

**NIGERIA**

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**O**ur purpose in this chapter is to help policymakers and researchers better understand and anticipate the likely impacts of climate change on agriculture and on vulnerable households in Nigeria. We do this by reviewing current data on agriculture and economic development, modeling anticipated changes in climate between now and 2050, using crop models to assess the impact of climate change on agricultural production, and globally modeling supply and demand for food to predict food price trends.

Vulnerability to climate change is considered high in developing countries due to social, economic, and environmental conditions that amplify susceptibility to negative impacts and contribute to a low capacity to cope with and adapt to climate hazards. Because of the high level of vulnerability in developing countries, there is an urgent need to understand the threats from climate change that they face, formulate policies that mitigate the risks, and take necessary action. The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (Parry et al. 2007) observed that information about the impacts of climate change on important sectors and systems in developing countries such as agriculture, forestry, fisheries, water resources, human health, human settlements, and ecological systems is inadequate for understanding key vulnerabilities and planning appropriate adaptive strategies. It also observed that many developing countries have an inadequate capacity to systematically evaluate potential impacts and adaptation responses. One of the major reasons for lack of understanding of vulnerability is the lack of political will to prioritize the issues of climate change in policy formulation and implementation.

The agricultural sector in Nigeria has not been sufficiently productive to have a positive impact on the country's economy and has been associated with environmental degradation. Consequently, the country is experiencing mounting food deficits and declines in both gross domestic product (GDP) and export earnings, while retail food prices and import bills have been increasing. These problems could be further exacerbated by climate change if the nation's

agricultural policies do not incorporate issues aimed at understanding and mitigating the impact of climate change. There is therefore a need to establish agricultural strategies that promote political stability, self-reliance, public participation, sustained production, and environmental security.

The broad objectives of the nation's current agricultural policy enunciated in 2001 are the following:

- Achievement of self-sufficiency in basic food supply and the attainment of food security.
- Increased production of agricultural raw materials for industries.
- Increased production and processing of export crops using improved production and processing technologies.
- Generation of gainful employment.
- Rational use of agricultural resources; improved protection of agricultural land resources from drought, desert encroachment, soil erosion, and flood; and the general preservation of the environment for the sustainability of agricultural production.
- Promotion of the increased application of modern technology to agricultural production.
- Improvement in the quality of life of rural dwellers.

Resilience to climate change is crucial in attaining these objectives. Therefore, policy measures to mitigate the impact of climate change on Nigeria's agricultural sector should aim at understanding the impact of climate change on the nation's agricultural resource base.

Although the analysis in this chapter may show uncertainties about the impact of climate change, it can help those developing policies and actions to mitigate the outcomes of climate change for the livelihoods of vulnerable groups, particularly farmers. Policy measures on adaptation as suggested by NEST (2004) should aim to address the development or refinement of early warning systems to enable timely remedial measures and research into agricultural strategies.

## Review of the Current Situation and Trends

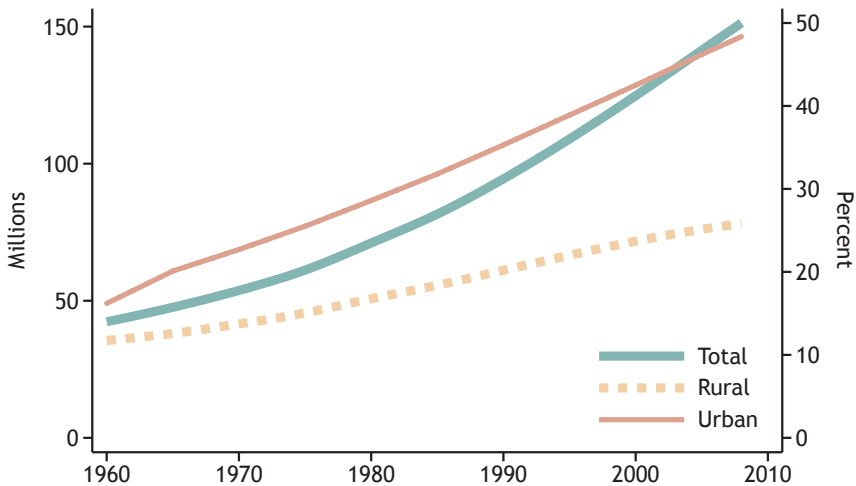
### Economic and Demographic Indicators

#### Population

Figure 10.1 shows the total and rural population counts (left axis) and the share of the urban population (right axis) in Nigeria. The rural population growth rate between 1960 and 2008 was lower than the urban population growth rate and declined to its lowest level during 2000–2008 (Table 10.1). The country has urbanized over time, as indicated by the population growth rate shown in Figure 10.1 and Table 10.1. Population growth in urban areas such as Lagos, Ibadan, Kano, and the Federal Capital Territory has been remarkable.

Figure 10.2 shows the geographic distribution of the population in Nigeria. The data are for 2000. The map shows high population densities in all of southern Nigeria, particularly Delta, Bayelsa, and parts of Edo States; the southeastern states of Anambra, Imo, Abia, Ebonyi, Rivers, and Akwa Ibom; and parts of the southwestern states of Ondo, Lagos, Ogun, Osun, and Ekiti.

**FIGURE 10.1** Population trends in Nigeria: Total population, rural population, and percent urban, 1960–2008

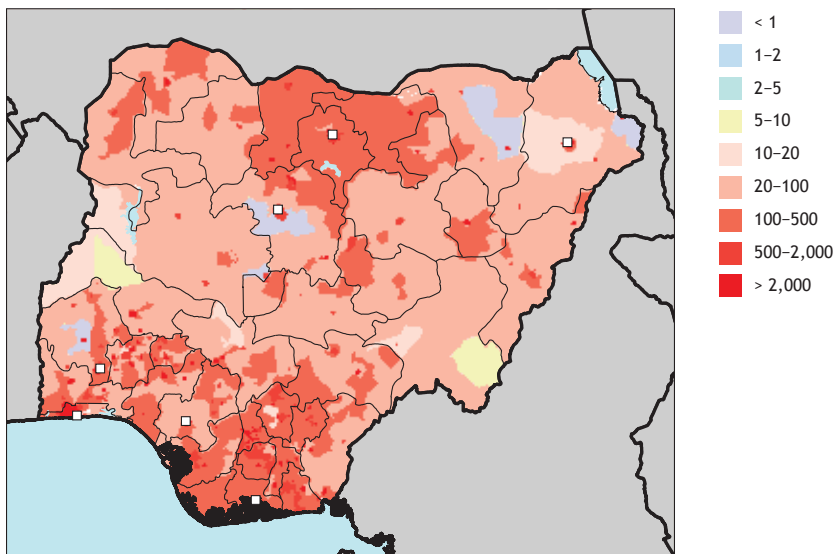


Source: World Development Indicators (World Bank 2009).

**TABLE 10.1** Population growth rates in Nigeria, 1960–2008 (percent)

Decade	Total growth rate	Rural growth rate	Urban growth rate
1960–69	2.4	1.5	5.9
1970–79	2.8	2.0	5.1
1980–89	2.8	1.9	4.9
1990–99	2.8	1.6	4.7
2000–2008	2.4	1.1	4.0

Source: Authors' calculations based on World Development Indicators (World Bank 2009).

**FIGURE 10.2** Population distribution in Nigeria, 2000 (persons per square kilometer)

Source: CIESIN et al. (2004).

Areas with high population densities in the central region include part of the Federal Capital Territory, Plateau, Benue, and Kogi States. The areas with high population densities in northern Nigeria are the north central states of Kaduna, Kano, Jigawa, and Katsina, as well as parts of Kebbi, Sokoto, and Gombe States.

### Income

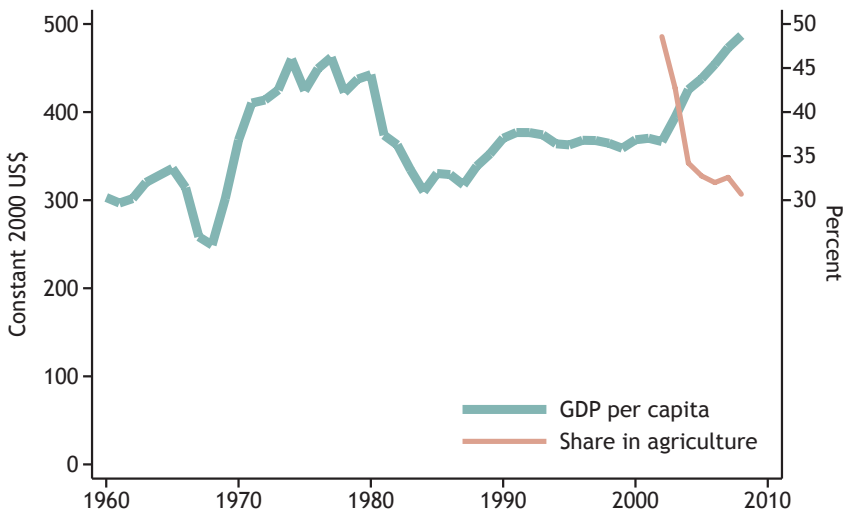
The Nigerian GDP per capita rose sharply from about US\$250 (US dollars) in the late 1960s to over US\$400 in the 1970s due to the oil revenue. However, the GDP per capita declined sharply with the structural adjustment programs

of 1980s, recovering slightly during the 1990s and increasing again sharply since 2000. The sharp increase in GDP coincided with a rapidly declining agricultural GDP, from about 50 percent in 2000 to about 30 percent toward the end of the decade, as shown in Figure 10.3. It is worth noting that the fall in agricultural GDP in itself does not reflect declining agricultural productivity but is in fact a consequence of the increasing value of other sectors of the economy.

### Vulnerability to Climate Change

Vulnerability has many dimensions. In this chapter the focus is on income, both level and sources, as we saw in the previous section and the data displayed in Figure 10.3. Table 10.2 provides some data on Nigeria's performance on additional indicators of vulnerability and resiliency to economic shocks: the level of education of the population, literacy, and the concentration of labor in the agricultural sector. The rate of enrollment in secondary school is low in Nigeria, whereas the rates of primary school enrollment and adult literacy are

**FIGURE 10.3** Per capita GDP in Nigeria (constant 2000 US\$) and share of GDP from agriculture (percent), 1960–2008



Source: World Development Indicators (World Bank 2009). Data on agricultural GDP for Nigeria were not available in the World Development Indicators prior to 2002.

Note: GDP = gross domestic product; US\$ = US dollars.

**TABLE 10.2** Education and labor statistics for Nigeria, 1980s and 2000s

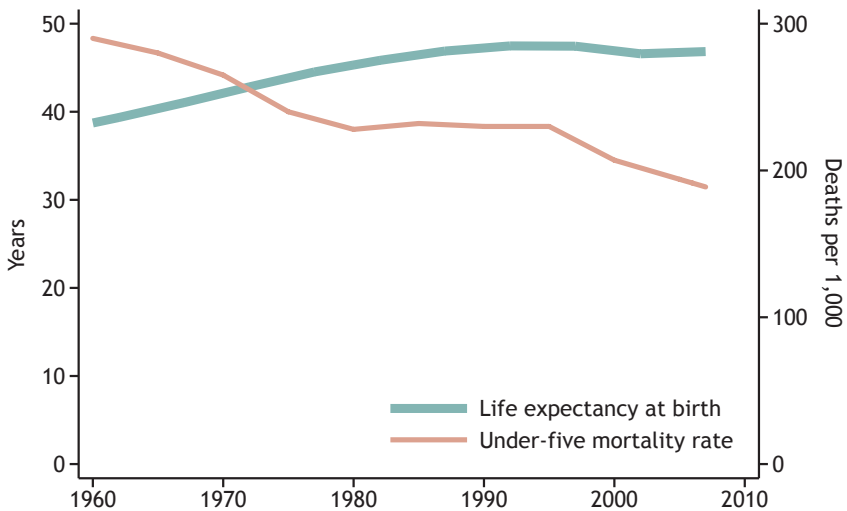
Indicator	Year	Percent
Primary school enrollment (percent gross, three-year average)	2006	96.7
Secondary school enrollment (percent gross, three-year average)	2006	31.9
Adult literacy rate	2007	72.0
Percent employed in agriculture	1986	46.8
Under-five malnutrition (weight for age)	2003	27.2

Source: Authors' calculations based on World Development Indicators (World Bank 2009).

relatively high. The percentage of the population employed in agriculture is lower than in many West African countries, suggesting that alternative livelihoods are available. Nigeria's rate of under-five malnutrition is also relatively lower than in many neighboring countries.

Figure 10.4 shows Nigeria's performance on two noneconomic correlates of poverty, life expectancy and under-five mortality. As shown in Figure 10.4, life expectancy at birth improved from 1960 to the late 1990s, then declined

**FIGURE 10.4** Well-being indicators in Nigeria, 1960–2008



Source: World Development Indicators (World Bank 2009).

**TABLE 10.3** Income distribution in Nigeria, 2004

Indicator	Measure
Gini coefficient (0 = perfect equality; 100 = perfect inequality)	42.9
Percent of total income earned by the richest 20 percent of the population	48.6
Percent of total income earned by the poorest 20 percent of the population	5.1
National poverty rate (percent)	54.7
Poverty rate, urban population (percent)	43.1
Percent of population living on less than US\$1.25 a day (PPP)	63.1
Percent of population living on less than US\$2.00 a day (PPP)	83.1

Source: World Bank (2012).

Notes: PPP = purchasing power parity; US\$ = US dollars.

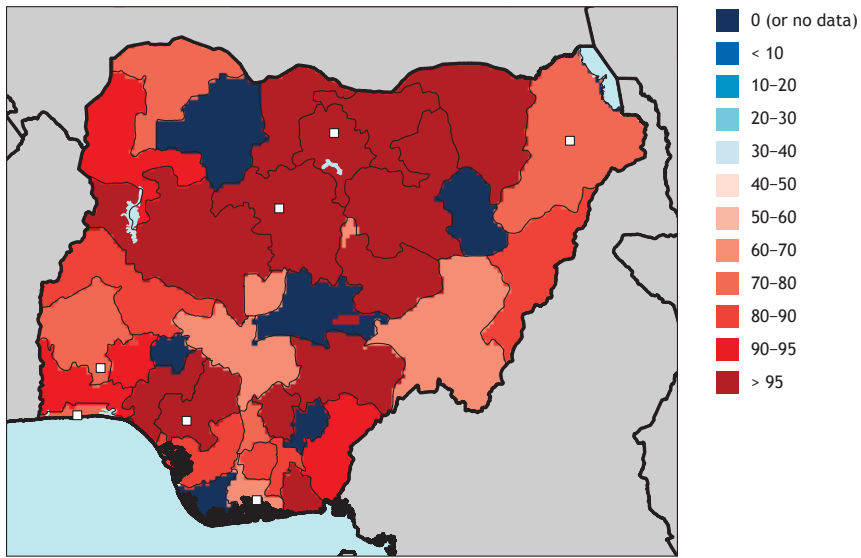
slightly. There was a solid decline in the under-five mortality rate between 1960 and 1980, a leveling off for about 15 years, and then a gradual decline. To sustain the country's drop in child mortality and improve life expectancy, policy measures should be developed that mitigate the vulnerabilities of all groups of the population to the drivers of all these indicators, including poverty and inadequate access to healthcare and food.

Table 10.3 presents some statistics related to income distribution in Nigeria. Income inequality is relatively high, as indicated by a Gini coefficient of 51, and the high level of poverty—with over 70 percent of the population living on less than US\$1 a day—despite a GDP per capita of around US\$500.

Given that the child malnutrition rate is also relatively high in Nigeria, special attention needs to be given to the most vulnerable in the country, particularly those who are food insecure. Circumstances that restrict the movement of food from surplus areas to deficit areas—for example, natural disasters such as flooding in Niger, Jigawa, Sokoto, and Kebbi States in 2010—could decrease food availability and affordability and increase the vulnerability of the poor to lack of access to food. Therefore, for a country with as a high population growth rate as Nigeria, policy measures should aim to provide enhanced resources that support the poorest and most vulnerable, a considerable proportion of whom are farmers. Many of them are located in the north central part of the country.

Figure 10.5 shows the geographic distribution of the population living on less than US\$2 per day. Many of these individuals are located in the north central part of the country.

**FIGURE 10.5** Poverty in Nigeria, circa 2005 (percentage of population living on less than US\$2 per day)



Source: Wood et al. (2010).

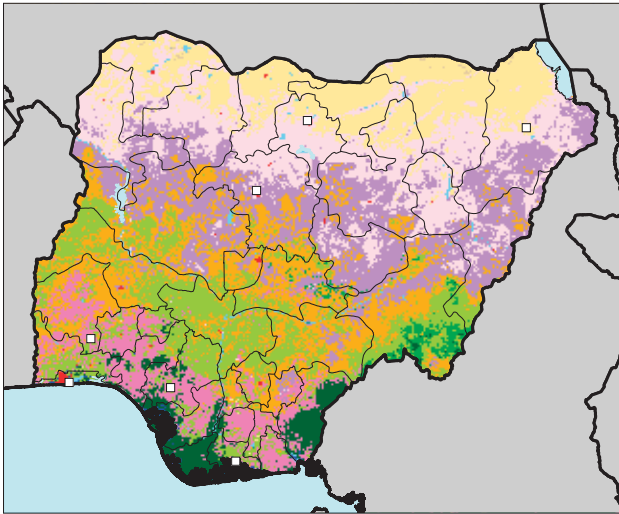
Note: Based on 2005 US\$ (US dollars) and on purchasing power parity value.

## Review of Land Use, Potential, and Limitations

### Land Use Overview

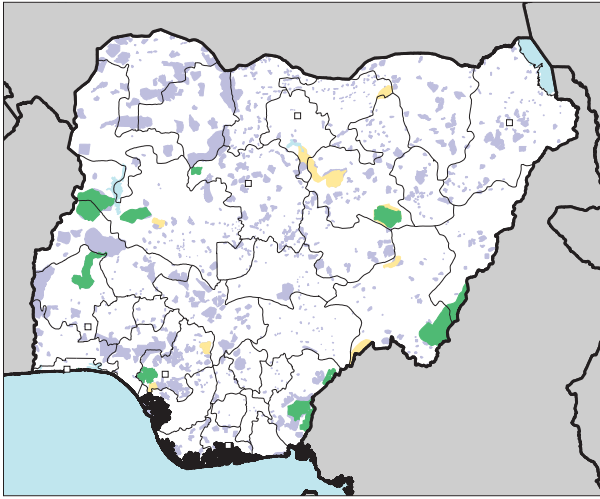
Figure 10.6 shows the land cover and land use in Nigeria as of 2000. The major agricultural areas are the two regions of mosaic croplands in the north central zone and the southeast to southwestern zones in the country. The other agricultural regions are the areas of herbaceous cover in the northern part of the country, where millet and sorghum are predominantly cultivated and livestock raised. Other parts of the country also support agricultural activities in one form or another but to a lesser extent. Remnants of the country's original forest vegetation (evergreen) can be seen only in the south and the southeast, which have the relatively favorable environmental conditions that support plantation agriculture, which is itself evergreen. Open, broad-leaved deciduous forests now cover the area referred to as the middle belt in Nigeria, while mosaic tree cover or other natural vegetation is confined to the eastern margins of the Adamawa highlands. Shrub cover, closed-open, evergreen and deciduous, is scattered around the southern parts of northern Nigeria, the middle belt region, and the northern parts of southern Nigeria.

**FIGURE 10.6** Land cover and land use in Nigeria, 2000



- Tree cover, broadleaved, evergreen
- Tree cover, broadleaved, deciduous, closed
- Tree cover, broadleaved, deciduous, open
- Tree cover, broadleaved, needle-leaved, evergreen
- Tree cover, broadleaved, needle-leaved, deciduous
- Tree cover, broadleaved, mixed leaf type
- Tree cover, broadleaved, regularly flooded, fresh water
- Tree cover, broadleaved, regularly flooded, saline water
- Mosaic of tree cover/other natural vegetation
- Tree cover, burnt
- Shrub cover, closed-open, evergreen
- Shrub cover, closed-open, deciduous
- Herbacious cover, closed-open
- Sparse herbacious or sparse shrub cover
- Regularly flooded shrub or herbacious cover
- Cultivated and managed areas
- Mosaic of cropland/tree cover/other natural vegetation
- Mosaic of cropland/shrub/grass cover
- Bare areas
- Water bodies
- Snow and ice
- Artificial surfaces and associated areas
- No data

Source: GLC2000 (Global Land Cover 2000) (Bartholome and Belward 2005).

**FIGURE 10.7** Protected areas in Nigeria, 2009

- Ia: Strict Nature Reserve
- Ib: Wilderness Area
- II: National Park
- III: National Monument
- IV: Habitat / Species Management Area
- V: Protected Landscape / Seascape
- VI: Managed Resource Protected Area
- Not applicable
- Not known

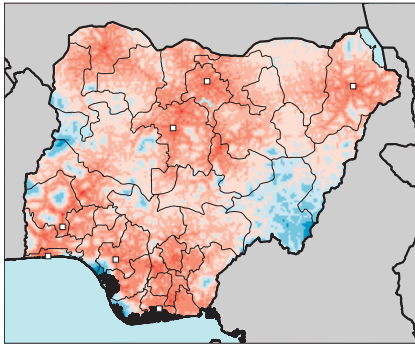
Sources: Protected areas are from the World Database on Protected Areas (UNEP and IUCN 2009). Water bodies are from the World Wildlife Fund's Global Lakes and Wetlands Database (Lehner and Döll 2004).

Major agricultural activities are also undertaken in the floodplains of the Niger and Benue Rivers and the inland valleys in the central part of the country.

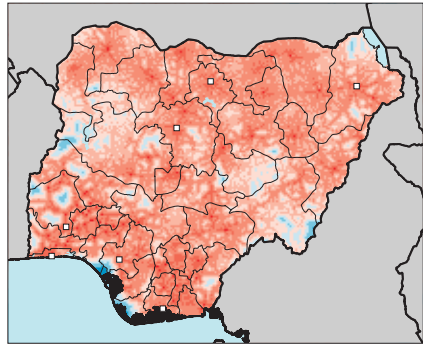
Figure 10.7 shows the locations of protected areas, including parks and reserves. These locations provide important protection for fragile environmental areas, which may also be important for the tourism industry. Two categories of protected areas are shown in Figure 10.7 that are applicable to Nigeria. These are International Union for the Conservation of Nature (IUCN) category II and IUCN category not known. The IUCN category not known includes the wetlands of Yobe in the northeastern part of the country, Kainji Lake National Park, north central Nigeria, and the mosaic of forest reserves.

Figure 10.8 shows the travel time to urban areas that provide potential markets for agricultural products as well as places where agricultural inputs and

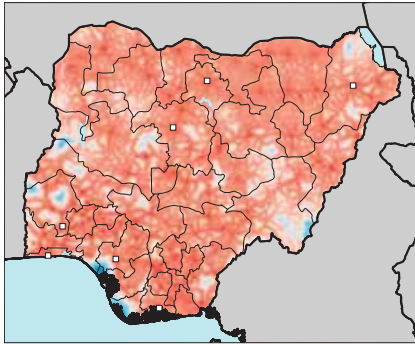
**FIGURE 10.8** Travel time to urban areas of various sizes in Nigeria, circa 2000



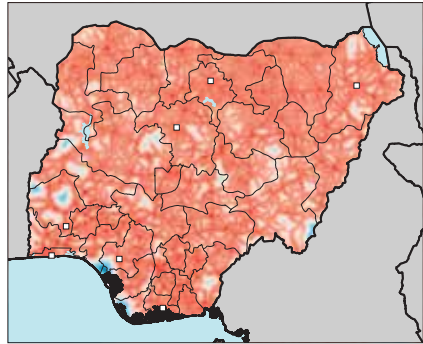
To cities of 500,000 or more people



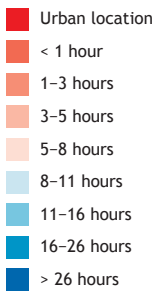
To cities of 100,000 or more people



To towns and cities of 25,000 or more people



To towns and cities of 10,000 or more people



Source: Authors' calculations.

consumer goods for farm households can be purchased. Policymakers need to keep in mind the importance of transport costs when considering areas' potential for agricultural expansion. That is, if fertile but unused land is far from markets, it represents potential land for expansion only if transportation infrastructure is put in place and if the land does not conflict with the preservation priorities seen in Figure 10.7. The maps in Figure 10.8 depict the travel times from the rural areas to towns and cities with populations of 10,000, 25,000, 100,000, and 500,000 or more people. The major population centers of Nigeria are also adequately captured. In general, most of the roads in rural areas of the country are in poor condition. In the coastal areas of Niger Delta, access to the nearest cities is made difficult by the travel times on water.

### Agriculture

Table 10.4 shows key agricultural commodities in terms of area harvested. Table 10.5 reports the value of the harvest of these commodities and Table 10.6 the quantity consumed. All commodities in these tables are significant to Nigeria because they are important to the food culture of the people or are cash crops providing significant income to farm families and national foreign exchange earnings; an example is cocoa beans. Cassava and yams are the most important foodcrops in the country. Other major foodcrops include sorghum and maize.

**TABLE 10.4** Harvest area of leading agricultural commodities in Nigeria, 2006–08 (thousands of hectares)

Rank	Crop	Percent of total	Harvest area
	Total	100.0	45,877
1	Sorghum	16.5	7,579
2	Millet	10.8	4,977
3	Cowpeas	9.6	4,395
4	Maize	8.5	3,898
5	Cassava	8.3	3,821
6	Oil palm fruit	6.8	3,142
7	Yams	6.7	3,068
8	Rice	5.5	2,519
9	Groundnuts	4.9	2,251
10	Cocoa beans	2.4	1,110

Source: FAOSTAT (FAO 2010).

Note: All values are based on the three-year average for 2006–08.

**TABLE 10.5** Value of production of leading agricultural commodities in Nigeria, 2005–07 (millions of US\$)

Rank	Crop	Percent of total	Value of production
	Total	100.0	66,008.7
1	Yams	29.4	19,380.3
2	Cassava	11.7	7,696.7
3	Sorghum	5.7	3,776.4
4	Other citrus	5.2	3,400.6
5	Millet	4.7	3,115.5
6	Maize	4.4	2,932.3
7	Other fresh vegetables	3.7	2,469.9
8	Plantains	3.1	2,075.1
9	Cowpeas	3.0	1,952.6
10	Groundnuts	2.7	1,811.3

Source: FAOSTAT (FAO 2010).

Note: All values are based on the three-year average for 2005–07. US\$ = US dollars.

**TABLE 10.6** Consumption of leading food commodities in Nigeria, 2003–05 (thousands of metric tons)

Rank	Crop	Percent of total	Food consumption
	Total	100.0	81,884
1	Cassava	18.5	15,139
2	Yams	12.3	10,071
3	Fermented beverages	10.1	8,291
4	Other vegetables	7.9	6,445
5	Sorghum	7.0	5,765
6	Millet	5.8	4,770
7	Rice	3.8	3,079
8	Maize	3.7	3,054
9	Other citrus	3.4	2,763
10	Other fruits	3.1	2,555

Source: FAOSTAT (FAO 2010).

Note: All values are based on the three-year average for 2003–05.

The next five figures show the estimated yield and growing areas of key crops. Both sorghum (Figure 10.9) and millet (Figure 10.10) are mainly grown in the central and northern regions of Nigeria. However, part of the north-east is not favorable to the growth of millet. As shown in Figure 10.11, cassava is now widely grown and is being introduced in the northern extremes of the country. Rainfed yams and sweet potatoes are widely grown across the country, with high concentrations in the north central and southeastern areas and on the southern flank of northeastern Nigeria (Figure 10.12). Rainfed maize is grown from the coast to the northern flank of the country (Figure 10.13). For all these crops, the yield does not vary significantly across the country.

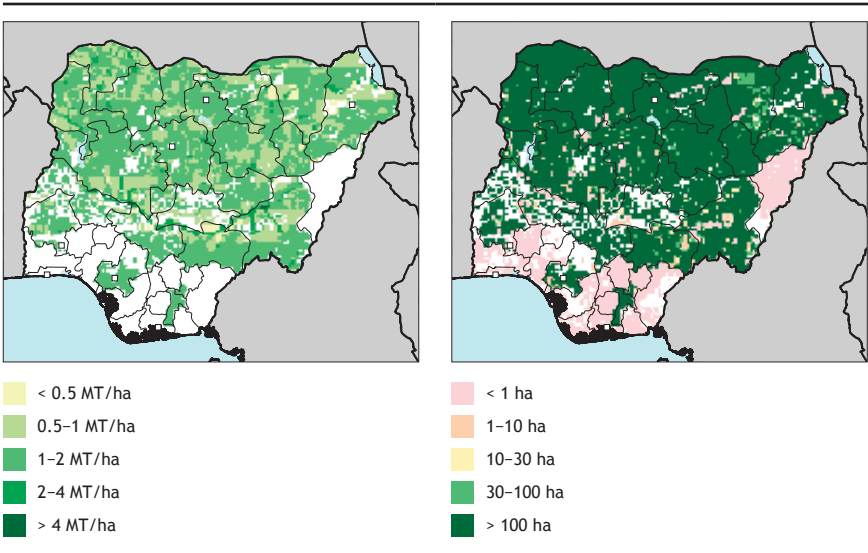
### Scenarios of the Future

#### Economic and Demographic Indicators

##### Population

Figure 10.14 shows population projections made for Nigeria by the United Nations (UN) population office through 2050. The projected population

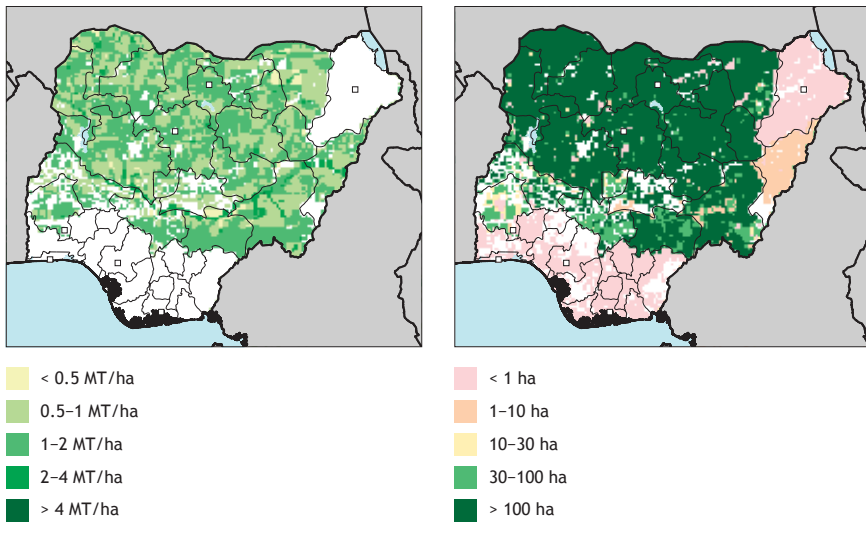
**FIGURE 10.9** Yield (metric tons per hectare) and harvest area density (hectares) for rainfed sorghum in Nigeria, 2000



Sources: SPAM (Spatial Production Allocation Model) (You and Wood 2006; You, Wood, and Wood-Sichra 2006, 2009).

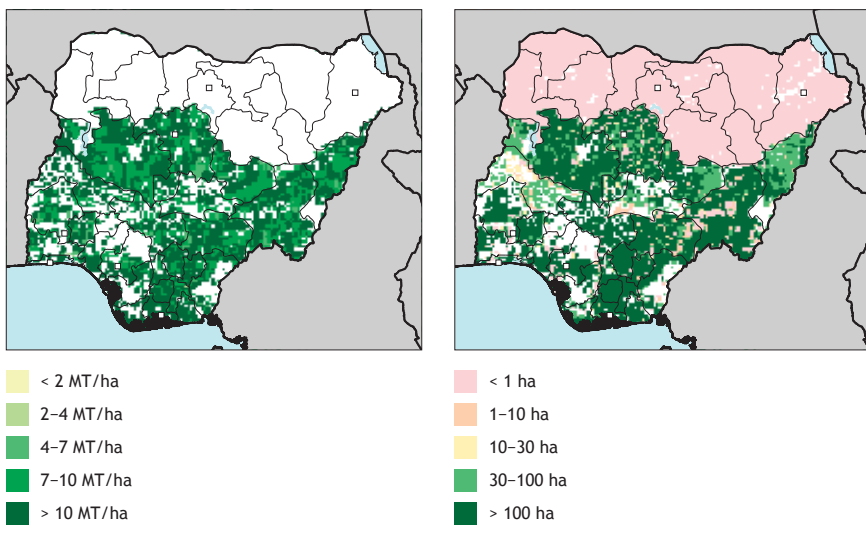
Notes: ha = hectare; MT = metric tons.

**FIGURE 10.10** Yield (metric tons per hectare) and harvest area density (hectares) for rainfed millet in Nigeria, 2000



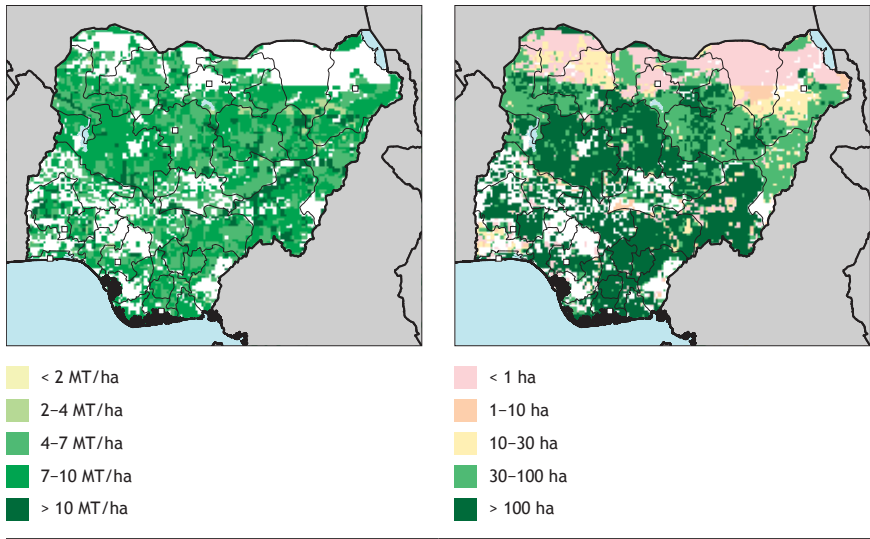
Sources: SPAM (Spatial Production Allocation Model) (You and Wood 2006; You, Wood, and Wood-Sichra 2006, 2009).  
 Notes: ha = hectare; MT = metric tons.

**FIGURE 10.11** Yield (metric tons per hectare) and harvest area density (hectares) for rainfed cassava in Nigeria, 2000



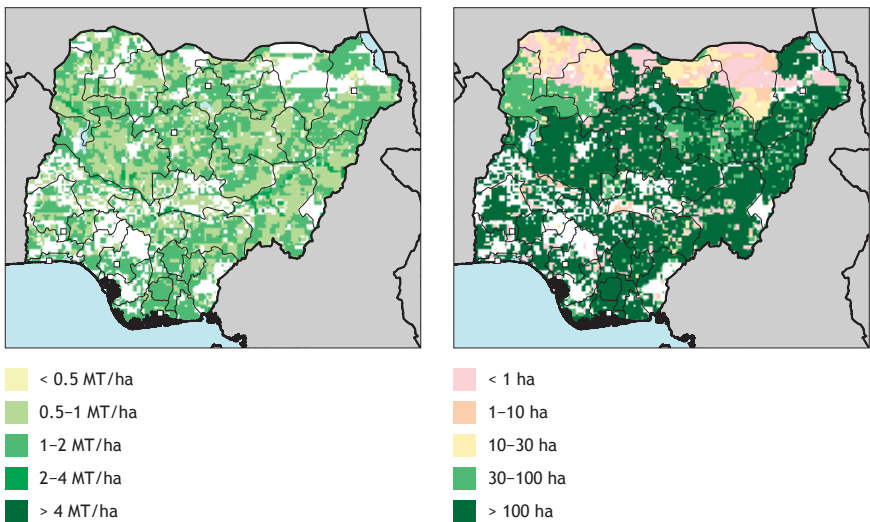
Sources: SPAM (Spatial Production Allocation Model) (You and Wood 2006; You, Wood, and Wood-Sichra 2006, 2009).  
 Notes: ha = hectare; MT = metric tons.

**FIGURE 10.12** Yield (metric tons per hectare) and harvest area density (hectares) for rainfed yams and sweet potatoes in Nigeria, 2000

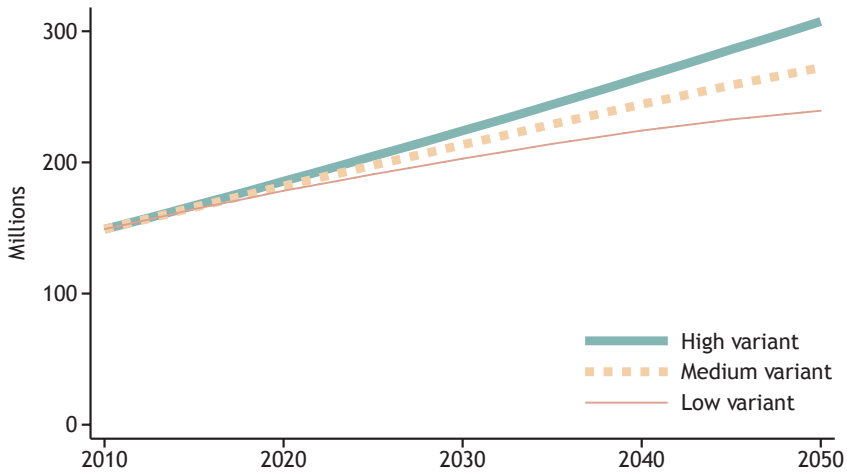


Sources: SPAM (Spatial Production Allocation Model) (You and Wood 2006; You, Wood, and Wood-Sichra 2006, 2009).  
 Notes: ha = hectare; MT = metric tons.

**FIGURE 10.13** Yield (metric tons per hectare) and harvest area density (hectares) for rainfed maize in Nigeria, 2000



Sources: SPAM (Spatial Production Allocation Model) (You and Wood 2006; You, Wood, and Wood-Sichra 2006, 2009).  
 Notes: ha = hectare; MT = metric tons.

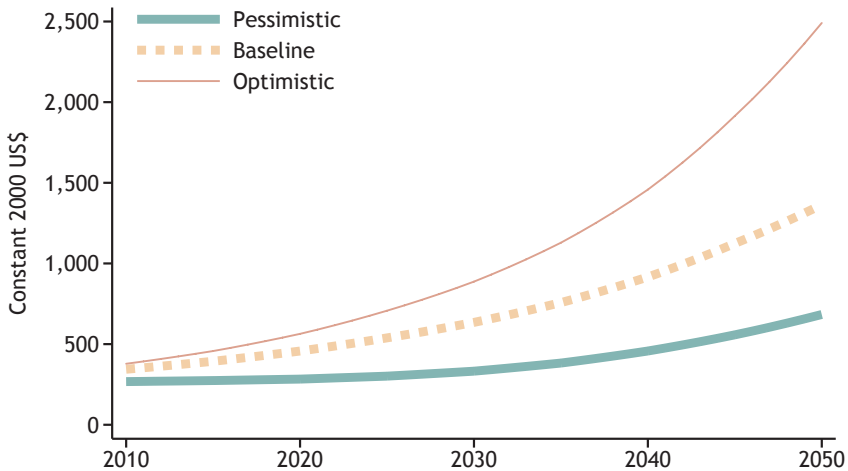
**FIGURE 10.14** Population projections for Nigeria, 2010–50

Source: UNPOP (2009).

will double in the next 40 years, from about 150 million presently to about 310 million based on the high variant projection or about 240 million, a 60 percent increase, based on the low variant projection. Challenges associated with a high rate of population growth will include providing food, shelter, and social amenities. The per capita land available for agriculture will likely be reduced (unless a substantial number of farmers give up farming to enter one of the other economic sectors), and consequently increased pressure on the land will make agricultural intensification inevitable. Farmers will therefore likely need to adjust to high-input agriculture.

### Income

Figure 10.15 shows the three GDP per capita scenarios used for our study. These are the results of combining three GDP projections with the three population projections of Figure 10.14 from the UN population office. The optimistic scenario combines high GDP with low population, the baseline scenario combines the medium GDP projection with the medium population projection, and the pessimistic scenario combines the low GDP projection with the high population projection. In all of the scenarios, GDP per capita is expected to grow with time. However, the differences by 2050 are noteworthy,

**FIGURE 10.15** Gross domestic product (GDP) per capita in Nigeria, future scenarios, 2010–50

Sources: Computed from GDP data from the World Bank Economic Adaptation to Climate Change project (World Bank 2010), from the Millennium Ecosystem Assessment (2005) reports, and from population data from the United Nations (UNPOP 2009). Note: US\$ = US dollars.

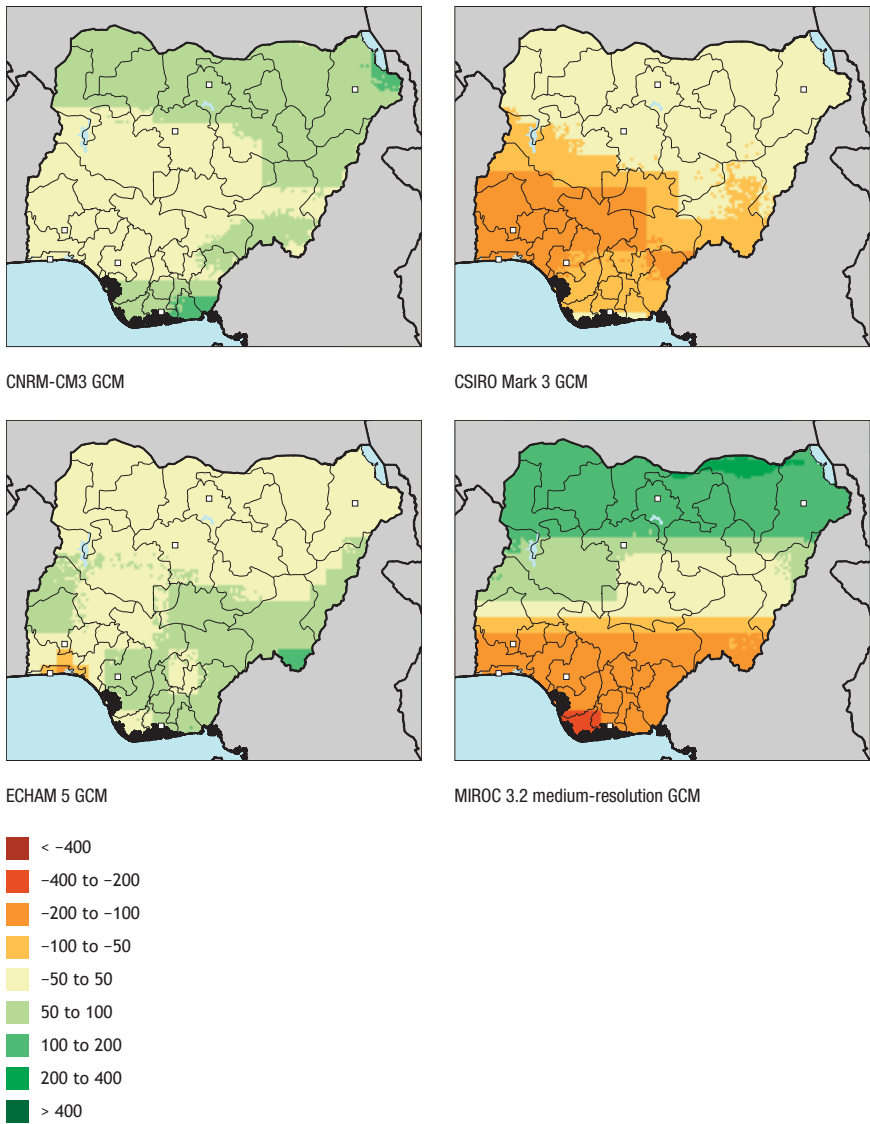
with GDP in the pessimistic scenario reaching only US\$684, almost exactly half that in the baseline scenario (\$1,364), and much lower than that in the optimistic scenario, which is just slightly less than \$2,500.

## Biophysical Analysis

### Climate Models

Figure 10.16 shows projected precipitation changes in Nigeria in the four downscaled general circulation models (GCMs) we use in this chapter in the A1B scenario. The CNRM-CM3 GCM predicts an increase in precipitation throughout the country except in the central portion. The ECHAM 5 GCM predicts some increase in rainfall, primarily in the coastal areas and the southeastern portion of the country along the border with Cameroon. The CSIRO Mark 3 GCM predicts less precipitation in the central and southwestern half of the country. The MIROC 3.2 medium-resolution GCM predicts a complete reversal of the climatic pattern of the

**FIGURE 10.16** Changes in mean annual precipitation in Nigeria, 2000–2050, A1B scenario (millimeters)



Source: Authors' estimates based on Jones, Thornton, and Heinke (2009).

Notes: A1B = greenhouse gas emissions scenario that assumes fast economic growth, a population that peaks midcentury, and the development of new and efficient technologies, along with a balanced use of energy sources; CNRM-CM3 = National Meteorological Research Center–Climate Model 3; CSIRO = climate model developed at the Australia Commonwealth Scientific and Industrial Research Organisation; ECHAM 5 = fifth-generation climate model developed at the Max Planck Institute for Meteorology (Hamburg); GCM = general circulation model; MIROC = Model for Interdisciplinary Research on Climate, developed at the University of Tokyo Center for Climate System Research.

geographical areas of the country.<sup>1</sup> Although the coastal areas of Nigeria, which currently receive more rainfall, will suffer more loss in precipitation, the northern part of the country will gain precipitation. This could create both hardship in the south and new opportunities in the north. There will be a need for change in the types of crops grown in the north and the south. Farmers may need to adjust their farming practices to accommodate the new crops they have not been used to cultivating.

Figure 10.17 shows the mean daily maximum temperature in Nigeria for the warmest month. The CNRM-CM3 GCM predicts an increase of 2.0°–2.5°C across the country. Both the CSIRO Mark 3 and the MIROC 3.2 medium-resolution GCMs predict a reasonably uniform increase of 1.0°–1.5°C, whereas the ECHAM 5 GCM predicts an increase of 2.0°–2.5°C in the northern half of the country and an increase of only 1.5°–2.0°C in the southern half.

#### **Yield Effects from Climate Change**

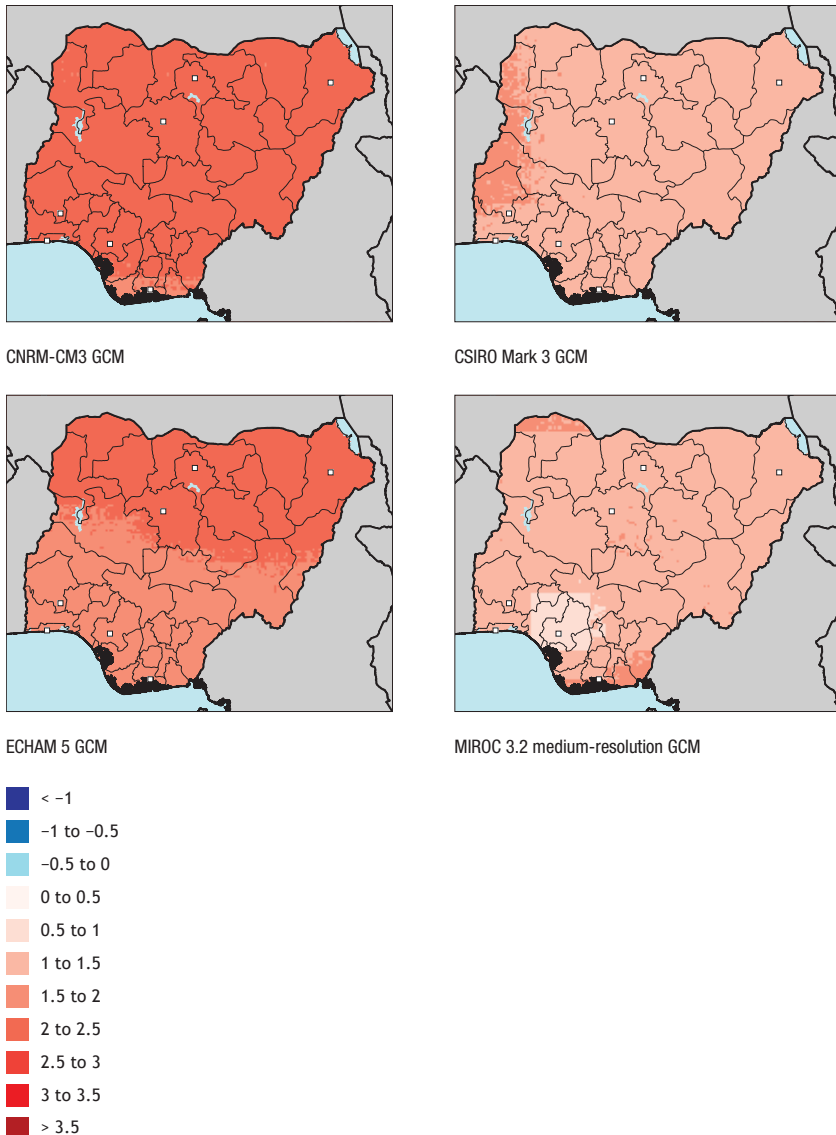
The effects of climate change on key crops in Nigeria are mapped in the next two figures. The comparison is between the crop yields in 2050 with climate change and the yields with a 2000 climate.

All the crop modeling results predict a loss of yield in areas planted with sorghum in the northern Sahelian zone, which is already prone to desertification (Figure 10.18). This means that the temperature increase will make it too hot for sorghum cultivation in these areas. Except in pockets of areas in Kebbi and some inland valleys, all the models predict yield losses on the order of 5–25 percent below baseline, with a few areas showing even higher losses. Maize will perform relatively better in the face of climate change, as shown in Figure 10.19, which shows a gain in yield of between 5 and 25 percent, with some areas predicted to have a yield increase greater than 25 percent. Less area is predicted to be lost to maize than to sorghum (see Figure 10.18). As in the case of sorghum, the areas predicted to be lost to maize fall within the Sahelian region of the northeastern extreme of the country (Figure 10.19).

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1 The A1B scenario is a greenhouse gas emissions scenario that assumes fast economic growth, a population that peaks midcentury, and the development of new and efficient technologies, along with a balanced use of energy sources. CNRM-CM3 is National Meteorological Research Center–Climate Model 3. ECHAM 5 is a fifth-generation climate model developed at the Max Planck Institute for Meteorology in Hamburg. CSIRO Mark 3 is a climate model developed at the Australia Commonwealth Scientific and Industrial Research Organisation. MIROC is the Model for Interdisciplinary Research on Climate, developed at the University of Tokyo Center for Climate System Research.

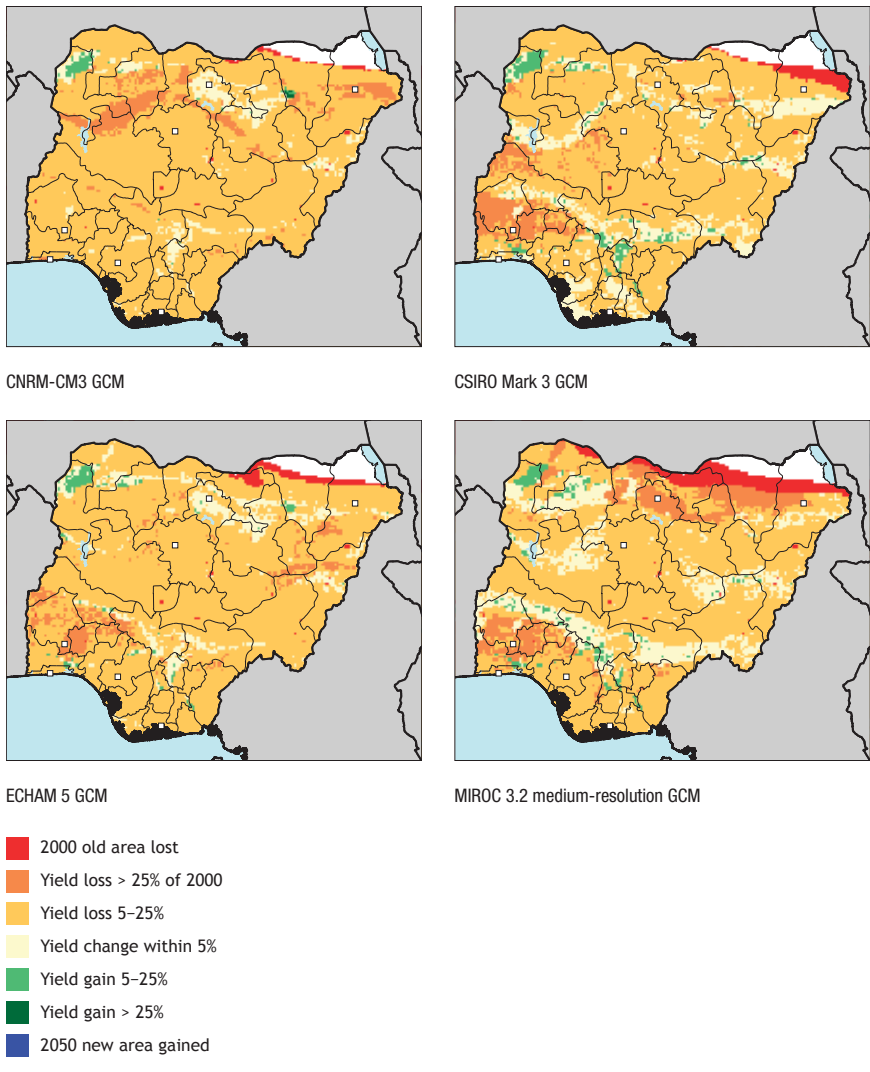
**FIGURE 10.17** Change in the normal daily maximum temperature in Nigeria for the warmest month, 2000–2050, A1B scenario (°C)



Source: Authors' calculations based on Jones, Thornton, and Heinke (2009).

Notes: A1B = greenhouse gas emissions scenario that assumes fast economic growth, a population that peaks midcentury, and the development of new and efficient technologies, along with a balanced use of energy sources; CNRM-CM3 = National Meteorological Research Center–Climate Model 3; CSIRO = climate model developed at the Australia Commonwealth Scientific and Industrial Research Organisation; ECHAM 5 = fifth-generation climate model developed at the Max Planck Institute for Meteorology (Hamburg); GCM = general circulation model; MIROC = Model for Interdisciplinary Research on Climate, developed at the University of Tokyo Center for Climate System Research.

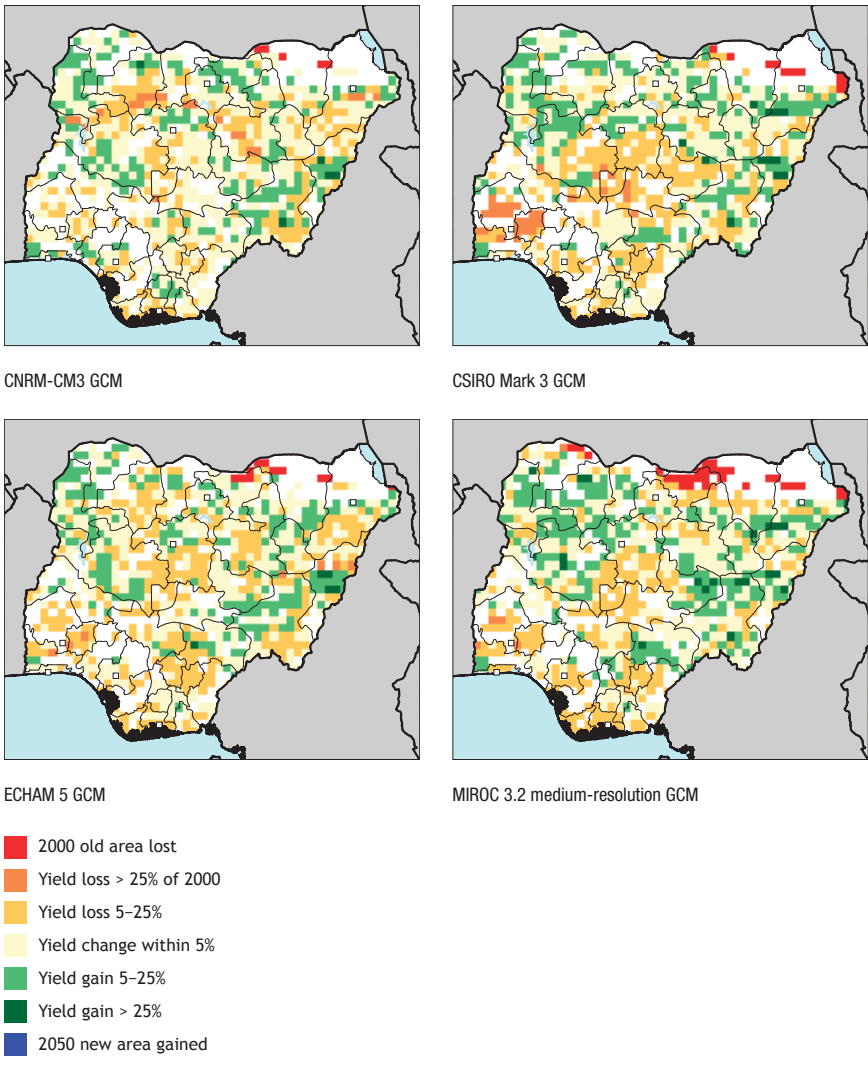
**FIGURE 10.18** Yield change under climate change: Rainfed sorghum in Nigeria, 2010–50, A1B scenario



Source: Authors' estimates.

Notes: A1B = greenhouse gas emissions scenario that assumes fast economic growth, a population that peaks midcentury, and the development of new and efficient technologies, along with a balanced use of energy sources; CNRM-CM3 = National Meteorological Research Center–Climate Model 3; CSIRO = Australia Commonwealth Scientific and Industrial Research Organisation; ECHAM 5 = fifth-generation climate model developed at the Max Planck Institute for Meteorology (Hamburg); GCM = general circulation model; MIROC = Model for Interdisciplinary Research on Climate, developed at the University of Tokyo Center for Climate System Research.

**FIGURE 10.19** Yield change under climate change: Rainfed maize in Nigeria, 2010–50, A1B scenario



Source: Authors' estimates.

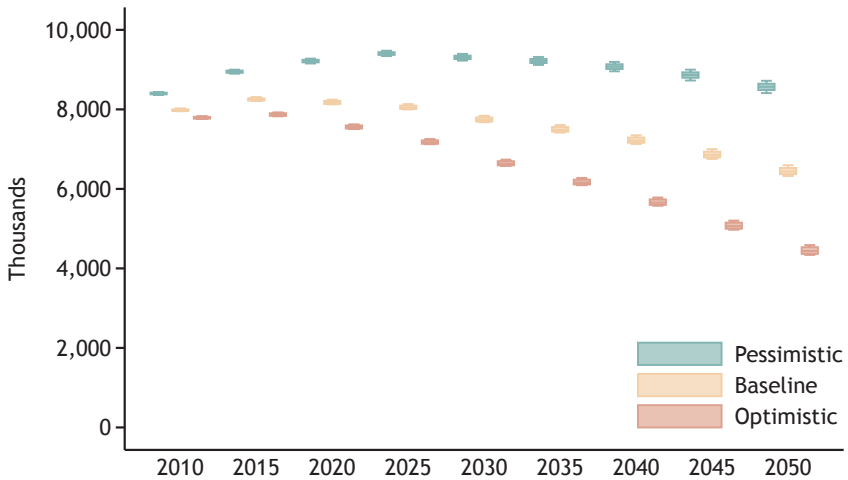
Notes: A1B = greenhouse gas emissions scenario that assumes fast economic growth, a population that peaks midcentury, and the development of new and efficient technologies, along with a balanced use of energy sources; CNRM-CM3 = National Meteorological Research Center–Climate Model 3; CSIRO = climate model developed at the Australia Commonwealth Scientific and Industrial Research Organisation; ECHAM 5 = fifth-generation climate model developed at the Max Planck Institute for Meteorology (Hamburg); GCM = general circulation model; MIROC = Model for Interdisciplinary Research on Climate, developed at the University of Tokyo Center for Climate System Research.

**Vulnerability**

Figure 10.20 shows the impact of the future scenarios on under-five malnutrition rates. Both the optimistic and the baseline scenarios predict a decline in the number of malnourished children under the age of five in Nigeria, while the pessimistic scenario predicts an initial increase, with a slightly higher number in 2050 than at present. Although the numbers increase slightly in the pessimistic scenario, we see declines by 2020 in the optimistic scenario and by 2030 in the baseline scenario. Furthermore, with population growth we would expect that the percentage of children who are malnourished would actually be declining in all scenarios.

Figure 10.21 shows the kilocalories per capita available to each person. Given the same period shown in Figure 10.20, the scenarios in Figure 10.21 indicate that the availability of calories will not improve in the pessimistic scenario, but there will be increased availability in the optimistic scenario and in the baseline scenario after 2030.

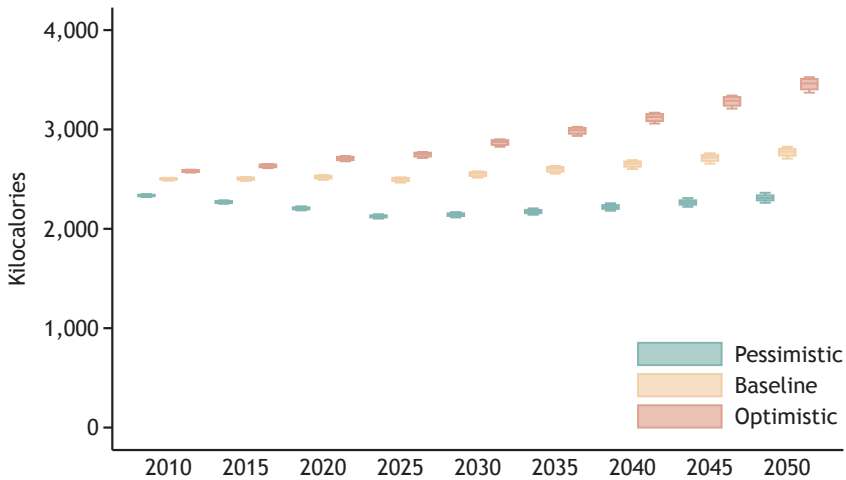
**FIGURE 10.20** Number of malnourished children under five years of age in Nigeria in multiple income and climate scenarios, 2010–50



Source: Based on analysis conducted for Nelson et al. (2010).

Note: The box and whiskers plot for each socioeconomic scenario shows the range of effects from the four future climate scenarios.

**FIGURE 10.21** Kilocalories per capita in Nigeria in multiple income and climate scenarios, 2010–50



Source: Based on analysis conducted for Nelson et al. (2010).

Note: The box and whiskers plot for each socioeconomic scenario shows the range of effects from the four future climate scenarios.

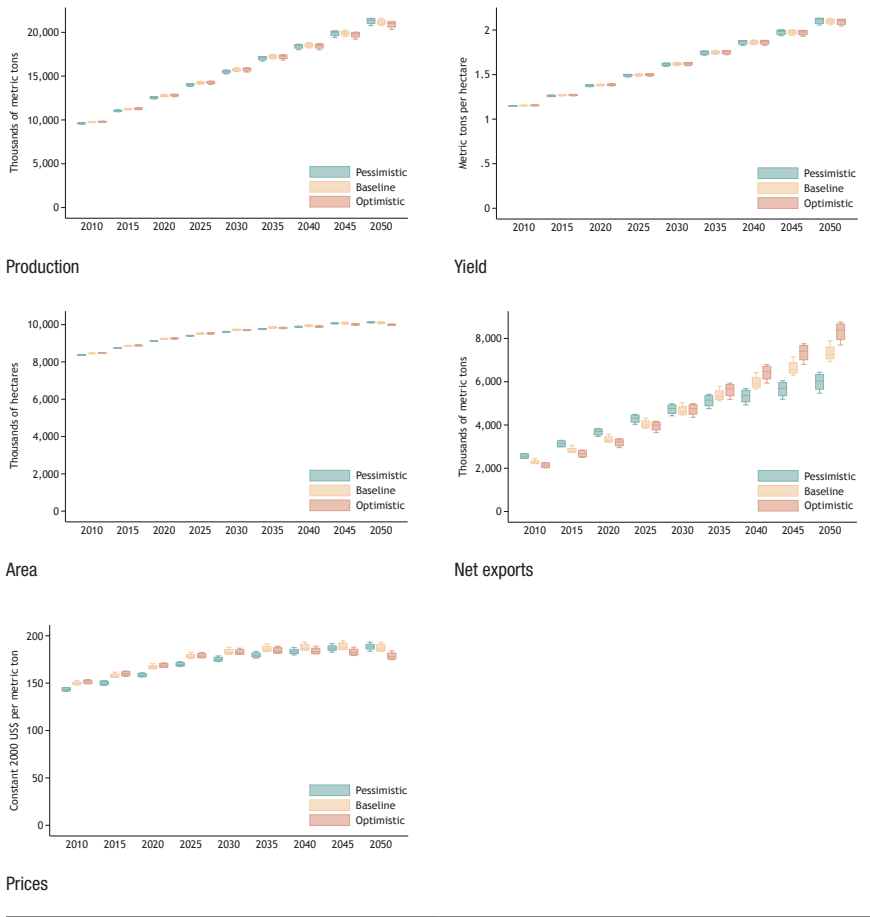
### Agricultural Outcomes

The next four figures show simulation results from the International Model for Policy Analysis of Agricultural Commodities and Trade associated with key agricultural crops in Nigeria. The figure for each featured crop has five graphs: one each showing production, yield, area, net exports, and world price. All scenarios predict a general increase in sorghum production, yield, area, net exports, and world price (Figure 10.22). However, area and world price will remain virtually the same after 2030. After 2040, the net exports predicted by the optimistic scenario will be greater than in the pessimistic scenario.

Millet production, yield, and net exports are predicted to increase in all the scenarios, although the area planted with the crop will remain unchanged and the world market price for millet will decline by 2050 (Figure 10.23). The net exports of millet will be virtually the same for all the scenarios in 2050 following relatively higher net exports in the pessimistic scenario until 2040.

The production of cassava and other root crops as well as sweet potatoes and yams is projected to increase in all scenarios (Figures 10.24 and 10.25).

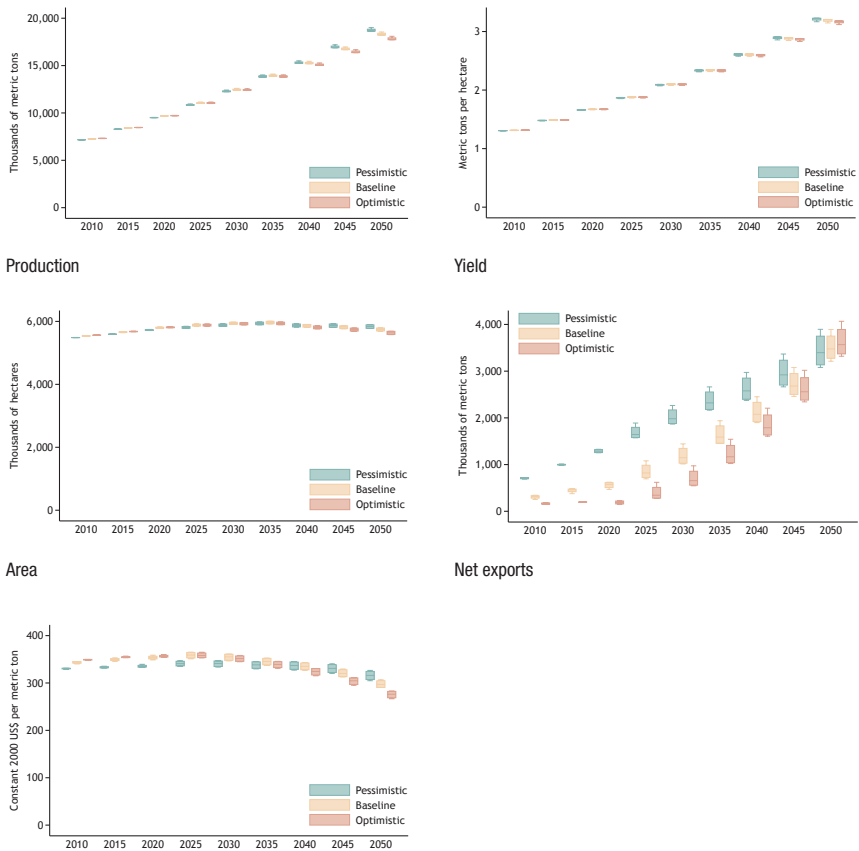
**FIGURE 10.22** Impacts of GDP, population, and climate change scenarios on sorghum area, yield, production, net exports, and prices in Nigeria, 2010–50



Source: Based on analysis conducted for Nelson et al. (2010).

Notes: The box and whiskers plot for each socioeconomic scenario shows the range of effects from the four future climate scenarios. GDP = gross domestic product; US\$ = US dollars.

**FIGURE 10.23** Impacts of GDP, population, and climate change scenarios on millet area, yield, production, net exports, and prices in Nigeria, 2010–50

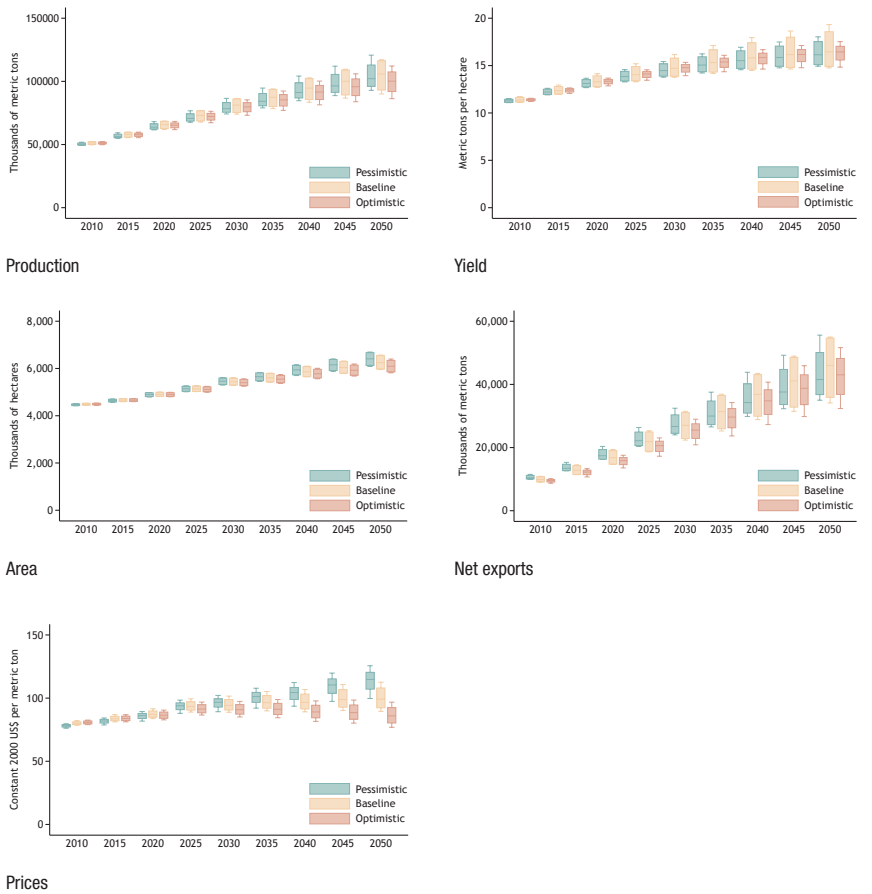


Prices

Source: Based on analysis conducted for Nelson et al. (2010).

Notes: The box and whiskers plot for each socioeconomic scenario shows the range of effects from the four future climate scenarios. GDP = gross domestic product; US\$ = US dollars.

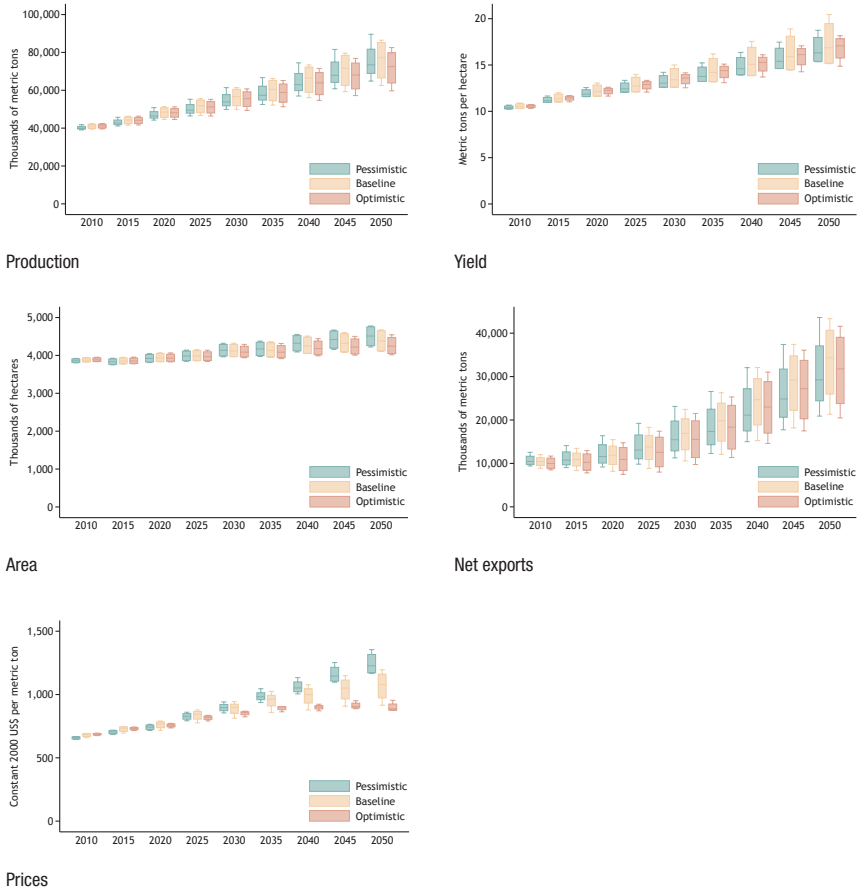
**FIGURE 10.24** Impacts of GDP, population, and climate change scenarios on cassava area, yield, production, net exports, and prices in Nigeria, 2010–50



Source: Based on analysis conducted for Nelson et al. (2010).

Notes: The box and whiskers plot for each socioeconomic scenario shows the range of effects from the four future climate scenarios. GDP = gross domestic product; US\$ = US dollars.

**FIGURE 10.25** Impacts of GDP, population, and climate change scenarios on sweet potatoes and yams area, yield, production, net exports, and prices in Nigeria, 2010–50



Source: Based on analysis conducted for Nelson et al. (2010).

Notes: The box and whiskers plot for each socioeconomic scenario shows the range of effects from the four future climate scenarios. GDP = gross domestic product; US\$ = US dollars.

The yield, area under production, world price, and net exports are all projected to generally increase. Toward 2050 the world price for roots and tubers will be higher in the pessimistic scenario than in the optimistic scenario.

For all crops presented here, exports are projected to grow, indicating a projected food surplus for the country.

### **Conclusions and Policy Recommendations**

In this chapter we have attempted to assess the vulnerability of agriculture in Nigeria to climate change using different GCMs. The GCMs are not in agreement with each other regarding the degree of temperature change or the direction of precipitation change and therefore indicate a need to develop some flexibility in policies, research, and extension to optimize adaptation strategies. It seems that temperature changes will cause the most difficulties in terms of projecting the loss of crop areas in the northern part of the country. It also seems that sorghum may be most adversely affected by climate change. Maize may actually experience some increase in yields, most likely due to increases in rainfall.

If the situation projected by the MIROC 3.2 medium-resolution GCM comes to pass, the reduction of rainfall in the southern parts of the country could adversely affect the rainforests and the yields of tree crops such as palm oil, cocoa, and rubber.

This chapter does not analyze the likely impact of climate change on livestock production. However, given the likely shift in vegetation patterns, the areas of concentration of the production of livestock, especially cattle, sheep, and goats, may be particularly affected by the increase in rainfall shown by the CNRM-CM3 and the MIROC 3.2 medium-resolution GCMs. Increasing rainfall could support the production of fodder crops but could also create favorable conditions for the proliferation of animal diseases and pests.

Following from these likely scenarios, the following policy measures are recommended to help farmers adapt to climate change:

- Institute early warning systems through the strengthening and coordination of the nation's meteorological services and the integration of indigenous knowledge of climate and early warning signals.
- Strengthen the nation's agricultural database.
- Improve agricultural productivity through the promotion and strengthening of the national agricultural research and extension institutions.

- Formalize and promote environmental standards to mitigate environmental degradation.
- Promote and strengthen the nation's food reserve and storage programs.
- Promote rural development strategies that can reduce rural–urban migration and depletion of the rural population and enhance rural infrastructure and road linkages with the urban areas.

These measures not only make sense in the face of climate change but also will be good for overall economic development in the agricultural sector even without climate change, as farmers strive to improve the yields and profitability of their farm operations.

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