Chapter 8

LIBERIA

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Liberia is situated at the southwest corner of the West Coast of Africa. It lies between the longitudes of 7°30′ and 11°30′ west and latitudes 4°18′ and 8°30′ north. It covers a surface area of about 111,370 square kilometers (about 43,506 square miles). The extent of its dry land is 96,160 square kilometers or 37,570 square miles (UNDP Liberia 2006). Liberia is bordered on the west by Sierra Leone, on the north by Guinea, on the east by Côte d'Ivoire, and on the south by the Atlantic Ocean. The country has two seasons: rainy and dry. The rainy season lasts from May to October, and the dry season runs from November to April. The farming system is characterized by shifting cultivation, which has led to the conversion of extensive areas of forest into farmland and grassland in many parts of the country.

Rice is the staple food of Liberians, while cassava is the second major foodcrop. Overall, Liberian farmers are resource poor and invariably produce at a subsistence level. Against the background of limited resources, the typical Liberian farmer is faced with numerous biophysical constraints, including low-yielding crop varieties, pests, and diseases, as well as poor soil conditions. Heavy reliance on rainfall exposes farmers to the vagaries of the weather. There are 700 kilometers of paved roads in Liberia, extending from Monrovia to Bo Waterside (on the Sierra Leone border), Ganta, and Buchanan Counties, making these areas easily accessible; they are very different from the 1,600 kilometers of unpaved roads, mostly in need of repair, that make it difficult to transport agricultural products from the southeastern counties to Monrovia.

According to the high-variant scenario, Liberia's population would double by 2040. Major challenges associated with population growth include the country's dilapidated infrastructure, weak health system, malnutrition, lack of clean drinking water, bad road conditions, and high level of unemployment. As the population increases, there will be a high demand for not only the currently limited basic social services but also for natural resources.

The purpose of the chapter is to help Liberian policymakers and researchers better understand and anticipate the likely impacts of climate change on

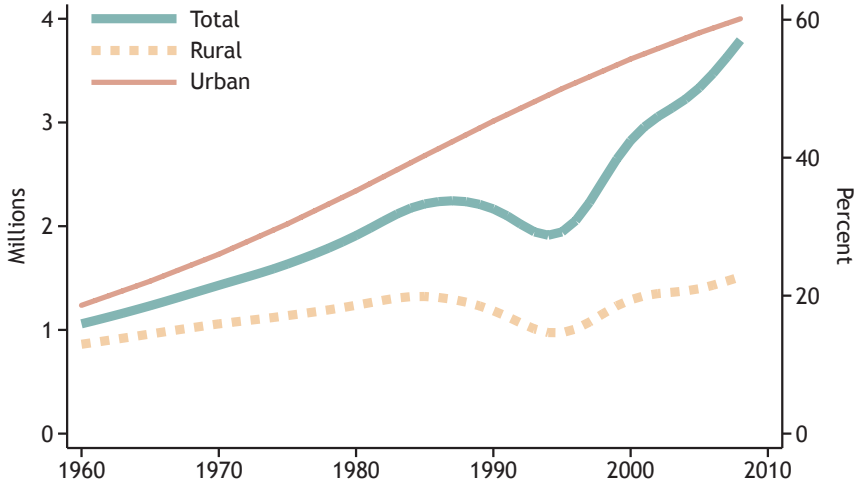
agriculture and on vulnerable households. The chapter reviews current data on agriculture and economic development, models anticipated changes in climate between now and 2050, applies crop models to assess the impact of climate change on agricultural production, and models global supply and demand for food to predict relevant food price trends. The findings of this chapter have several significant policy implications, especially because the Government of Liberia, through the Ministry of Agriculture, has made it a priority to monitor the actual and potential impacts of climate change on the agricultural sector.

Review of the Current Situation

Population

The total population of Liberia increased from about 1 million in 1960 to just over 2 million in the mid-1980s (Figure 8.1). The population declined markedly during 1987–94 due to the civil war in the country (especially in the rural areas,

FIGURE 8.1 Population trends in Liberia: Total population, rural population, and percent urban, 1960–2008



Source: World Development Indicators (World Bank 2009).

where the fighting took place). There was also a steady increase in the percentage of the urban population due to the mass migration from rural areas to urban areas in search of safety and food. Table 8.1 shows that the urban growth rate is higher than the rural growth rate, possibly reflecting the relatively better health facilities in the urban areas, as well as employment opportunities, more social amenities, better communication and transport connections, and commercial activities that serve as driving forces of urban migration.

Figure 8.2 shows the geographic distribution of the population in Liberia based on census data and other sources. The population density is relatively lower in the southeastern region, particularly in Grand Gedeh, Sinoe, and River Gee Counties, as well as Gbarpolu in the western part of the country; these areas are characterized by heavy forest cover, poor communications and transport systems, and underdeveloped physical infrastructure and social amenities, coupled with generally fewer employment opportunities (Liberia, ISGS 2009). The counties with relatively high population densities are Montserrado, Nimba, Margibi, and Maryland Counties (Maryland County, bordering Côte d'Ivoire, is highly populated compared to other southeastern counties). These areas have better transport and communication systems, fertile agricultural lands, local alluvial mining activities, and international commercial mining and agricultural operations, as well as opportunities for employment and trade with neighboring countries. The capital city, Monrovia, is densely populated, with relatively superior socioeconomic conditions, including better infrastructure; better health, transport, and communication systems; and its status as a major hub for employment opportunities, including those at its seaport.

Income

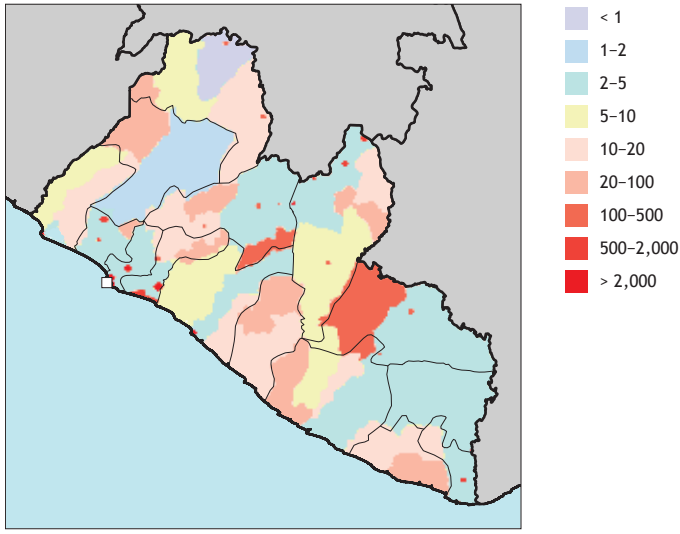
The share of income earned in agriculture in Liberia shows the importance of agriculture as a sector of the economy. Figure 8.3 shows trends in gross

TABLE 8.1 Population growth rates in Liberia, 1960–2008 (percent)

Decade	Total growth rate	Rural growth rate	Urban growth rate
1960–69	3.0	2.1	6.4
1970–79	2.8	1.5	5.9
1980–89	1.7	0.0	4.3
1990–99	2.1	0.3	4.0
2000–2008	3.5	1.8	4.8

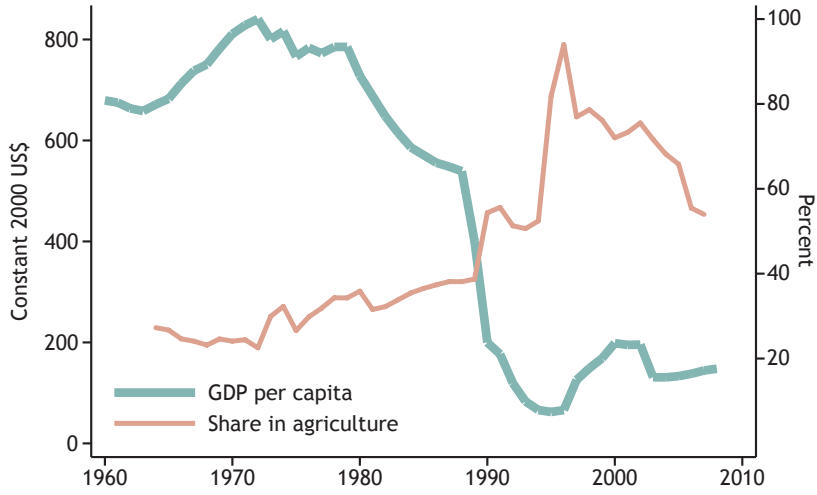
Source: Authors' calculations based on World Development Indicators (World Bank 2009).

FIGURE 8.2 Population distribution in Liberia, 2000 (persons per square kilometer)



Source: CIESIN et al. (2004).

FIGURE 8.3 Per capita GDP in Liberia (constant 2000 US$) and share of GDP from agriculture (percent), 1960–2008



Source: World Development Indicators (World Bank 2009).
Note: GDP = gross domestic product; US$ = US dollars.

domestic product (GDP) per capita and the proportion of GDP from agriculture—a sector that is vulnerable to the impacts of climate change.

Liberia's GDP per capita increased from about US$700 (US dollars) in 1960 to just above US$800 in 1970 and then dropped throughout the 1980s to its lowest level, less than US$100, during the civil war of the mid-1990s. The decrease from 1970 to 1990 reflected the downward shift in the global economy. From 1995 onward, Liberia's GDP started improving. The share of its GDP from agriculture increased slowly, from about 30 to 40 percent between the mid-1960s and 1990. During the civil war, the share of its agricultural GDP increased sharply because other sectors of the economy were disrupted and most became nonfunctional. Agricultural companies such as Firestone were still in operation, with intermittent interruptions during the civil war. Later, during the civil crisis (1999–2003), agricultural production started to drop as people fled their farms and the supporting infrastructure collapsed. After the 2005 general election and presidential election, other sectors of the economy revived, including forestry, mining, and international trade, leading to a gradual rise in GDP.

Vulnerability to Climate Change

Vulnerability is the lack of ability to recover from a stress. Poor people are vulnerable to many different kinds of stresses because they lack the financial resources to respond. In agriculture, poor people are particularly vulnerable to the stresses of an uncertain climate. At the national level, vulnerability arises in the interactions among population and income growth and the availability of natural and manufactured resources. Vulnerability has many dimensions; in this chapter, the focus is on income level and income sources.

Table 8.2 provides data on Liberia's performance on additional indicators of a country's vulnerability and resiliency to economic shocks: level of education, literacy, and concentration of labor in poorer or less dynamic sectors. As

TABLE 8.2 Education and labor statistics for Liberia, 2000s

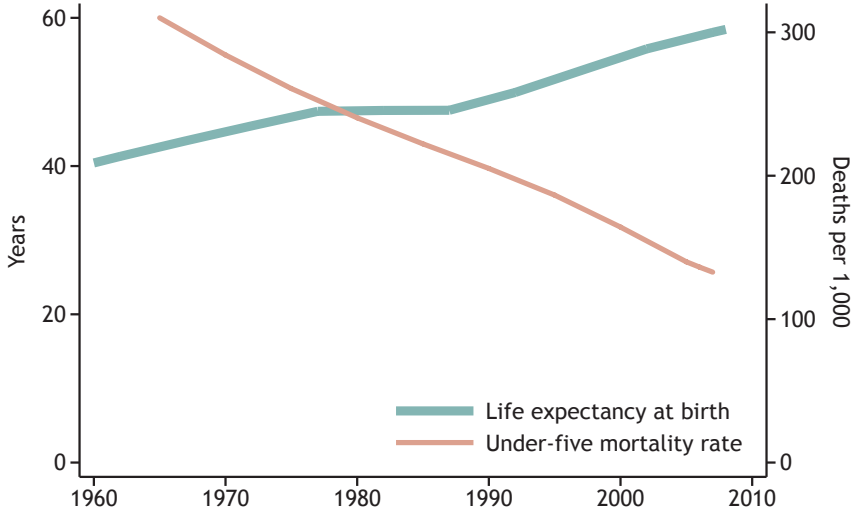
Indicator	Year	Percent
Primary school enrollment (percent gross, three-year average)	2008	83.4
Secondary school enrollment (percent gross, three-year average)	2000	32.3
Adult literacy rate	2007	55.5
Percent employed in agriculture	2008	70.0
Under-five malnutrition (weight for age)	2007	20.4

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

in most countries in West Africa, secondary school enrollment in Liberia is significantly lower than primary school enrollment. The low literacy rate, poverty, and associated sociocultural circumstances—including the need for farm labor as well as early marriages—account for the high dropout rate in secondary schools. Table 8.2 also shows that the bulk of the Liberian population is engaged in agriculture and that under-five malnutrition is still high in the country, at 20.4 percent.

Figure 8.4 shows Liberia's performance on two noneconomic correlates of poverty—life expectancy and under-five mortality. Life expectancy increased slightly from 1960 to 1979 and stabilized at about 48 years through the late 1980s. Since then, life expectancy has been increasing, to about 60 years in 2008. Under-five mortality has been falling steadily. According to the Liberian Poverty Reduction Strategy Paper (PSRP) (Liberia 2008), between 1999–2000 and 2006–07, the infant mortality rate fell from 117 to 72 deaths per 1,000 live births, while under-five mortality fell from 194 to 111 deaths per 1,000 births. This steady decline is attributable to the cessation of conflict, the restoration of basic services in some areas, and increased immunization.

FIGURE 8.4 Well-being indicators in Liberia, 1960–2008



Source: World Development Indicators (World Bank 2009).

According to Wood et al. (2010), the proportion of the population living on less than US$2 per day is 90–95 percent of the population of Liberia based on the 2005 US dollar and the purchasing power parity measure. According to the 2010 Millennium Development Goals report (Liberia, MPEA 2010), 63.8 percent of the population lives in extreme poverty, living on less than US$1 per day, a situation that needs significant improvement. The Government of Liberia developed the Poverty Reduction Strategy Paper to address this issue (Liberia 2008).

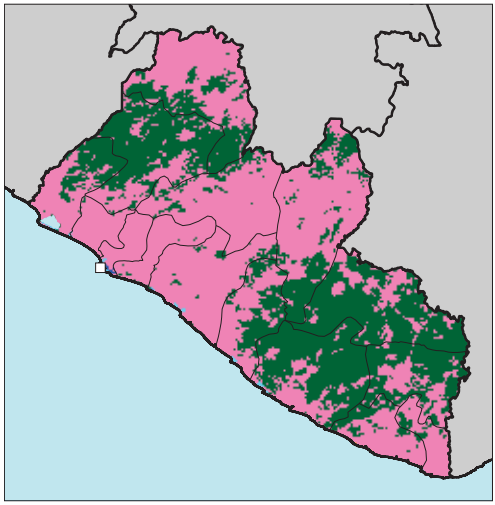
Review of Land Use and Agriculture

Land Use Overview

Figure 8.5 shows Liberia's land cover and land use as of 2000. Agricultural production in Liberia is based on subsistence farming largely using shifting cultivation, which has led to the cutting down of extensive areas of forest. A significant portion of the forested areas of the country has been converted to farmland, bush, and grasslands. Tree cover and broad-leaved evergreen vegetation are now present in only about one-fourth of the country. Other human activities, such as charcoal production and alluvial mining, have contributed immensely to land cover change. Recently the government has ratified oil palm concessions that will entail massive felling of old rubber trees in the northwestern and southeastern parts of the country, exposing the land to erosion for extensive periods before a full canopy can form. Patches of rubber plantations remain in the central region of the country (in Margibi, Bassa, Bong, and Nimba Counties).

Figure 8.6 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. In Liberia there are two gazetted protected areas: Sapo National Park is located in the southeastern part of the country, bordering the Sinoe River in the south and the Putu Range in the north; the Mount Nimba Nature Reserve is located in the north, sharing a massif with Côte d'Ivoire and Guinea. Sapo National Park has an area of 180,363 hectares of lowland rainforest, including swampy areas, drylands, and riparian forests; it represents one of the most intact forest ecosystems in Liberia, located in the only remaining evergreen block of forest in the Upper Guinea Forest Ecosystem. Mount Nimba Nature Reserve covers an area of 11,723 hectares. In addition, there are five proposed protected areas: Lake Piso Nature Reserve (estimated area 30,766 hectares), Cestos Senkwen National Park (estimated area 91,698 hectares), Wologezi National

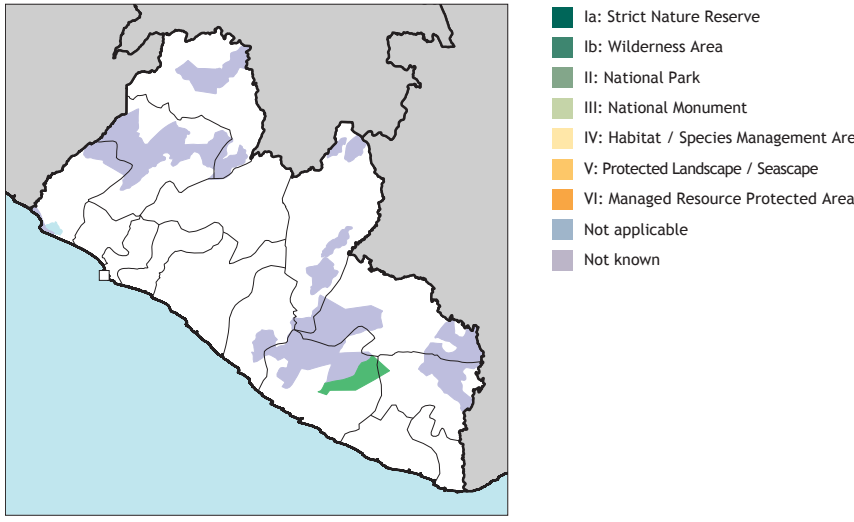
FIGURE 8.5 Land cover and land use in Liberia, 2000



- 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 8.6 Protected areas in Liberia, 2009



Source: 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).

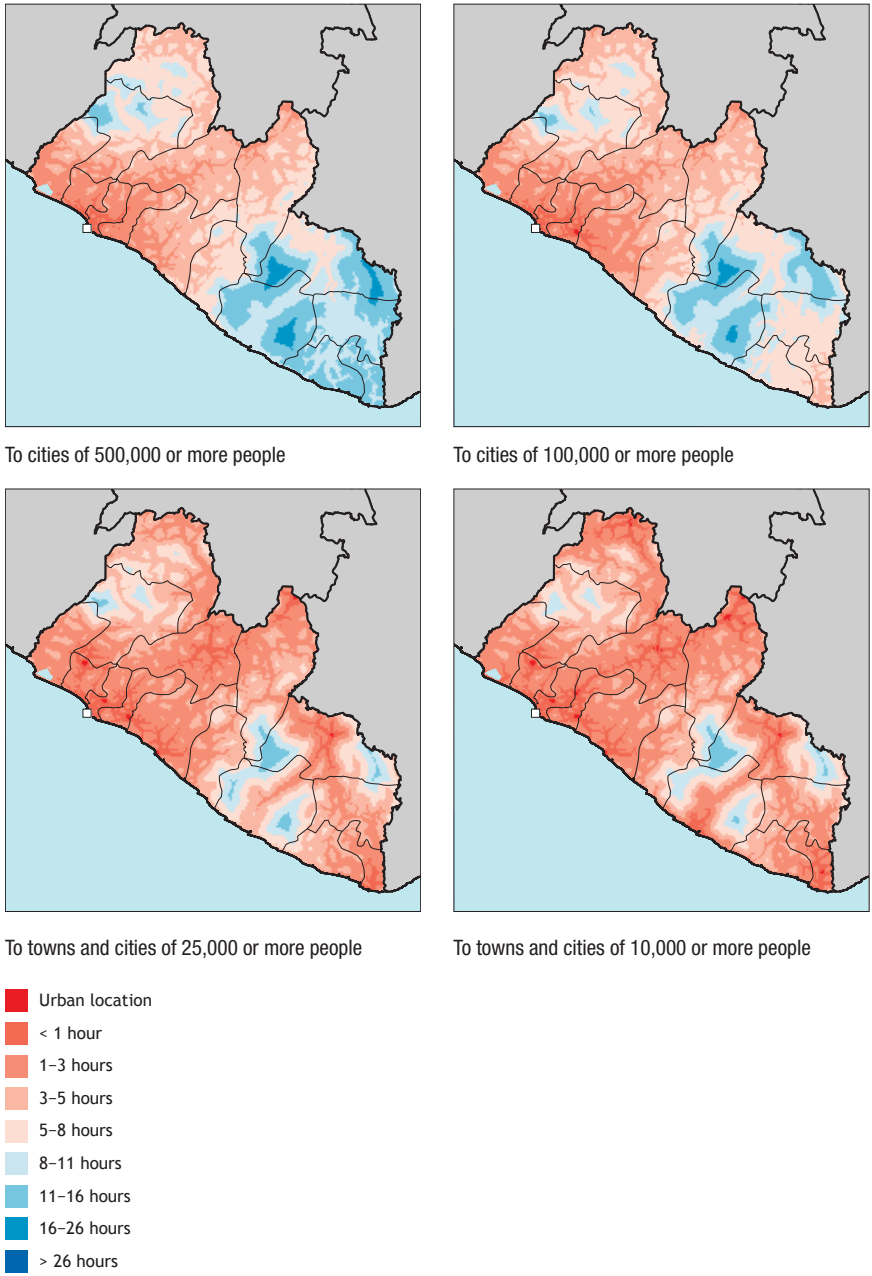
Park (estimated area 80,001 hectares), Wenegizi National Park (estimated area 71,422 hectares), and Grebo National Park (estimated area 260,326 hectares) (UNDP Liberia 2006; UNEP-WCMC 2006).

Figure 8.7 shows travel time to urban areas as potential markets for agricultural products and as sources of consumption items and agricultural inputs. There are 700 kilometers of paved roads in Liberia, extending from Monrovia to Bo Waterside (at the Sierra Leone border), Ganta, and Buchanan. These areas are easily accessible, unlike the 1,600 kilometers of unpaved roads, which are mostly in need of repair. Traveling from the southeastern part of the country to Monrovia requires more time due to road conditions, and it is very difficult to transport agricultural products from the southeastern counties to Monrovia.

Agriculture Overview

Tables 8.3 and 8.4 show key agricultural commodities of Liberia in terms of area harvested and food for human consumption (as ranked by weight). Rice occupies the largest cultivated area, followed by rubber and cassava. Rice and cassava are the first- and second-ranked staple foodcrops. Rice production

FIGURE 8.7 Travel time to urban areas of various sizes in Liberia, circa 2000



Source: Authors' calculations.

TABLE 8.3 Harvest area of leading agricultural commodities in Liberia, 2006–08 (thousands of hectares)

Rank	Crop	Percent of total	Harvest area
	Total	100.0	536
1	Rice	29.9	160
2	Rubber	23.4	125
3	Cassava	15.9	85
4	Sugarcane	4.8	26
5	Plantains	3.6	19
6	Coffee	3.2	17
7	Oil palm fruit	3.2	17
8	Cocoa beans	3.1	17
9	Other fresh vegetables	2.5	13
10	Bananas	2.0	11

Source: FAOSTAT (FAO 2010).

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

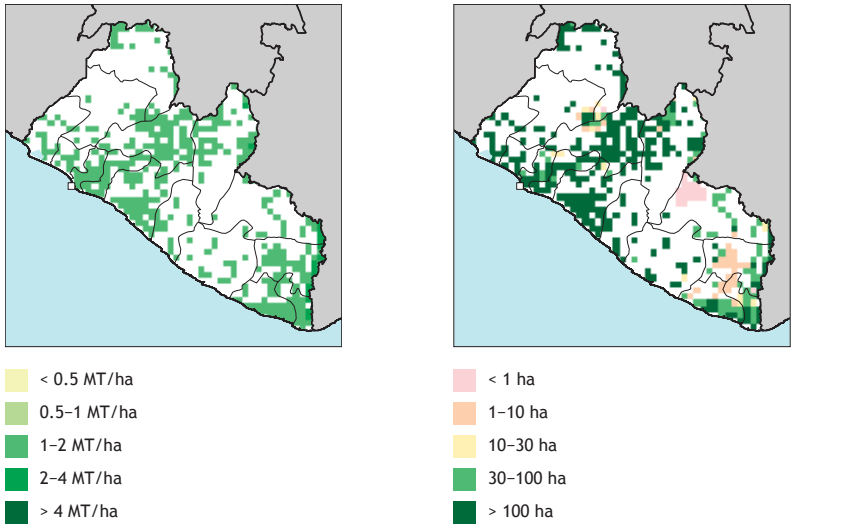
TABLE 8.4 Consumption of leading food commodities in Liberia, 2003–05 (thousands of metric tons)

Rank	Crop	Percent of total	Food consumption
	Total	100.0	1,261
1	Cassava	38.8	490
2	Rice	13.5	170
3	Bananas	8.0	101
4	Wheat	8.0	101
5	Other vegetables	5.4	68
6	Palm oil	3.4	43
7	Plantains	3.1	39
8	Sugarcane	2.9	36
9	Other roots and tubers	1.8	23
10	Yams	1.4	18

Source: FAOSTAT (FAO 2010).

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

FIGURE 8.8 Yield (metric tons per hectare) and harvest area density (hectares) for rainfed rice in Liberia, 2000



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

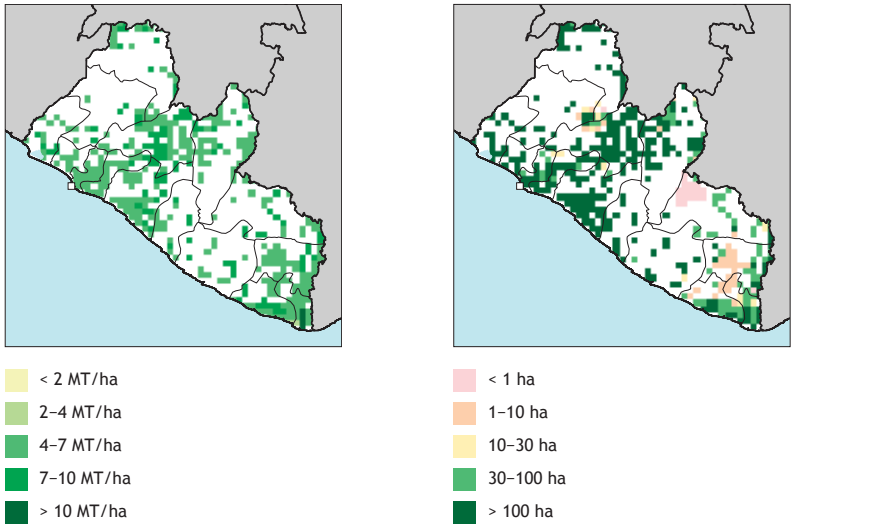
was estimated at 693,770 metric tons in 2007 (Liberia, MOA 2008).[1] Approximately 63 percent of subsistence households produce rice, mainly on the uplands. Rubber, a major export crop, contributes 26 percent of the country's GDP (Liberia 2008).

The next four figures show the estimated yield and growing areas of key crops. Rice (Figure 8.8) and cassava (Figure 8.9) are widely cultivated in the middle part of Liberia (Nimba, Bong, Bassa, and Margibi Counties) and some parts of Maryland and River Gee.[2] Yields range from 1 to 2 tons per hectare for rice and from 4 to 7 metric tons per hectare for cassava. Sugarcane (Figure 8.10) and plantains and bananas (Figure 8.11) are mainly cultivated in counties bordering the coast, as well as River Gee and Grand Gedeh Counties. Sugarcane yields an average of 10 metric tons per hectare, whereas plantains yield 2–4 metric tons per hectare.

1 All tons are metric tons.

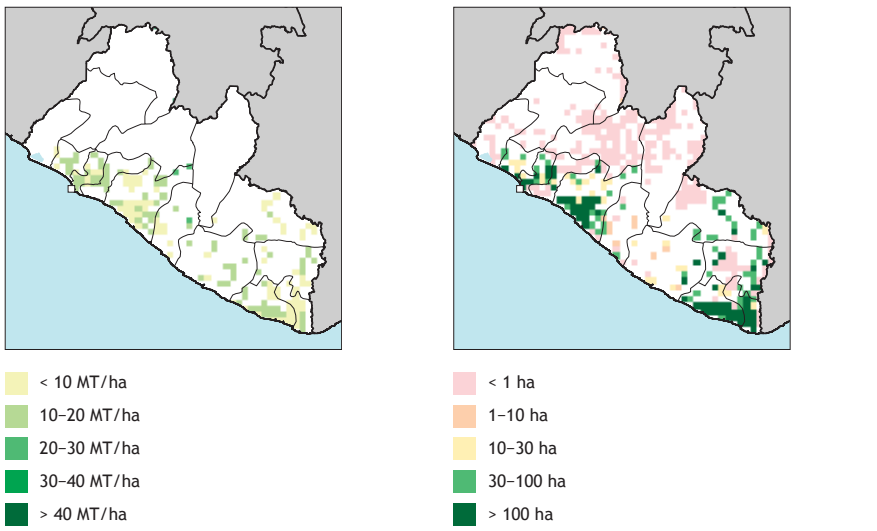
2 Because of the civil war, Lofa County, formerly known as one of the bread baskets of rice production in Liberia, had a low yield in 2000.

FIGURE 8.9 Yield (metric tons per hectare) and harvest area density (hectares) for rainfed cassava in Liberia, 2000



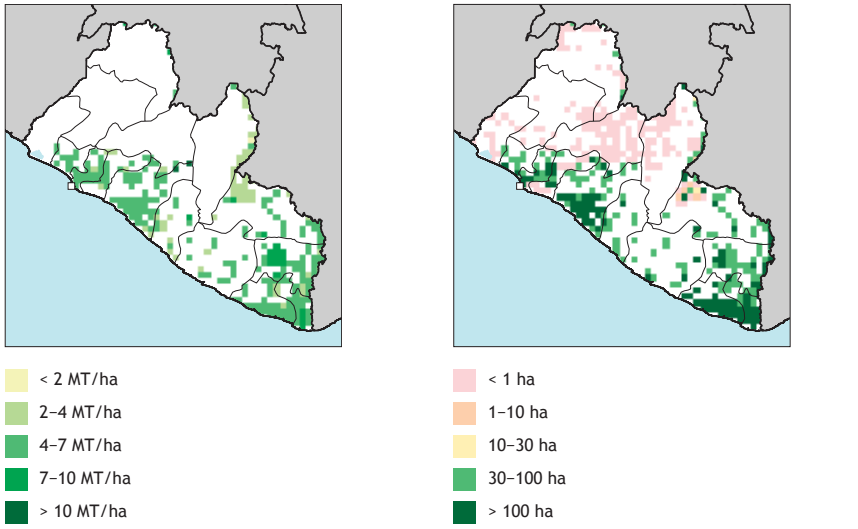
Sources: SPAM (Spatial Production Allocation Model) (You and Wood 2006; You, Wood, and Wood-Sichra 2006, 2009).
Notes: ha = hectare; MT = metric tons.

FIGURE 8.10 Yield (metric tons per hectare) and harvest area density (hectares) for rainfed sugarcane in Liberia, 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 8.11 Yield (metric tons per hectare) and harvest area density (hectares) for rainfed plantains and bananas in Liberia, 2000



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

Economic and Demographic Scenarios

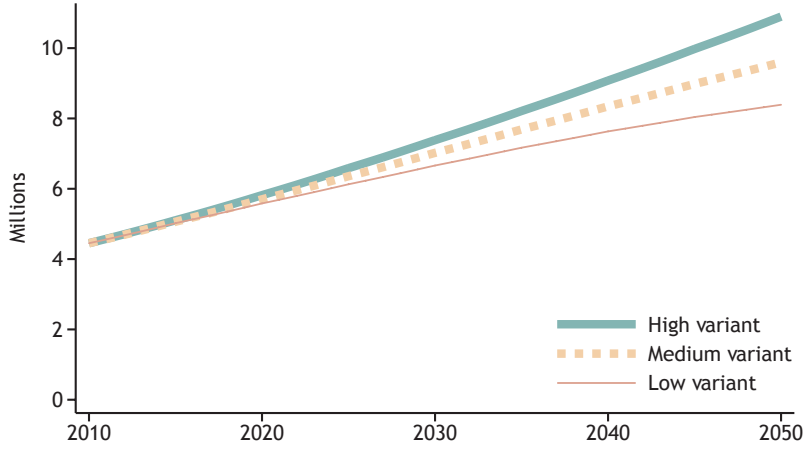
Population

Figure 8.12 shows population projections for Liberia by the United Nations (UN) population office through 2050 (UNPOP 2009). As the population increases, there will be a high demand for the limited basic social services. Liberia has abundant natural resources, but they are largely untapped. The high-variant scenario predicts a doubling of the population before 2040. Major challenges associated with an increase in population include the country's dilapidated infrastructure, weak health system, malnutrition, lack of clean drinking water, poor road conditions, and high level of unemployment.

Income

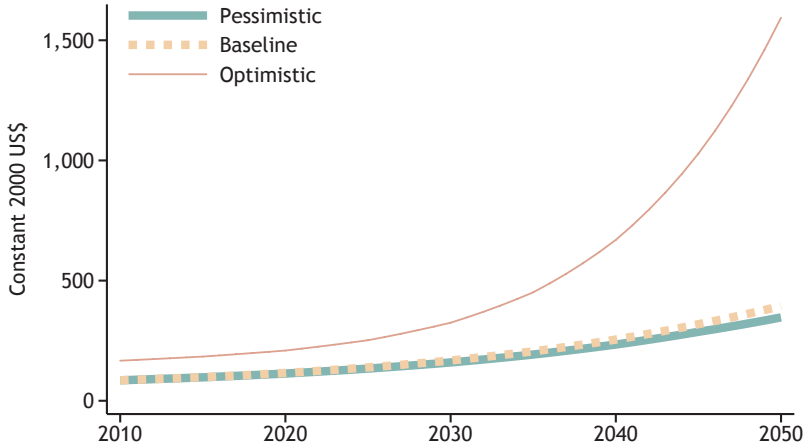
Figure 8.13 presents three overall scenarios for Liberia's future GDP per capita derived by combining three GDP scenarios with the three population scenarios of Figure 8.12 (based on UN population data). The optimistic scenario combines high GDP with low population scenarios for all countries, the baseline scenario combines the medium GDP projection with the medium

FIGURE 8.12 Population projections for Liberia, 2010–50



Source: UNPOP (2009).

FIGURE 8.13 Gross domestic product (GDP) per capita in Liberia, 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.

population scenario, and the pessimistic scenario combines the low GDP scenario with the high population scenario. The agricultural modeling in the next section uses these scenarios.

The pessimistic scenario for per capita GDP is similar to the baseline scenario, with GDP per capita less than US$200 in 2030 and no higher than US$400 in 2050. GDP per capita in the optimistic scenario is at least double these levels. The optimistic scenario shows a sharp increase after 2030 in GDP per capita, which will reach US$600 before 2040 and over US$1,500 by 2050. Crucial policy approaches will be needed to address population growth and allow for the adoption of prudent economic policies, including policies related to agriculture.

Biophysical Scenarios

Climate Scenarios

Figure 8.14 shows precipitation changes in Liberia in the four downscaled general circulation models (GCMs) using the A1B climate scenario.[3] The CSIRO Mark 3 GCM shows a wetter situation than does CNRM-CM3.[4] The ECHAM 5 GCM also shows wet conditions in central Liberia but a reduction in rainfall (–100 to –50 millimeters) in Grand Kru, River Geo, and Maryland Counties.[5] The MIROC 3.2 medium-resolution GCM predicts very dry conditions all over the country, with decreases in rainfall of up to –400 millimeters.[6]

Figure 8.15 shows how the average daily maximum temperature of the warmest month of the year will change in the A1B scenario according to various GCMs. All the models show a relatively uniform increase in temperature across the country, with variation among the models in the level of increase in temperature. The CNRM-CM3 GCM predicts an increase of 2.0°–2.5°C; both CSIRO Mark 3 and the MIROC 3.2 medium-resolution GCM predict

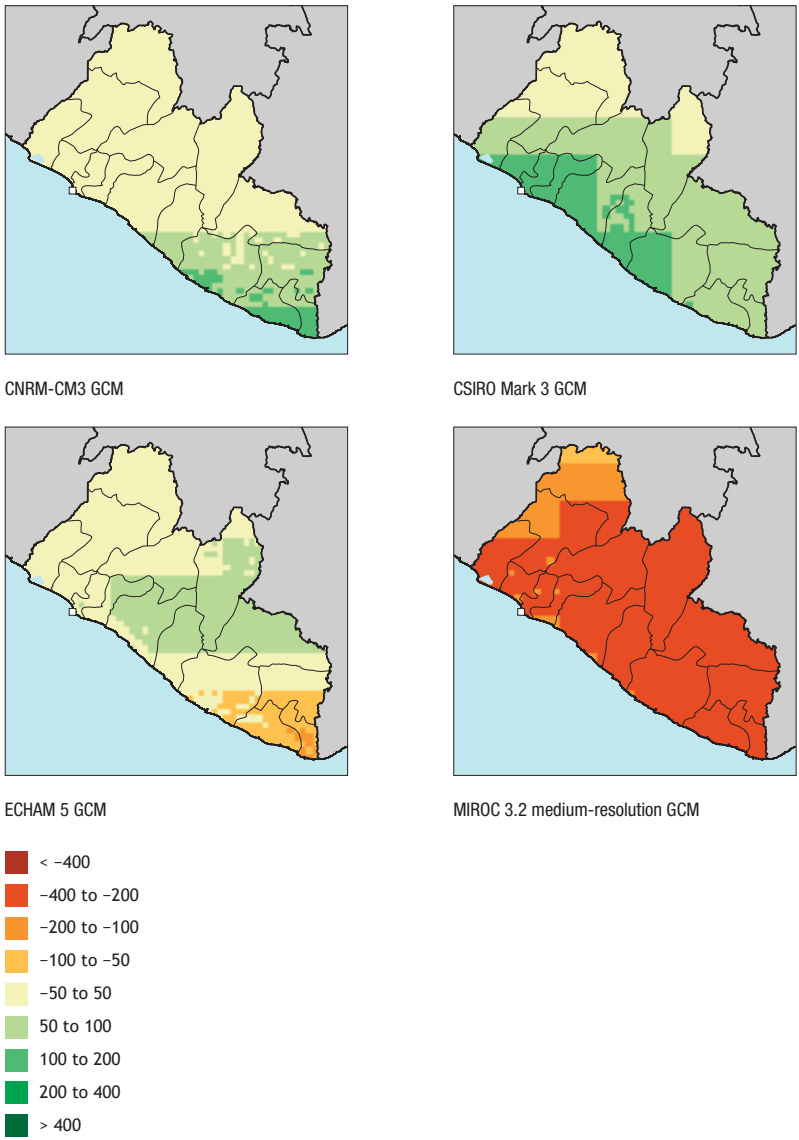
3 The A1B scenario is a greenhouse gas emissions scenario that assumes fast economic growth, a population that peaks midcentury, and the development of new and efficient technologies, along with a balanced use of energy sources.

4 CSIRO Mark 3 is a climate model developed at the Australia Commonwealth Scientific and Industrial Research Organisation. CNRM-CM3 is National Meteorological Research Center–Climate Model 3.

5 ECHAM 5 is a fifth-generation climate model developed at the Max Planck Institute for Meteorology in Hamburg.

6 MIROC is the Model for Interdisciplinary Research on Climate, developed at the University of Tokyo Center for Climate System Research.

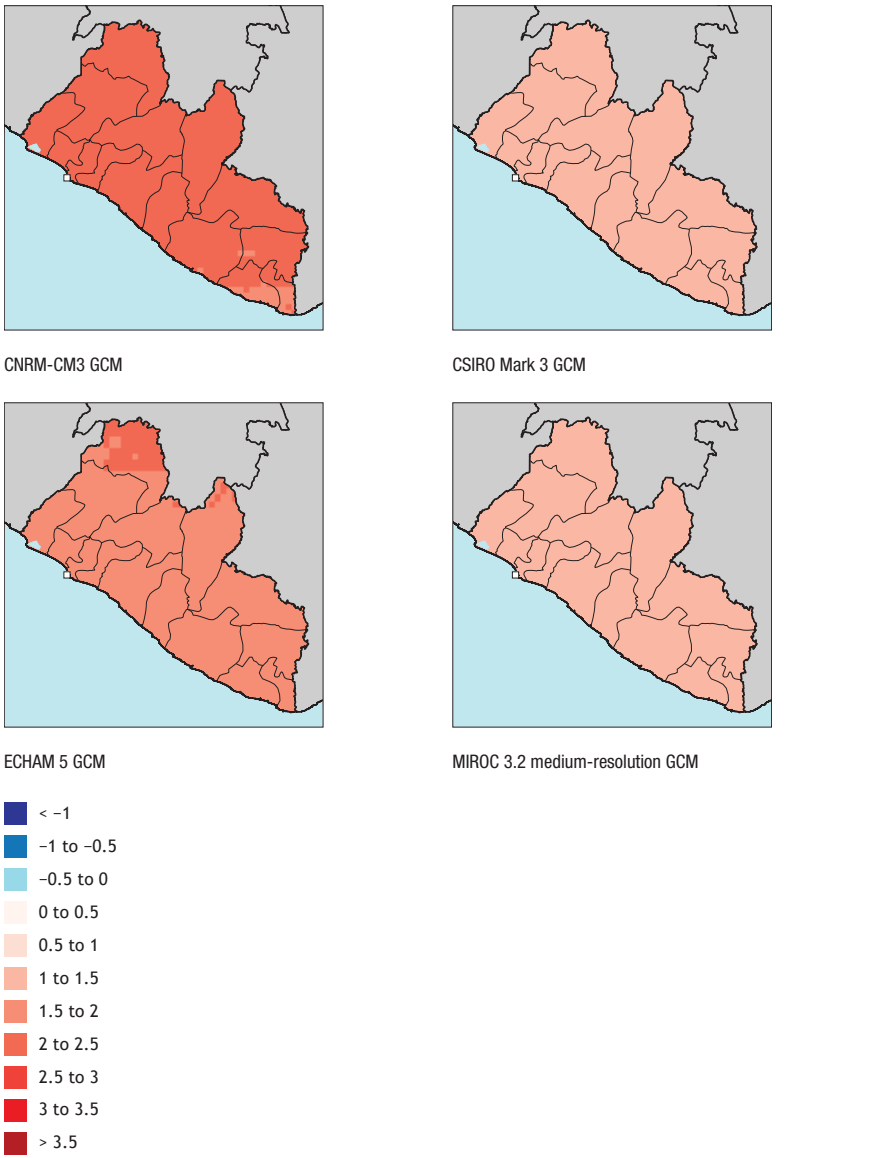
FIGURE 8.14 Changes in mean annual precipitation in Liberia, 2000–2050, A1B scenario (millimeters)



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 8.15 Change in normal daily maximum temperature in Liberia for the warmest month, 2000–2050, A1B scenario (°C)



Source: Authors' calculations based on Jones, Thornton, and Heinke (2009).
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an increase of 1. 0°–1.5°C. The ECHAM 5 GCM predicts an increase of 1.5°–2.0°C.

Crop Physiological Response to Climate Change

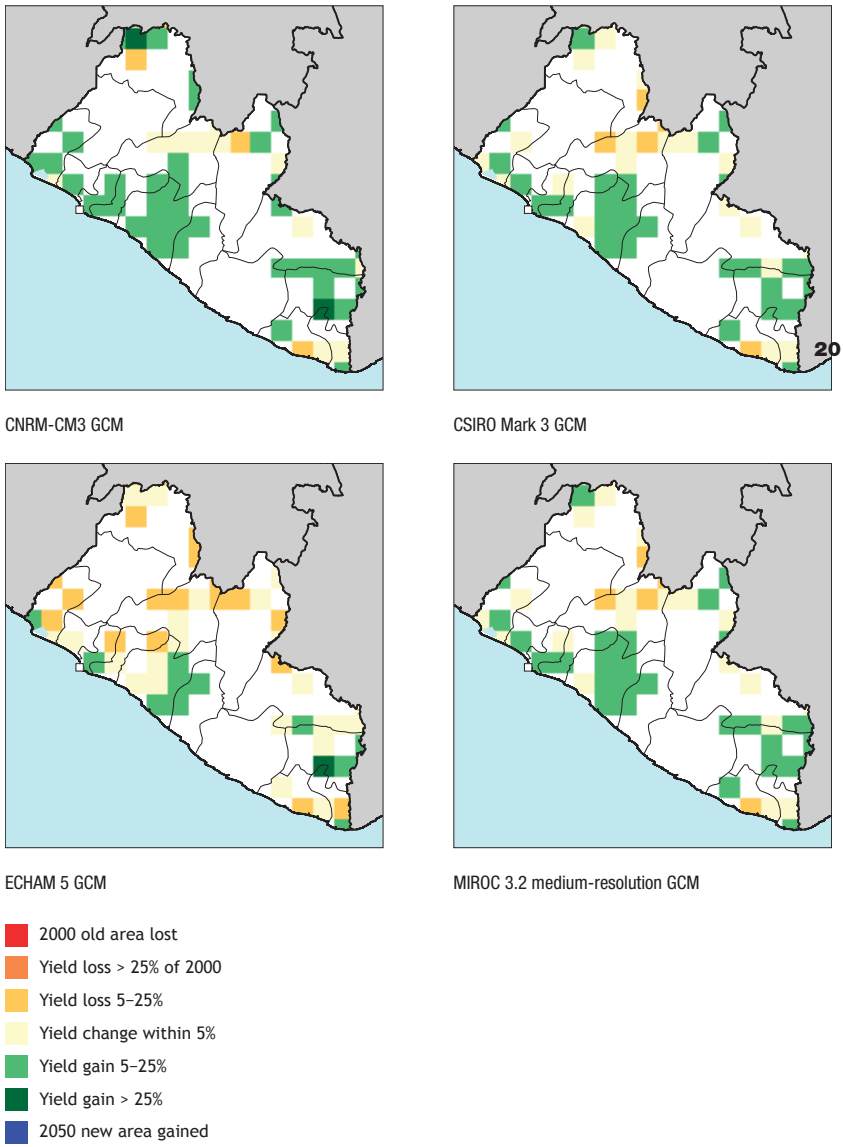
The output for rainfed rice is mapped in Figure 8.16, which compares the potential crop yields in Liberia for 2050 assuming climate change with the potential yields assuming an unchanged (2000) climate. All the GCMs predict more areas of yield increase than yield decrease, and for the most part the changes are less than 25 percent of the baseline yields for 2000. Although the GCMs have very similar results, it seems that the CNRM-CM3 GCM has a slightly higher ratio of gains to losses, and it even has two areas for which yield increases are predicted to exceed 25 percent. The MIROC 3.2 GCM has probably the lowest ratio of gains to losses ratio, with most of the losses concentrated in the northern portion of the country. These results are encouraging because they suggest that climate change will bring more benefits than costs, at least for rainfed rice. It is not entirely clear why the projected drop in annual rainfall in MIROC did not result in more yield reduction, but it could be that the rainfall was not too adversely affected during the growing season, which is all the crop models in the DSSAT software focus on.

Agricultural Vulnerability Scenarios (Crop-Specific)

The next three figures show simulation results from the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) for key agricultural crops in Liberia. The figure for each featured crop has five graphs showing production, yield, area, net exports, and world price. Rice production is shown to increase, reflecting productivity increases. All scenarios show very little change in the area planted with rice (Figure 8.17). Any projected increase in rice production will be the result of improved management, because there are already rice varieties with a yield potential of up to 4 tons. Liberia is not self-sufficient in rice, and the scenarios show an increasing deficit based on an increase in population without a sufficiently large corresponding increase in rice production. An increasing world price for rice would therefore increase the burden on the country's economy.

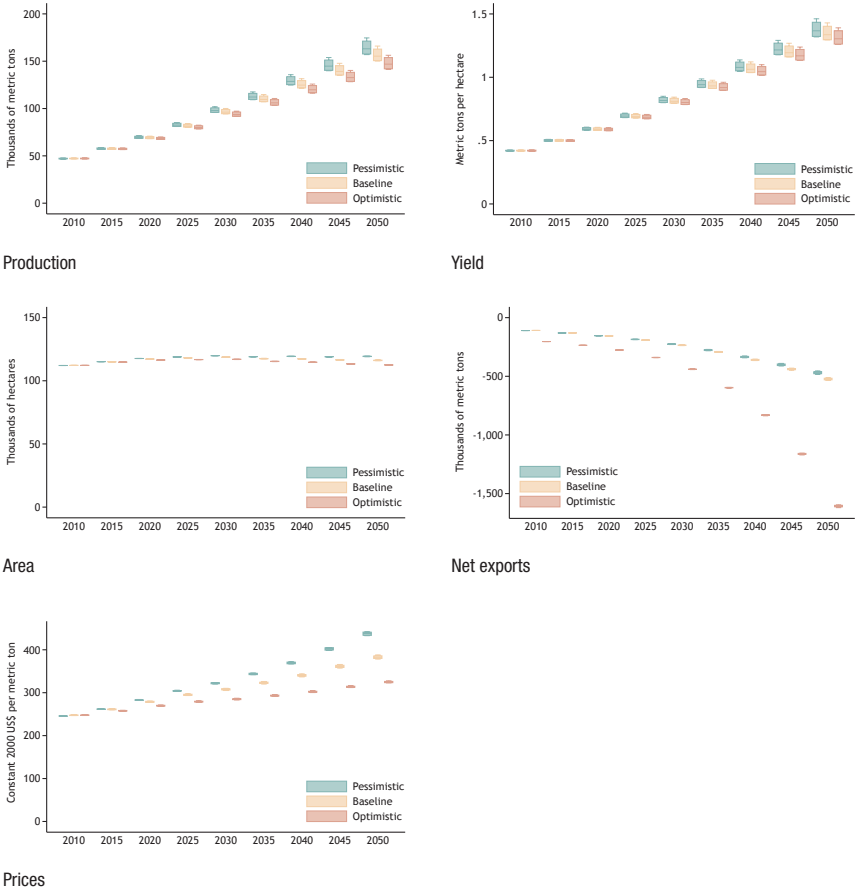
Unlike rice production, cassava production is predicted to increase only until 2030 and then to be relatively flat (with some small increases and some small decreases) thereafter. Similar to the case of rice, improved management practices rather than improved varieties will be responsible for any increase in production (Figure 8.18). The area planted with cassava will decrease more

FIGURE 8.16 Yield change under climate change: Rainfed rice in Liberia, 2000–2050, A1B scenario



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.

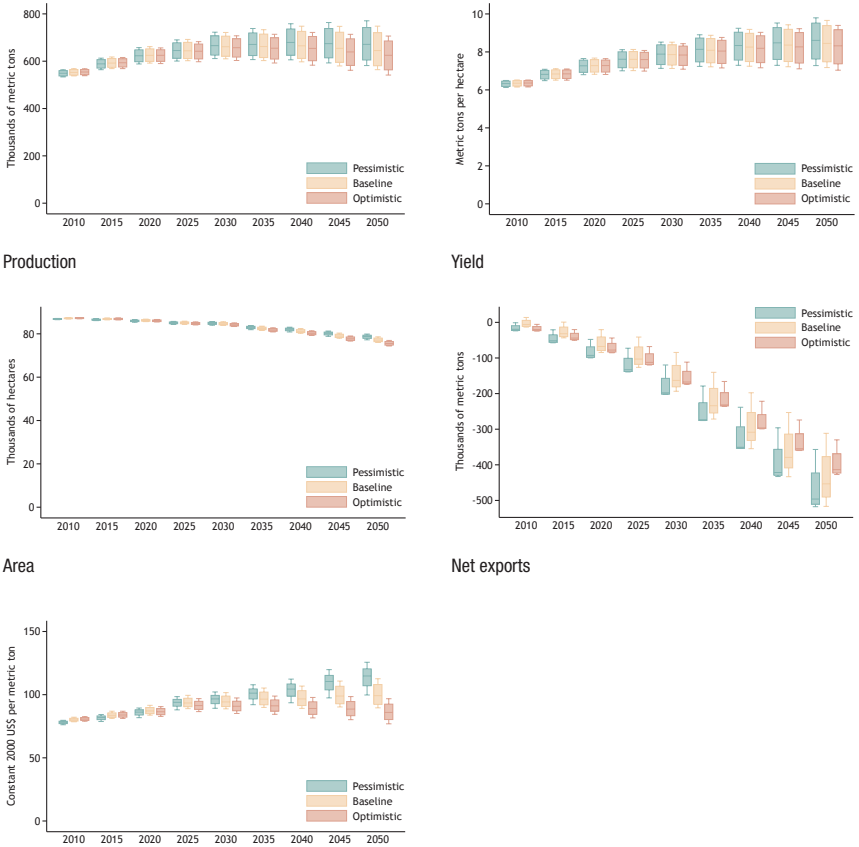
FIGURE 8.17 Impact of changes in GDP and population on rice in Liberia, 2010–50



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 8.18 Impact of changes in GDP and population on cassava in Liberia, 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.

than the area planted with rice. The decrease in the area planted and the possible increase in population will cause the country to become an increasingly larger importer of cassava. After 2025, the world price for cassava will tend to be higher in the pessimistic scenario than in the optimistic scenario.

Unlike the production of rice and cassava, the production of sugarcane will be significantly influenced by the area under cultivation. Figure 8.19 shows the area planted with sugarcane increasing in line with production increases, while productivity appears to be unchanged. However, similar to the cases of both rice and cassava, the net export of sugarcane would decrease despite the increase in world price. The increase in imports is a consequence of increased consumption in the country as a result of population increase.

Human Vulnerability Scenarios

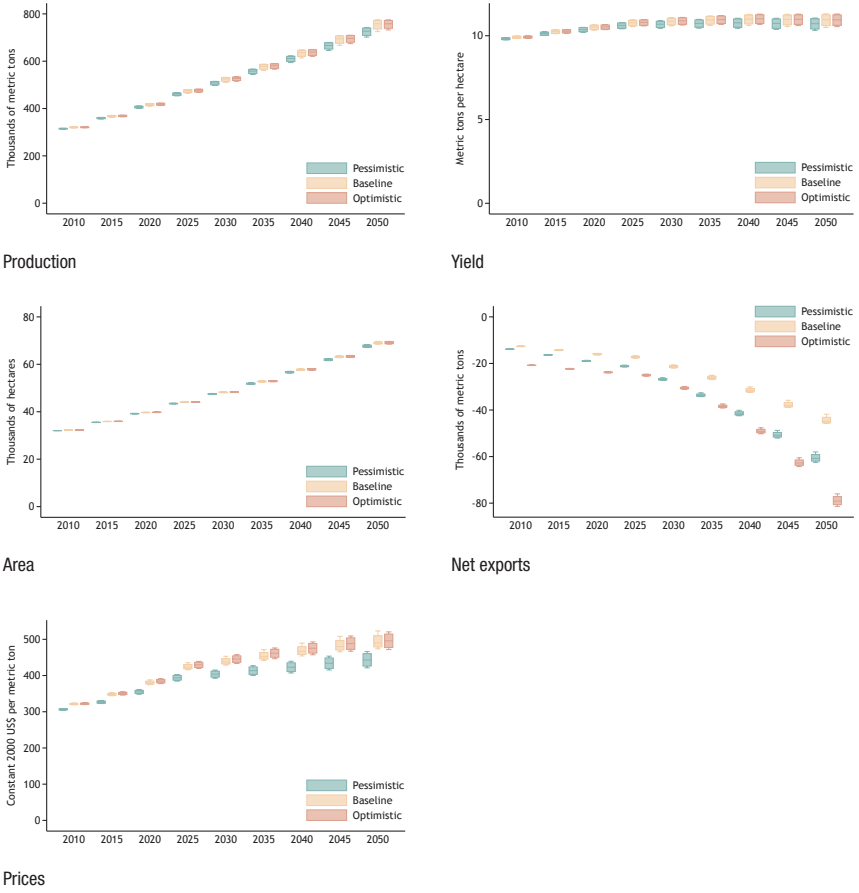
In addition to agricultural outcomes, IMPACT also predicts the number of malnourished children under the age of five and the number of available kilocalories per capita. Figure 8.20 shows the impact of future GDP and population scenarios on under-five malnutrition rates. The box-and-whisker plots in the figure indicate the range of climate scenario effects. Low GDP per capita and a larger population will result in an increase in the number of children under age five who suffer from malnutrition until 2030 in the baseline scenario and until 2035 in the pessimistic scenario, though the malnutrition rates might fall slightly during those years because the population is projected to grow at a faster rate than the number of malnourished children.

We also note that the kilocalories available to each person will eventually increase with the increase in GDP per capita (Figure 8.21), though they will be fairly constant between 2010 and 2025. There is a correlation between the availability of kilocalories and the reduction of under-five malnutrition.

Conclusions and Policy Recommendations

Liberia has experienced a relatively high rate of urban population growth promoted by better transport and communication systems, fertile agricultural lands, local alluvial mining activities, and the presence of international mining and agricultural companies, as well as opportunities for employment and trade with contiguous West African countries. Monrovia is the most densely populated city due to its relatively superior socioeconomic conditions. Major challenges associated with population growth include dilapidated infrastructure,

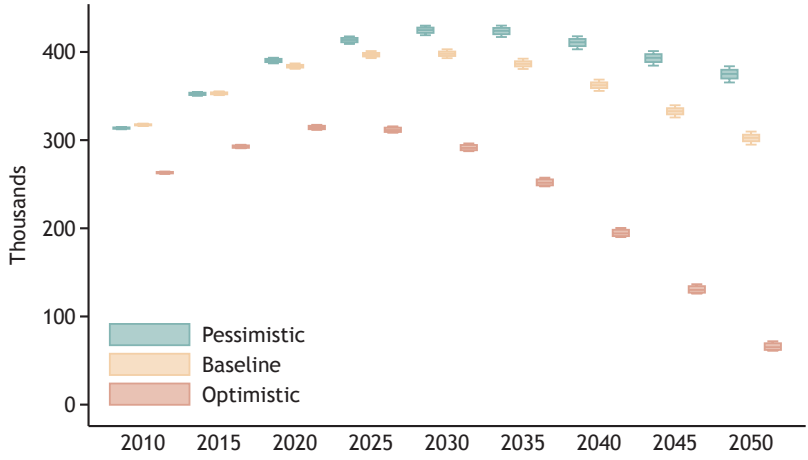
FIGURE 8.19 Impact of changes in GDP and population on sugarcane in Liberia, 2010–50



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.

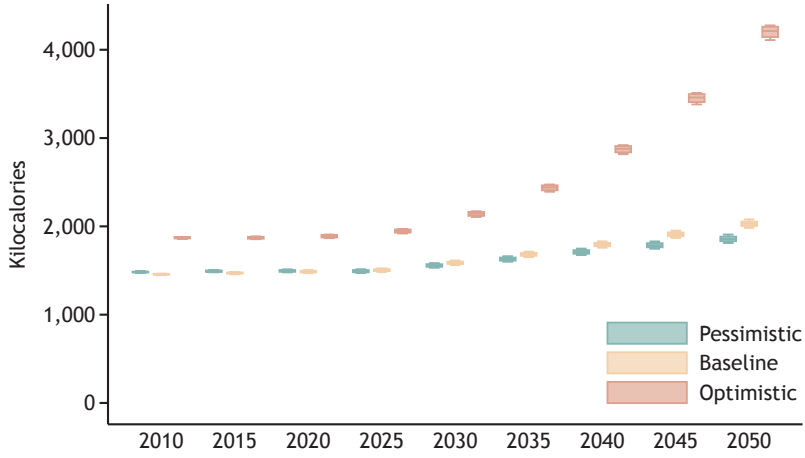
FIGURE 8.20 Number of malnourished children under five years of age in Liberia in multiple income and climate scenarios, 2010–50



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 8.21 Kilocalories per capita in Liberia 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.

a weak health system, malnutrition, a lack of clean drinking water, bad road conditions, and high levels of unemployment. As the population increases, there will be a high demand not only for the limited basic social services but also for the untapped natural resources. Transportation is very important for agricultural development. In Liberia, the poor road conditions make it very difficult to transport agricultural products from the southeastern counties to Monrovia.

During the civil war, the share of agricultural GDP increased sharply because most other sectors of the economy became disrupted and nonfunctional. The majority of the population is engaged in agriculture. However, 90–95 percent of the population of Liberia lives on less than US$2 per day. This is certainly a situation that needs significant improvement. To address this issue of extreme poverty, the Government of Liberia has developed a Poverty Reduction Strategy.

Although our analysis shows an increase in the importation of staple commodities, it does not appear that this will adversely affect the nation's food security, because the IMPACT model predicts that in the latter half of the period under study, the malnutrition rates of children will decline and the number of calories consumed per capita will increase.

There has been considerable variation in the predictions for temperature and precipitation changes due to climate change, which has resulted in different projected outcomes regarding the production of rice, with some models showing most areas actually increasing in yield due to favorable changes in climate and other models showing losses in yield due to unfavorable changes in climate. These results point to a need for flexibility and responsiveness in the agricultural sector in regard to adapting to climate change.

Based on the results of our study, we recommend the following:

- Liberia's Ministry of Agriculture (MOA) should improve its policy on monitoring climate change, incorporating guidance on adaptation measures to reduced rainfall and higher temperatures.
- The MOA should strengthen its policies on nationwide awareness of environmental considerations in all agricultural activities by providing farmers with climate change–related information.
- The government should develop policies to address the challenges associated with population growth.

- The government should improve the implementation of its policy on rehabilitated, reconstructed, and recommissioned rural infrastructure to facilitate transporting agricultural products from rural to urban areas.
- The MOA should incorporate policies to support the development of suitable varieties of major crops as well as associated management practices to enhance the productivity of these crops, particularly staple foods and rice.
- The government should strengthen its policy on food and nutrition security for vulnerable groups—especially those who depend on agricultural activities for their livelihoods—including the provision of safety nets.

As Liberia continues to rebuild after decades of civil unrest, there are many competing demands for limited funds. The good news about adaptation to climate change is that many of the same policies and investments needed to make agriculture more productive now will also help farmers adapt in the future. It is encouraging that the government has taken steps to increase funding to agriculture since 2005, and agriculture as a sector is receiving substantially more money than before. Continued commitment to the sector by the government will likely result in much enhanced performance, both in the short run and in the longer run, when the more serious impacts of climate change will be felt.

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