing increased productivity in grain production. In areas with good market access, the priority will be to develop or improve links between agricultural production and agroindustries (e.g., for processed foods, feed, and intermediate products). Three related sets of measures would be needed over time: first, the growth of agroprocessing, distribution, and farm-input provisions off-farm; second, institutional and organizational adjustments in relations among agroindustrial firms and farms such as greater vertical integration (this may involve producer organizations, cooperatives, and contract farming); and third, concomitant changes in product composition, technology, and sectoral and market structures. An example of a crop with the possibility of expanding in areas with good market access is cassava in coastal countries. Due to its short shelf life, better processing technologies, improved varieties (for agroindustry and biofuel), and the development of links to agroindustries will be critical to improving overall productivity of this crop to compete in regional and international markets.

APPENDICES

Appendix A. Development Domains

Using available information on agro-ecological conditions, population, and distance to markets, we define unique "development domains" as geographic areas that are similarly endowed in these three attributes. Figure A.1 illustrates the resulting development domains for West Africa based on the intersection of agricultural potential, population density, and market access. Three levels for each of these three factors (high, medium, and low) are combined and result—in the case of West Africa—in 27 domains. Domains are classified by their high or low status in the sequence as shown in Figure A.1.[15] Domains straddle national and subnational boundaries, delimiting areas where development conditions and potential for a particular crop are similar.

Length of growing period is used as a basis for classifying areas by high, medium, and low agricultural potential. The availability of water—be it from rainfall, local groundwater or surface water use, or formal irrigation schemes—is generally the most binding of constraints and determines the most prominent agro-ecological zones in West Africa: humid, semihumid, semiarid, and arid zones. Humid and semihumid zones are defined as the regions with high agricultural potential, while medium and low potential regions correspond to semiarid and arid zones, respectively. In general, humidity in the region increases from north to south, and this can be seen in the map in Figure A.1 as three broad west-east swathes corresponding to arid, semiarid, and semihumid/humid zones, captured, respectively, as groups of domains with low, medium, and high agricultural potential. While zones of medium and high agricultural potential are suitable for agriculture growth, zones of low agricultural potential (mostly the arid zone of the Sahel) have very limited rainfall and little vegetation coverage and are hence used primarily for livestock herding.

West Africa's sizable humid and subhumid agroclimatic zones are found mainly within the coastal and central regions where forest-based farming systems and tree crop farming systems are prevalent. The coastal region concentrates 41 percent of total West African production compared to only 9 and 8 percent in the Sahel and central regions, respectively. West Africa's most common tree crops (cocoa and coffee) are predominant here. Fruits and vegetables, root crops including yams and cassava, and mixed farming systems, including crop-livestock and cereal–root crop systems, are also very common. The semiarid agroclimatic zone is predominantly found in the Sahel as well as the central subregions of West Africa. This zone has a limited growing season, but its environment is more conducive to agriculture. Here, traditional coarse grains and cereals, crop-livestock systems, and cereal–root crop systems dominate.

High population density16 in West Africa follows strict patterns, represented as —/high/— domains in Figure A.1. The most densely populated areas are found primarily in the coastal areas (0.73 people per hectare of total area), along the Niger River, and in the Great Lakes region on the eastern Democratic Republic of the Congo border. Population densities tend to be quite low in much of the Sahelian region, as well as in the forested areas of Central Africa (0.36 and 0.15 people per hectare of total area in the Sahel and central regions, respectively).

To define access to markets in different regions, this study focuses on a simplified set of criteria that reflect the physical accessibility (expressed in terms of expected travel times) to a range of markets (identified as towns/cities of different sizes for domestic markets, and major ports for export markets).[17]

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[15] For instance, "high/high/high" denotes high agricultural potential, high market access, and high population density. When referring to all domains with high agricultural potential we will use the following notation: high/—/—. Similarly for all domains with low population density or medium market access we will use —/low/— and —/—/medium, respectively.

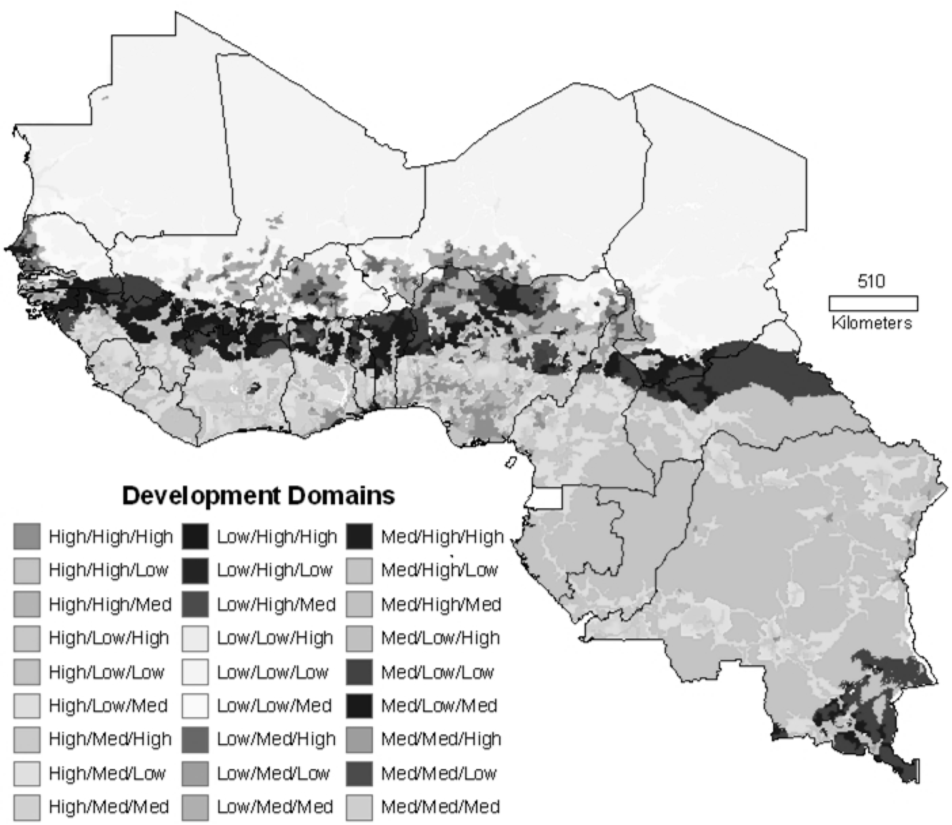
[16] Population densities are assumed to be high at densities of 100 per square kilometer or greater, medium at 20 to 100, and low at less than 20.

[17] Markets within four hours' travel of major seaports or large cities of 500,000 or more inhabitants (for international trade routes), within two hours of towns of 100,000 or more, or within one hour of towns of 10,000 or more are considered high-access

Although several distinct types of markets may be identified, here we characterize access based on travel time to a variety of locations with different economic implications. In general, the Sahelian and Central African countries have the largest areas of low access while the West African coastal countries have the broadest high-access conditions. Still, no area is predominantly or uniformly characterized by high access.

The importance of the different domains by country is shown in Tables A.1 through A.4. The largest individual domain is the one with low agricultural potential, low population density, and low markets access, 37 percent of West Africa's land area. Areas with high agricultural potential and high market access account for only 2 percent of the land area but include more than 8 percent of cropland and almost 20 percent of the rural population. Enormous portions of the region are economically underutilized. The low-access, low-density areas of the Sahelian and Central African forest areas together account for almost 60 percent of the total area. Even if these areas are fundamentally more limited, exploring sustainable or nonextractive uses of these resources should be a part of a regional development strategy.

Figure A.1. Development domains for West and Central Africa



Source: Authors' calculations.
Note: Med = medium.

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areas. Areas of medium access are those within six hours of large cities, within four hours of large towns, or within two hours of smaller towns. Other locations are considered low–access areas.

Table A.1. Land area shares by country and development domain

Domain	Benin	Burkina Faso	Came-roon	CAR	Chad	Congo	Gabon	Gambia	Ghana	Guinea	Guinea-Bissau	Ivory Coast	Liberia	Mali	Mauri-ttania	Niger	Nigeria	Senegal	Sierra Leone	Togo	Zaire	WCA Total
High/High/High	3%		1%						5%								7%		3%	1%		1%
High/High/Med	3%		1%						4%				2%				6%		1%	1%	1%	1%
High/High/Low													3%				2%				1%	
High Med/High	2%		3%			1%			5%	5%		10%					5%		20%	10%	1%	1%
High/Med/Med	4%		2%						17%	6%		21%	2%				9%		27%	19%	5%	3%
High/Med/Low	3%		1%			1%			13%	1%		5%	2%				3%			5%	4%	2%
High/Low/High	1%		8%	2%		4%	3%			10%		5%	18%				1%		8%		3%	2%
High/Low/Med	2%		33%	14%		8%	10%		9%	20%		22%	35%				2%		42%	4%	13%	7%
High/Low/Low	1%		32%	46%		86%	87%		11%	1%		15%	37%				3%			4%	64%	22%
Med/High/High	1%	1%							2%								2%			3%		
Med/High/Med									1%								2%			3%		
Med/High/Low																						
Med/Med/High			1%						2%		18%	1%					2%	1%		3%		
Med/Med/Med	5%	3%	3%		1%				8%	1%	9%	1%		1%			11%	2%		14%		2%
Med/Med/Low	2%								1%	5%							5%			3%		1%
Med/Low/High	5%	1%							2%	13%	16%	1%		1%			1%			1%	1%	1%
Med/Low/Med	40%	11%	3%	4%	3%				14%	31%	50%	11%		3%			4%	7%		20%	2%	4%
Med/Low/Low	17%	2%	5%	30%	2%				5%	7%	5%	8%		2%			3%	5%		11%	6%	5%
Low/High/High		2%						4%									3%	4%				
Low/High/Med		1%															7%	1%				1%
Low/High/Low																						
Low/Med/High		9%	3%					20%						1%		2%	2%	7%				1%
Low/Med/Med		24%	4%		1%			45%						3%		6%	10%	8%				3%
Low/Med/Low		4%												1%		1%	1%					
Low/Low/High		3%			1%			6%						2%	1%	1%	2%	4%				1%
Low/Low/Med	3%	24%			7%			26%			1%			10%	5%	7%	5%	31%				5%
Low/Low/Low	7%	15%		5%	83%									77%	94%	82%	2%	29%				37%
country total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

A Source: Authors' calculations.
Note: CAR = Central African Republic; WCA = West and Central Africa; Med = medium.

Table A.2. Rural population shares by country and development domain

Domain	Benin	Burkina Faso	Came-roon	CAR	Chad	Congo	Gabon	Gambia	Ghana	Guinea	Guinea-Bissau	Ivory Coast	Liberia	Mali	Mauri-tania	Niger	Nigeria	Senegal	Sierra Leone	Togo	Zaire	WCA total
High/High/High	18%		10%						17%	2%							17%		12%	1%	3%	9%
High/High/Med	17%		8%						9%			1%	16%				13%		3%	2%	7%	8%
High/High/Low			1%						1%				26%				3%				5%	2%
High Med/High	4%		7%			9%			9%	9%		18%	1%				3%		26%	12%	5%	5%
High/Med/Med	6%		6%			7%			20%	15%		37%	4%				7%		35%	22%	15%	10%
High/Med/Low	4%		2%			7%			12%	1%		8%	3%				2%			4%	12%	4%
High/Low/High			5%	6%		18%	1%			9%		4%	14%						4%		2%	2%
High/Low/Med	1%		16%	28%		13%	17%		3%	16%		15%	20%				1%		20%	2%	10%	5%
High/Low/Low			9%	49%		47%	81%		5%	1%		7%	17%				1%			2%	35%	9%
Med/High/High	8%	3%							5%	2%							3%	1%		8%		2%
Med/High/Med	3%	1%							3%								3%			8%		2%
Med/High/Low																						
Med/Med/High		1%	7%		1%				2%	1%	35%	1%		3%			1%	3%		3%		1%
Med/Med/Med	7%	4%	8%		11%				7%	1%	16%	1%		3%			8%	5%		17%		5%
Med/Med/Low	2%				3%				1%	6%							3%			4%		2%
Med/Low/High	3%	1%			1%				1%	14%	17%	1%		2%								1%
Med/Low/Med	17%	5%	1%	6%	11%				4%	18%	26%	5%		9%			1%	4%		9%	1%	3%
Med/Low/Low	6%	1%	1%	11%	6%				1%	4%	4%	3%		3%			1%	1%		6%	3%	2%
Low/High/High		7%						8%								1%	8%	23%				4%
Low/High/Med		3%														8%	13%	4%				5%
Low/High/Low																						
Low/Med/High		15%	8%		2%			23%			1%			6%		13%	1%	17%				3%
Low/Med/Med		34%	11%		15%			51%						19%		46%	7%	15%				9%
Low/Med/Low		4%												8%	3%	4%	1%					1%
Low/Low/High		1%			2%			2%						5%	7%	3%		3%				1%
Low/Low/Med	1%	13%			15%			15%			2%			19%	19%	13%	1%	16%				3%
Low/Low/Low	2%	6%			35%									24%	70%	13%		8%				4%
country total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Source: Authors' calculations, based on population distribution data from Center for International Earth Science Information Network, Columbia University; International Food Policy Research Institute; the World Bank; and Centro Internacional de la Agricultura Tropical (2005).
Note: CAR = Central African Republic; WCA = West and Central Africa]; Med = medium.

Table A.3. Cropland area shares by country and development domain

Domain	Benin	Burkina Faso	Came-roon	CAR	Chad	Congo	Gabon	Gambia	Ghana	Guinea	Guinea-Bissau	Ivory Coast	Liberia	Mali	Mauri-tania	Niger	Nigeria	Senegal	Sierra Leone	Togo	Zaire	WCA total
High/High/High	1%					66%			3%	5%		10%					4%		1%	12%	1%	7%
High/High/Med	1%		1%																15%	11%	12%	1%
High/High/Low									3%													
High Med/High	7%		69%			17%			2%			1%	4%						2%		17%	14%
High/Med/Med	2%		1%						42%	3%		6%					2%		32%	1%	16%	4%
High/Med/Low										10%		7%	24%							15%	6%	2%
High/Low/High	1%		9%				7%			4%		36%	12%				2%		2%		23%	6%
High/Low/Med			5%	7%		14%	62%		14%	12%		10%	12%				2%				11%	5%
High/Low/Low	22%			3%		3%	27%		12%	1%		23%	9%						1%	18%		3%
Med/High/High									2%	18%										6%		1%
Med/High/Med	1%								4%											3%		
Med/High/Low																	1%					
Med/Med/High	5%				1%				1%	3%	12%							2%		1%		1%
Med/Med/Med	1%				12%				3%	5%	1%	1%					1%	2%		1%		1%
Med/Med/Low	5%		11%		2%				2%	1%										14%		2%
Med/Low/High					7%					9%	6%									2%		1%
Med/Low/Med	12%	1%		4%	5%					23%	9%		37%	2%				1%		5%	11%	4%
Med/Low/Low	37%	8%		78%						4%	36%	5%		2%						10%	1%	4%
Low/High/High		6%						11%	5%								16%	18%				4%
Low/High/Med		1%														3%	27%	3%			2%	4%
Low/High/Low																	1%					
Low/Med/High		23%	2%					45%	6%		22%			4%		11%	4%	21%				5%
Low/Med/Med		33%	1%		1%			19%						14%		41%	21%	15%				9%
Low/Med/Low		3%			15%					2%				5%			2%					2%
Low/Low/High		2%			3%			7%			13%			5%	2%	9%	5%	5%	48%			3%
Low/Low/Med	2%	18%						18%			1%		2%	36%	77%	25%	9%	20%				8%
Low/Low/Low	2%	4%		8%	43%		4%							33%	21%	10%	1%	13%				7%
country total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Source: Authors' calculations, based on crop and pasture distribution data from Centre for Sustainability and the Global Environment (2004).
Note: CAR = Central African Republic; WCA = West and Central Africa; Med = medium.

Table A.4. Pasture area shares by country and development domain

Domain	Benin	Burkina Faso	Came-roon	CAR	Chad	Congo	Gabon	Gambia	Ghana	Guinea	Guinea -Bissau	Ivory Coast	Liberia	Mali	Mauri-tania	Niger	Nigeria	Senegal	Sierra Leone	Togo	Zaire	WCA total
High/High/High			1%			63%			14%	6%		4%					2%			4%		3%
High/High/Med			1%														5%		13%	1%	26%	2%
High/High/Low			1%						1%								1%					
High Med/High	10%		57%			14%			3%			1%	28%				2%		4%		5%	6%
High/Med/Med	1%		1%						15%	3%		6%					6%		57%	3%	32%	4%
High/Med/Low	1%					2%				11%		14%	13%				2%			4%	5%	2%
High/Low/High	1%		6%			1%	5%			15%		13%	27%				5%		3%		12%	4%
High/Low/Med			5%	6%		9%	79%		18%	2%		12%	3%				4%		3%	1%	8%	3%
High/Low/Low	4%			3%		10%	14%		7%			26%	3%				1%			11%		2%
Med/High/High		1%							1%	18%										3%	1%	1%
Med/High/Med		1%							15%											14%		1%
Med/High/Low																	1%					
Med/Med/High	34%	1%							4%		3%	1%					1%			2%		2%
Med/Med/Med	2%		5%		7%				6%	9%	2%	3%		1%			3%	2%		6%	2%	3%
Med/Med/Low	13%	1%	11%		1%				5%	7%										26%		3%
Med/Low/High	1%		1%		1%					8%	3%	1%								2%		1%
Med/Low/Med	3%	6%	1%	1%	4%					15%	7%	2%	22%	4%			1%	3%		10%	5%	4%
Med/Low/Low	21%	5%	1%	81%						3%	9%	17%		2%				2%		13%		4%
Low/High/High		2%						4%	8%								8%	5%				1%
Low/High/Med		1%														1%	15%	1%			4%	2%
Low/High/Low																						
Low/Med/High		10%	3%					20%	2%		59%			1%		4%	4%	9%				3%
Low/Med/Med		26%	4%					43%						5%		14%	23%	9%				6%
Low/Med/Low		4%			2%									3%		1%	2%					1%
Low/Low/High		3%			2%			8%			16%			3%	1%	3%	4%	4%	20%			2%
Low/Low/Med	2%	25%			14%			25%					2%	15%	15%	16%	7%	33%				9%
Low/Low/Low	4%	14%	2%	9%	67%		2%							66%	84%	61%	3%	33%				29%
country total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Source: Authors' calculations, based on crop and pasture distribution data from SAGE (2002).
Note: CAR = Central African Republic; WCA = West and Central Africa]; Med = medium

Appendix B. Economy-wide, Multimarket Modeling

B.1 Crops

Supply functions:

Yield function (for crops)

$Y^{q}_{R,Z,i,t} = \mathrm{YA}^{q}_{\mathrm{R,Z,i,t}} P^{\alpha^{q}_{R,Z,i}}_{R,Z,i,t}$,

where $Y^{q}_{R,Z,i,t}$ is the yield for crop *i* with technology *q* in region *R* and zone *Z*, $P_{R,Z,i}$ is the producer price for *i,* and $YA^{q}_{R,Z,i,t}$ is the productivity shift parameter, which varies according to different technologies, *q*. $YA^{q}_{R,Z,i,t}$ can be estimated as a function of modern inputs such as irrigation, fertilizer, and improved seed, if more data were available. At this moment, the model captures only the different levels (i.e., average, not marginal, effect of modern inputs) of yield across technologies. There are in total 15 different technologies for major crops (mainly cereal crops), which implies that there are 15 yield functions for a crop, for example, maize, characterized by the different level of $YA^{q}_{R,Z,i,t}$. $YA^{q}_{R,Z,i,t}$ also changes over time:

$\mathrm{YA}^{q}_{R,Z,i,t+1} = \mathrm{YA}^{r}_{\mathrm{R,Z,i,t}} (1 + g_{Y_{R,Z,i}})$,

where $g_{Y_{R,Z,i}}$ is the annual productivity growth rate in yield.

Area function (for crops)

$A^{q}_{R,Z,i,t} = \mathrm{AA}^{q}_{\mathrm{R,Z,i,t}} \prod_{j} P^{\beta_{R,Z,j}}_{R,Z,j,t}$, , and $\sum_{j}^{J} \beta_{R,Z,j} = 0$

where $A^{q}_{R,Z,i,t}$ is the area for crop *i* with technology *q,* and $P_1, P_2, \ldots P_J$ is the vector of producer prices and $AA^{q}_{R,Z,i,t}$ is the shift parameter. The area expansion is captured in the $AA^{q}_{R,Z,i,t}$:

$\mathrm{AA}^{q}_{R,Z,i,t+1} = \mathrm{AA}^{\mathrm{q}}_{\mathrm{R,Z,i,t}} \left(1 + g_{A_{R,Z,i}}\right)$,

where $g_{A_{R,Z,i}}$ is the annual area expansion rate for crop *i* with technology *q*. Given most prices are endogenous in the model, area functions, similar as the supply functions for noncrop production, are used to capture cross-sector linkages among crops, between crops and noncrop agriculture (such as livestock), and between agriculture and nonagriculture.

Total supply of crops

$S_{R,Z,i,t} = \sum_{q} Y^{q}_{R,Z,i,t} \cdot A^{q}_{R,Z,i,t}$.

Supply function for fish, other meat, and nonagricultural sectors

$S^{NA}_{R,Z,i,t} = \mathrm{SA}^{\mathrm{NA}}_{\mathrm{R,Z,i,t}} \prod_{j} P^{\beta^{LV}_{R,Z,j}}_{R,Z,j,t}$.

Trends in the nonagricultural supply function are

$\mathrm{SA}^{\mathrm{NA}}_{\mathrm{R,Z,i,t+1}} = \mathrm{SA}^{\mathrm{NA}}_{\mathrm{R,Z,i,t}} ,(1 + g_{S_{R,Z,i}})$,

where $g_{S_{R,Z,i}}$ is the annual growth rate in the livestock and nonagricultural productivity and varies by zone and commodity.
g_Y, g_A, and g_S are exogenous variables in the model and are affected by the investment shocks in the scenarios.

B.2 Livestock

Yields

$$Y_{R,Z,i,t}^{qLV} = \mathrm{YA}_{\mathrm{R,Z,i,t}}^{qLV} P_{R,Z,i,t}^{\alpha_{R,Z,i}^{qLV}},$$

where $Y_{R,Z,i,t}^{qLV}$ is the yield for livestock production *i* with technology *qLV* in region *R* and zone *Z, $P_{R,Z,i}$* is the producer price for *i,* and $YA_{R,Z,i,t}^{qLV}$ is the productivity shift parameter, which varies according to different technologies, *qLV.* Two technologies are considered for each livestock production: "traditional technology" and "improved technology." Yield obtained with traditional technologies is defined using current production and animal stock numbers. Yields obtained with improved technology are from Fernandez-Rivera, Okike, and Ehui (2003). In the case of beef production, a third technology/production system is considered: production from draught animals, which has a lower yield than that in traditional technology.

Yields also change over time:

$$\mathrm{YA}_{R,Z,i,t+1}^{qLV} = \mathrm{YA}_{\mathrm{R,Z,i,t}}^{r}(1 + g_{Y_{R,Z,i}}),$$

where $g_{Y_{R,Z,i}}$ is the annual productivity growth rate in yield.

Number of animals

$$A_{R,Z,i,t}^{qLV} = \mathrm{AA}_{\mathrm{R,Z,i,t}}^{qLV} \prod_c \left(F_{R,Z,c,i,t}\right)^{\gamma_{R,Z,c,i}^{qLV}} \prod_j P_{R,Z,j,t}^{\beta_{R,Z,j}}, \text{ and } \sum_j^J \beta_{R,Z,j} = 0,$$

where $A_{R,Z,i,t}^{qLV}$ is the number of animals producing livestock product *i* (e.g., milk) with technology *qLV,* $F_{R,Z,c,i,t}$ is demand for crop *c* as feed by livestock activity *i* produced with technology *qLV, P_1, P_2, … P_J* is the vector of producer prices of the different livestock products, and $AA_{R,Z,i,t}^{q}$ is the shift parameter.

Growth of animal stock is captured in the $AA_{R,Z,i,t}^{qLV}$:

$$AA_{R,Z_{i,t+1}}^{qLV} = AA_{R,Z_{i,t}}^{qLV}\,(1 + g_{A_{R,Zi}})$$

where $g_{A_{R,Z,i}}$ is the annual expansion rate of number of animals producing *i* with technology *qLV.*

The total number of animals producing *i* results from adding the number of animals producing *i* with different technologies:

$$A_{R,Z,i,t} = \sum_{qLV} \mathrm{A}_{\mathrm{R,Z,i,t}}^{qLV}.$$

Output

Total output of livestock products produced with different technologies is the result of

$$S^{qLV}_{R,Z,i,t} = \Upsilon^{qLV}_{\mathrm{R,Z,i,t}} A^{qLV}_{R,Z,i,t}.$$

Supply of livestock product *i* in *R* and *Z* is derived by adding output produced using different technologies:

$$S_{R,Z,i,t} = \sum_{qLV} \mathrm{S}^{qLV}_{\mathrm{R,Z,i,t}}.$$

Feed demand

Feed demand is defined as a function of crop production and prices of feed crops:

$$F^{qLV}_{R,Z,i,t} = \mathrm{FA}^{qLV}_{\mathrm{R,Z,i,t}} \left(S_{R,Z,c,t}\right)^{\lambda^{qLV}_{R,Z,c,i}} \prod\nolimits_c \left(P_{R,Z,c}\right)^{\nu^{qLV}_{R,Z,c,i}},$$

where $\lambda^{qLV}_{R,Z,c,i}$ and $\nu^{qLV}_{R,Z,c,i}$ are elasticities regulating the response in terms of feed demand of different livestock productions and technologies to changes in crop production and prices, respectively.

B.3 Demand Functions

Zonal-level per capita demand is a function of prices and income:

$$Dpc_{R,Z,i,t} = \prod\nolimits_j PC^{\varepsilon_{R,Z,i,j}}_{R,Z,j,t} \, GDPpc^{\varepsilon^I_{R,Z,i}}_{R,Z,t},$$

where $Dpc_{R,Z,i}$ is per capita demand for commodity *i* in region *R* and zone *Z* and $PC_{R,Z,i}$ is consumer price for *i* in region *R* and zone *Z*. *j* = 1, 2, …, 36 (including two aggregate nonagricultural goods). $GDPpc_{R,Z}$ is per capita rural or urban income for region *R* and zone *Z*, $\varepsilon_{R,Z,i,j}$ is price elasticity between demand for commodity *i* and price for commodity *j*, and $\varepsilon^I_{R,Z,i}$ is income elasticity, such that

$\sum_j^J \varepsilon_{R,Z,i,j} + \varepsilon^I_{R,Z,i} = 0$ and $\sum_j^J sh_{R,Z,j} \cdot \varepsilon^I_{R,Z,j} = 1,$ where $sh_{R,Z,i}$ is expenditure share of commodity *i*.

B.4 Relationship between Producer and Consumer Prices

We assume that import and export parity prices are the border prices adjusted by trade margin. There exist national market prices, represented by the prices in the Addis Ababa market, and zonal-level prices, which are higher in the food deficit area and lower in the food surplus area compared with the national market prices. The farther the zone from the nearest major market centers, the lower are the prices. The difference between zonal-level prices and the prices at the national markets is defined as regional market margins. Specifically, for importable commodities, there is the following relationship between import parity prices and consumer prices in the national markets:

$$PC^{Addis}_{i,t} = \left(1 + Wm_i\right) \cdot PWM_i,$$

where Wm_i is the trade margin between cost, insurance and freight (CIF) prices, PWM_i, and consumer prices, PC_i, in the national markets when commodity *i* is importable. The relationship between zonal-level and national market prices (for consumer prices) is as follows:

$$PC_{R,Z,i,t} = \left(1 + Dgap_{R,Z,i}\right) \cdot PC^{Addis}_{i,t},$$

and $Dgap_{R,Z,i}$ is negative if *Z* is in the food surplus area and positive if *Z* is in the food deficit area.

The national market prices and export parity prices for exportable commodities have the following relationship:

$$P_{i,t}^{Addis} = \left(1 - Wm_i\right) \cdot PWE_i$$

where P is producer prices and PWE is free on board (FOB) prices; the equation holds only when commodity i is exportable.

Consumer and producer prices are not necessary the same, such that $PC_{R,Z,i,t} = \left(1 + Dm_{R,Z,i}\right) \cdot P_{R,Z,i,t}$, and Dm is the margin between consumer and producer prices.

There is the following relationship between domestic market and import/export parity prices for nontradable commodities: $(1 - Wm_i) \cdot PWE_i < P_{i,t}^{Addis} \leq PC_{i,t}^{Addis} < \left(1 + Wm_i\right) \cdot PWM_i$.

B.5 Exports and Imports

Trade (either exports or imports) is determined by the difference between national market prices and import/export parity prices, that is, if $P_{i,t}^{Addis} = \left(1 - Wm_i\right) \cdot PWE_i,\ E_{i,t} > 0$; otherwise, $E_{i,t} = 0$. E_i is exports of commodity *i;* and if $PC_{i,t}^{Addis} = \left(1 + Wm\arg in_i\right) \cdot PWM_i,\ M_{i,t} > 0$; otherwise, $M_{i,t} = 0$. M_i is imports of commodity *i.*

Notice that E_i and M_i can be zero in the early periods in the model, and hence the prices for nontraded goods are endogenously determined and can either rise or fall over time (but not the border prices). If PC rises over time due to demand's increasing faster than increased supply, PC_i starts to approach $(1 + Wm_i)PWM_i$. Once $PC_i = (1 + Wm_i)PWM_i$, imports occur for commodity *i,* and PC is linked to PWM, which is exogenous. A similar but opposite situation holds for P_i, that is, if P falls over time such that $P_i = (1 - Wm_i)PWE_i$, exports occur, and P is linked to PWE.

B.6 Regional Crop Deficit and Surplus

The model can identify which zones have food deficits or surpluses but cannot identify trade flows among the zones. That is, total deficits and surpluses are cleared (balanced) at the national market, and there is no regional differential market. A crop i is in the deficit (surplus) zone if $DEF_{R,Z,i,t} = Dpc_{R,Z,i,t} \cdot PoP_{R,Z,t} - S_{R,Z,i,t}$ is positive (negative).

B.7 Balance of Demand and Supply at the National Level

$$\textstyle\sum_{R,Z} S_{R,Z,i,t} + M_{i,t} - E_{i,t} = \sum_{R,Z} Dpc_{R,Z,i,t} \cdot PoP_{R,Z}\ .$$

This equation solves for the price for commodity i if both M and E are zero. Otherwise, it solves for the value of M or E.

B.8 GDP and Per Capita Zonal Income Function

Income in the model is endogenous and is determined by production revenues. Given that the model does not explicitly include input and hence the costs of input, the prices for agricultural commodities are adjusted such that the sector production revenues are close to the value added of this sector.

$$GDP_{R,Z,t} = \textstyle\sum_j P_{R,Z,j,t} \cdot S_{R,Z,j,t}\ \text{(sectors including nonagriculture)}.$$

Income per capita is calculated as follows:

$$GDPpc_{R,Z,t} = \frac{GDP_{R,Z,t}}{PoP_{R,Z,t}}.$$

B.9 Poverty Population and Poverty Rate

Household data are linked to the per capita income solved from the model such that the model can calculate the poverty population and poverty rate for rural, urban, and the national average. Given zonal-level income distribution, share of each household group (represented by the sample household weighted by the sample size, taking into account the sample household size) is constant and is linked to zonal-level rural or urban total income, which is endogenously solved in the model. The poverty-line income is constant but different between rural and urban (and hence, the income used in the poverty analysis is in real terms). The new poverty population for either rural or urban or at a specific subnational level is obtained by comparing the newly solved income (per capita) for each time period from the model to the constant poverty line. The poverty rate is the ratio of the new poverty population (rural or urban) over total population (rural or urban) updated with an exogenous population growth.

Specifically, let $PoorInc_t^{rur}$ be poverty-line income (per capita) for rural, $GDP_{R,Z,t}^{rur}$ be total rural income in region *R* and zone *Z* at time *t,* $Sh_{R,Z,h}^{rur}$ be income share for rural household group *h* in region *R* and zone *Z,* and population $Pop_{R,Z,h,t}^{rur}$ of household group *h* equal the sample weights multiplied by the household size represented by the sample household for group *h,* updated with population growth rate. The household group *h*'s income is defined as

$$I_{R,Z,h,t}^{rur} = Sh_{R,Z,h}^{rur} \cdot GDP_{R,Z,t}^{rur}; \sum_h Sh_{R,Z,h}^{rur} = 1$$

Per capita income in this household group is

$$Ipc_{R,Z,h,t}^{rur} = \frac{I_{R,Z,h,t}^{rur}}{Pop_{R,Z,h,t}^{rur}}.$$

Whether the population in the group *h* is included in or excluded from the poverty population is according to the following condition:

$Pop_{R,Z,h,t}^{rur}$ is in the poverty population if $Ipc_{R,Z,h,t}^{rur} < PoorInc_t^{rur}$.

Notice that since the available information about income is by household group represented by the sample household, we cannot separately estimate poverty situation within each group. That is, if $Ipc_{R,Z,h,t}^{rur} < PoorInc_t^{rur}$, all the population within the group *h* is defined as poverty population, similar for $Ipc_{R,Z,h,t}^{rur} \geq PoorInc_t^{rur}$.

The total poverty population in rural is the sum of $Pop_{R,Z,h,t}^{rur}$ over *h* for all *h* with $Ipc_{R,Z,h,t}^{rur} < PoorInc_t^{rur}$. The poverty rate is calculated by the ratio of this number over total rural population. We can define urban poverty population and poverty rate using a similar method. As poverty population is defined at the household group level, we can easily calculate poverty rate at a specific subnational level, for example, for the food deficit area or at the national level.

Appendix C. Crops, Vegetable Products and Livestock Production Activities Included in the Economy-wide, Multimarket and Dynamic Research Evaluation for Management Models

Following is the list of agricultural activities for which the contribution to growth is measured through simulation of the reduction of the productivity gap in different agro-ecologic environments in West Africa.

Cereals
Maize
Rice
Wheat
Sorghum
Barley
Millet
Other Cereals

Roots & Tubers
Cassava
Potatoes
Sweet Potatoes
Yams
Other Roots

Pulses
Beans
Other Pulses

Oil crops
Groundnut
Soybean
Other Oil Crops

Fruits and Vegetables
Vegetables for Domestic
Vegetables for Exports
Fruits for Domestic
Fruits for Exports
Banana

Export crops and products
Sugar Crops
Cocoa
Coffee
Cotton
Tree Nuts
Rubber
Tea
Vegetable Oil
Oil Palm

Livestock
Cattle
Goat
Bovine Meat
Mutton Meat
Other Meats
Milk
Poultry/Eggs
Fish

Forestry

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