

**MALAWI**

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**M**alawi is located in the eastern part of southern Africa between latitude 9°22' and 17°7' South and between longitude 32°40' and 35°55' East. Its total area is 118,483 square kilometers, of which 94,275 square kilometers is land, while 24,208 square kilometers is water. Malawi is a land-locked country bordering Tanzania, Mozambique, and Zambia and does not have direct access to the Indian Ocean.

The topography of the country is highly varied; the Great Rift Valley runs from north to south through the country, containing Lake Malawi, and the landscape around the valley consists of large plateaus at an elevation of around 800–1,200 meters but with peaks as high as 3,000 meters. The climate of the country is tropical, but its high elevation means that the temperatures are relatively cool.

Lake Malawi is Africa's third largest lake and the world's eleventh largest and covers much of the country. It measures about 550 kilometers by 15–80 kilometers and occupies a deep Rift Valley trough that cuts through the country along a north–south line. The lake's surface elevation is about 474 meters, and its deepest point is 230 meters below sea level.

Lake Malawi and the Shire River are part of the Great Rift Valley, and on either side of the rift are escarpments. In the west, the highlands include the Nyika (highest elevation 2,607 meters), Viphya (2,058 meters), and Dedza (2,198 meters) Plateaus; in the east they include the Shire Highlands (1,774 meters), the Zomba Plateau (2,087 meters), and the Mangochi and Namizimu Hills (1,796 meters). The eastern highlands continue northward into Mozambique and Tanzania. Behind the rift-edge highlands the land descends gently to the Central African Plateau, which, at elevations around 1,000 meters, covers the Lilongwe and Kasungu Plains. The country's lowest elevation of about 37 meters is on the Rift Valley floor at the extreme south, while Mulanje Mountain, an ancient volcanic plug standing on the plateau to the southeast, at 3,050 meters, is the highest point in central Africa.

### **Climate and Climate Change in Malawi**

The great variations in Malawi's landscape result in wide spatial differences in climate. The vast water surface of Lake Malawi has a cooling effect, but because of its low elevation, the margins of the lake generate long hot seasons and high humidity, with a mean annual temperature of 24°C (75°F).

The climate is tropical continental but is significantly moderated by the effects of Lake Malawi, high altitudes, and proximity to the influence of westerly frontal systems that move eastward around the South African coast. There are two distinct seasons: the rainy season (October–April) and the dry season (May–October). The latter is further subdivided into two parts: (1) cool and wet (May–August) and (2) hot and dry (September–October).

### **Climate Change and the Vulnerability of Agriculture**

Agriculture is the backbone of Malawi's economy, providing more than 50 percent of the country's gross domestic product (GDP). Both crop and livestock production depend on rainfall as the main source of water supply because less than 5 percent of arable land is under irrigation. In the past 30 years, Malawi has experienced variability and unpredictability in its seasonal rainfall.

High variability in rainfall could imply recurrent drought conditions in lower-rainfall zones (e.g., in the Shire Valley region). Malawi could therefore subsequently experience failure of the more desired foodcrops and pasturage. These changes are expected to cause many shifts in food production. Most crops are sensitive to changes in climate conditions, including alterations in temperature, moisture, and carbon dioxide levels. Furthermore, major changes in climate influence populations of beneficial organisms and pests and alter their effectiveness in agricultural ecosystems. Although there will be gains in certain crops in some regions of the world, the overall global impacts of climate change on agriculture, especially rainfed agriculture, are expected to be negative, threatening global food security. These impacts are (1) direct, on crops and livestock productivity domestically; (2) indirect, on the availability and prices of food domestically and in international markets; and (3) indirect, on income from agricultural production at both the farm and the country levels.

This chapter concerns the outcomes of various general circulation models (GCMs) relating to Malawi's agricultural vulnerability to climate change and how various policies and programs influence the capacity of the national systems to address the vulnerability of agriculture to climate change.

## Review of Current Trends

### Climate Change Concepts

In the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), Working Group 1 defines *climate* as “average weather, usually described in terms of the mean and variability of temperature, precipitation, and wind over a period of time ranging from months to millions of years (the classical period is 30 years)” (IPCC 2007).

GCMs model the physics and chemistry of the atmosphere, its interactions with oceans and land surface, and greenhouse gas levels. Several GCMs have been developed independently around the world. In this study, GCMs together with crop and socioeconomic models were used to simulate the interactions between humans and their surroundings. Precipitation and temperature levels in the A1B scenario were obtained from four GCMs: CNRM-CM3, CSIRO Mark 3, ECHAM 5, and MIROC 3.2.<sup>1</sup> These data were used with Decision Support Software for Agrotechnology Transfer (DSSAT) crop models to assess the likely impact of climate change on yield. Additionally, the International Model for Policy Analysis of Agricultural Commodities and Trade developed by the International Food and Policy Research Institute was used to estimate the impact of GDP and population, together with climate change, on the various agriculture outcomes: yield in metric tons per hectare; crop area, net exports; and world price for the crop.

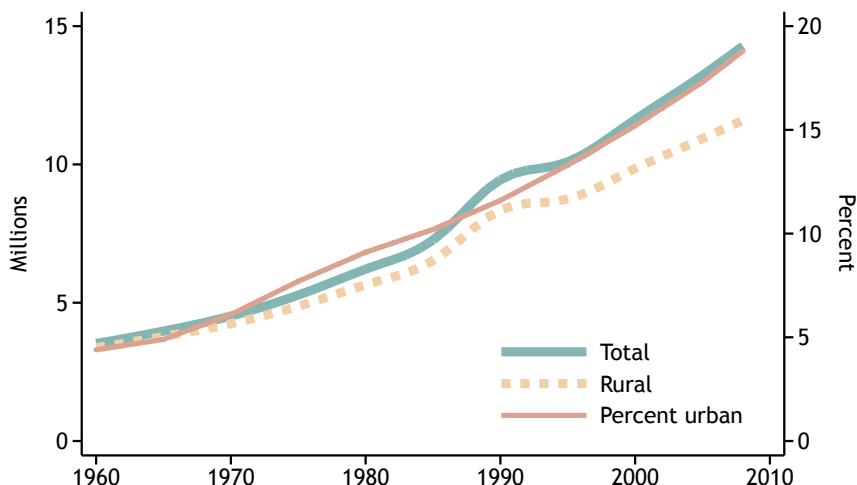
### Economic and Demographic Indicators

#### Population

The 2008 Malawi Population and Housing Census revealed a total population of nearly 13.1 million and a national annual population growth rate of 2.8 percent (World Bank 2009). The population increased from 9.9 million in 1998, so the rate of the overall population increase was 32 percent in 10 years. The population 18 years of age and over was 6.2 million, of whom 3.2 million were female and 3 million were male. In Figure 5.1, the total and rural population

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<sup>1</sup> 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. CSIRO is a climate model developed at the Australia Commonwealth Scientific and Industrial Research Organisation. ECHAM 5 is a fifth-generation climate model developed at the Max Planck Institute for Meteorology in Hamburg. MIROC is the Model for Interdisciplinary Research on Climate, developed at the University of Tokyo Center for Climate System Research.

**FIGURE 5.1** Population trends in Malawi: Total population, rural population, and percent urban, 1960–2008

Source: *World Development Indicators* (World Bank 2009).

counts (left axis) and the share of the population that was urban (right axis) are provided.

In 2008 the urban population of Malawi constituted 18.8 percent of the estimated population (World Bank 2009), up from 8.5 percent in 1994. In such urban areas, employment, water services, electricity, postal services, bus services, and businesses are most prominent. The relative population growth rates and urbanization are shown in Table 5.1. The decade with the highest growth rate was 1980–1989 (4.3 percent), and this was largely due to a major influx of refugees from the war in Mozambique. The decade with the lowest

**TABLE 5.1** Population growth rates in Malawi, 1960–2008 (percent)

Decade	Total growth rate	Rural growth rate	Urban growth rate
1960–1969	2.4	2.3	5.6
1970–1979	3.2	2.9	7.3
1980–1989	4.3	4.0	6.7
1990–1999	1.8	1.4	4.5
2000–2008	2.6	2.0	5.2

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

growth rate was 1990–1999 (1.80 percent), which coincided with the repatriation of the refugees back to Mozambique after the war.

Malawi has witnessed rapid urbanization in the past 50 years, with urban growth rates higher than rural growth rates. Much of the urbanization has been due to youth looking for employment and business opportunities. The highest rate of urbanization was seen during 1970–1979 (at 7.3 percent), and the lowest rate was seen during 1990–1999 (at 4.50 percent).

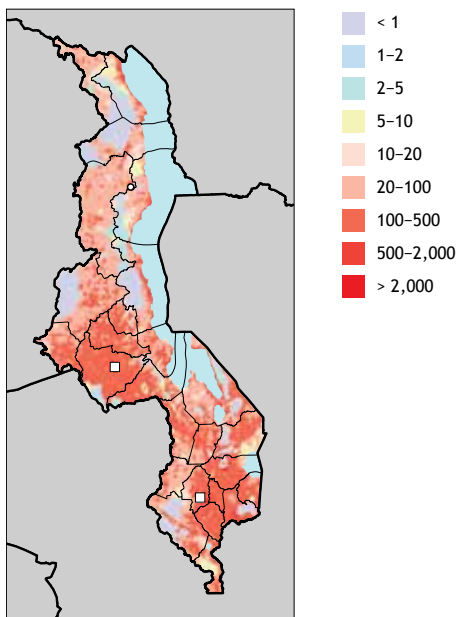
One of the United Nations (UN) Millennium Development Goals (MDGs) on education, especially MDG 2, calls for universal access to basic education by 2015. Malawi has not made significant progress toward achieving this goal. The program is off track; only about 38 percent of the 91 percent of children who enroll in primary school complete Standard 8 (Malawi, Ministry of Economic Planning and Development 2006). Further, at the completion of Standard 8, most girls drop out of schools for various reasons. Policymakers should ensure that programs are in place to keep girls in school beyond Standard 8.

Despite the high rate of growth in the urban population, the rural population is still growing at a rate of 2 percent per annum. This indicates that agriculture will continue to be important in the economy of Malawi for the foreseeable future.

The population density in south and central Malawi is higher than in the north (Figure 5.2). The actual population density figures from the last census are 185 persons per square kilometer for the south, 154 for the center, and 63 for the north (Malawi, National Statistics Office 2008). The geographic distribution of the population in Malawi is shown in Figure 5.2, based on data available in 2000.

### **Income**

Malawi is one of the least developed countries in the world, and therefore poverty remains a key challenge in the country. Figure 5.3 shows the GDP per capita for 1960–2009. There was a steady increase in GDP per capita of about \$30 per decade from 1960 to about 1980; thereafter, no significant growth has been seen. However, significant progress has been made in tackling food insecurity. During the past decade, the country has witnessed increased household food security (Malawi, Ministry of Agriculture and Food Security 2006). Although overall well-being remains low, it is improving, to the extent that the country's UN Human Development Index score was 0.493 in 2009, which gave Malawi a ranking of 160 out of 182 countries; it had moved up from 164 out of 177 countries in 2007/2008. The share of agriculture in GDP has

**FIGURE 5.2** Population distribution in Malawi, 2000 (persons per square kilometer)

Source: CIESIN et al. (2004).

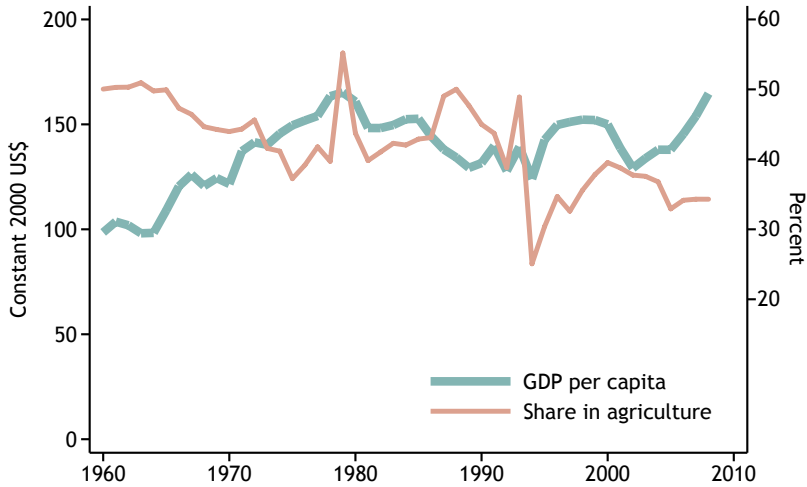
fallen through the years, from around 50 percent in 1960 to around 35 percent in 2008 (see Figure 5.3).

The country's education enrolment and labor statistics are shown in Table 5.2. The data show that the primary school gross enrollment rate in Malawi is very high (116.5 percent). However, the secondary school enrollment rate is low (28.3 percent). This is due to the high dropout rates among girls, largely due to early marriages and family pressures to remain at home. Malawi needs an educated population to manage climate shocks. This is particularly important because the agriculture sector employs 90 percent of the rural population, of which 80 percent are employed in off-farm activities or as day laborers.

Additional well-being indicators for Malawi are shown in Figure 5.4. Over the past 50 years, life expectancy at birth marginally improved, from 37 years in 1960 to about 50 years in 1992, before dropping to 45 years in 2002. This drop has been attributed to the HIV/AIDS pandemic. Life expectancy has since improved, to about 48 years in 2005, and it is currently rising.

The under-five mortality rate has significantly dropped, to nearly 100 deaths per 1,000 births as of 2010, from more than 360 in 1960. This is at least in part

**FIGURE 5.3** Per capita GDP in Malawi (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.

because several government programs—for immunization, provision of bed nets, and improvement of nutrition—are under way, checking malaria and other diseases. This trend needs to be sustained.

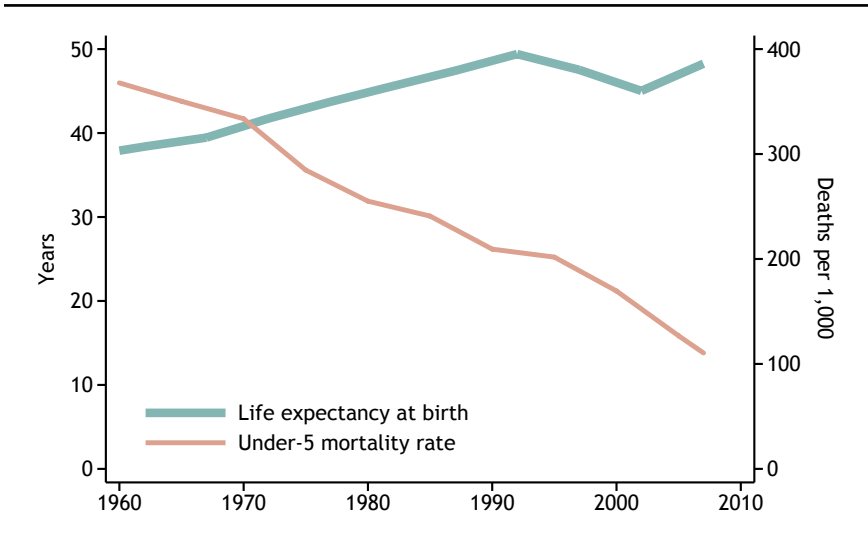
In Figure 5.5, the proportion of the population living on less than \$2 per day is given. The highest concentration of poor people live in the southern (about 49.7 percent) and central (about 33.9 percent) regions, which are also the most densely populated rural areas (Malawi, Ministry of Agriculture and Food Security 2006).

**TABLE 5.2** Education and labor statistics for Malawi, 2000s

Indicator	Year	Value (percent)
Primary school enrollment (percent gross, three-year average)	2007	116.5
Secondary school enrollment (percent gross, three-year average)	2007	28.3
Adult literacy rate	2007	71.8
Percent employed in agriculture	2007	90.0
Percent with vulnerable employment (own farm or day labor)	2007	80.0
Under-five malnutrition (weight for age)	2005	18.4

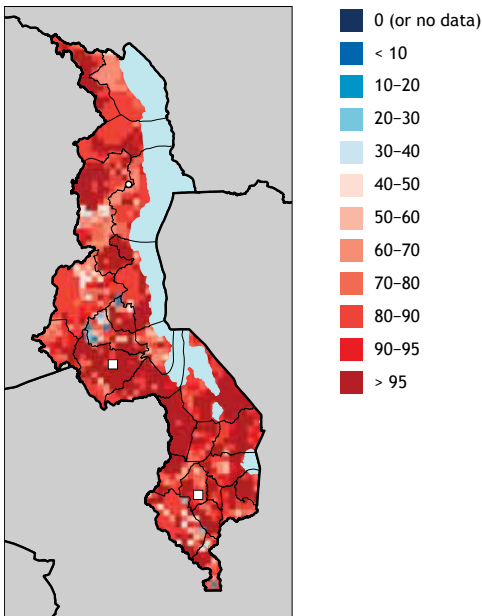
Source: *World Development Indicators* (World Bank 2009).

**FIGURE 5.4** Well-being indicators in Malawi, 1960–2008



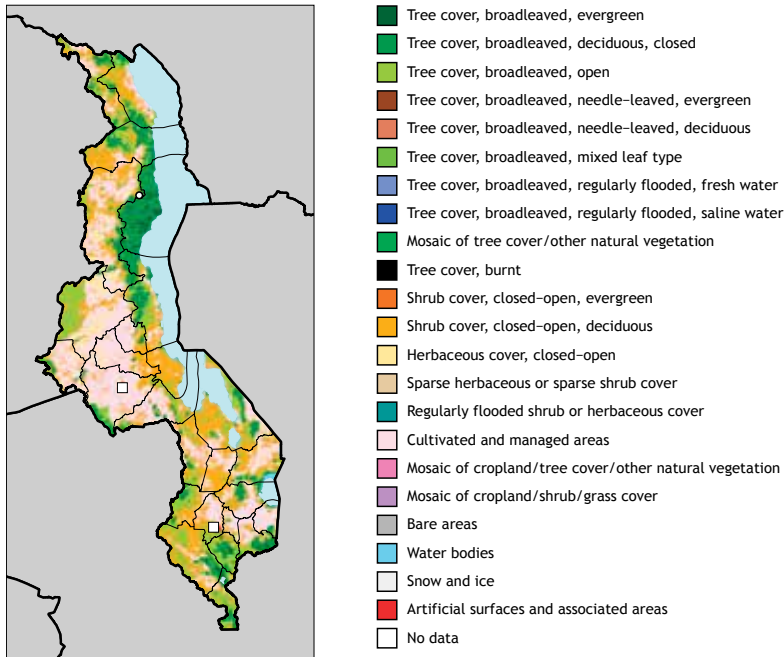
Source: *World Development Indicators* (World Bank 2009).

**FIGURE 5.5** Poverty in Malawi, circa 2005 (percentage of population below US\$2 per day)



Source: Wood et al. (2010).

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

**FIGURE 5.6** Land cover and land use in Malawi, 2000

Source: GLC2000 (Bartholome and Belward 2005).

### Land Use Overview

The land cover and land use in Malawi are shown in Figure 5.6. In the 1900s, prior to colonization, almost 100 percent of the land area in Malawi was covered with forests. The forest cover has decreased drastically due to increased human activity. For example, between 1972 and the 1990s, forest resources decreased by 41 percent, representing an average annual loss of 2.4 percent (Malawi SDNP 1998). This was due to several factors, including the increasing growth of urban settlements, overdependence on forest products as sources of energy, and the clearing of forests for agriculture-related activities. Further, in the tobacco sector, the processing of flue-cured tobacco by most commercial estates continued to contribute significantly to environmental degradation. The loss of biomass due to the harvesting of wood to provide fuel for tobacco curing is estimated at almost 85,000 cubic meters per year (Malawi, Ministry of Lands and Housing 2002). Over a 20-year period (1972–1992), Malawi's forest resources were reduced by more than half (57 percent) of their size, with an estimated annual deforestation rate of 2.8 percent (Haarstad 2009).

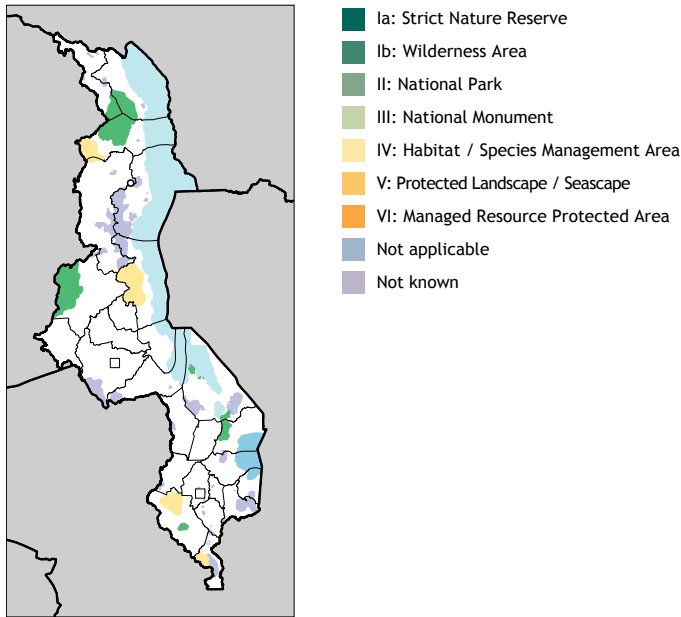
Approximately 35 percent of the land area of Malawi is now covered by forests. The country has between 5,000 and 6,000 plant species in both montane and lowland ecosystems. According to the Red Data Lists Assessment for Malawi, 114 plant species are endemic, 5 species are critically endangered, and 14 species are endangered (IUCN 2010).

In Malawi the Land Act classifies three major forms of tenure, namely public, private, and customary (Malawi, Ministry of Lands and Housing 2002). The adoption of the land tenure system will facilitate farmers' investment in land improvement and the improvement of agricultural technologies such as agroforestry and reforestation.

Agricultural activities in Malawi are located in all the rural areas where there is cultivable land. Malawi has 3 million hectares under cultivation, with more than 95 percent of this land under rainfed agriculture. The average size of land holdings per household in Malawi is 1.2 hectares, while the average land per capita is 0.33 hectare (Malawi Government and World Bank 2006). The rainfed nature of smallholder farming makes agricultural production prone to adverse weather conditions such as droughts and floods. Drought years have most often resulted in poor crop yields and sometimes in total crop failure, leading to serious food shortages, hunger, and malnutrition. Flooding also disrupts food production, destroys household and community assets, and causes loss of life for both livestock and people.

In Malawi, places where no cultivation is allowed are protected areas, including parks and reserves (Figure 5.7). These locations provide important protection for fragile environmental areas, which may also be important for the tourism industry. The national parks are Nyika, Kasungu, Lengwe, and Liwonde; the game reserves are Nkhota Kota, Majete, Dzalanyama, and Vwaza Marches. Other protected areas are Lake Chilwa and Mulanje Mountain, which are designated as conservation and world heritage sites by the United Nations Educational, Scientific, and Cultural Organization. The parks and reserves are useful as environmental protection areas, acting as water catchment areas for several important rivers in Malawi. The parks and reserves are also useful areas for the protection and conservation of wildlife and for tourism.

The major climatic hazard that affects wildlife in the protected areas is drought, which affects animal reproduction systems and migratory habits. Extended drought also leads to the deaths of animals. For example, the 1979/1980 drought resulted in the deaths of Nyala antelope in Lengwe National Park and in the migration of most of the animals from the reserve (Malawi, EAD 2006).

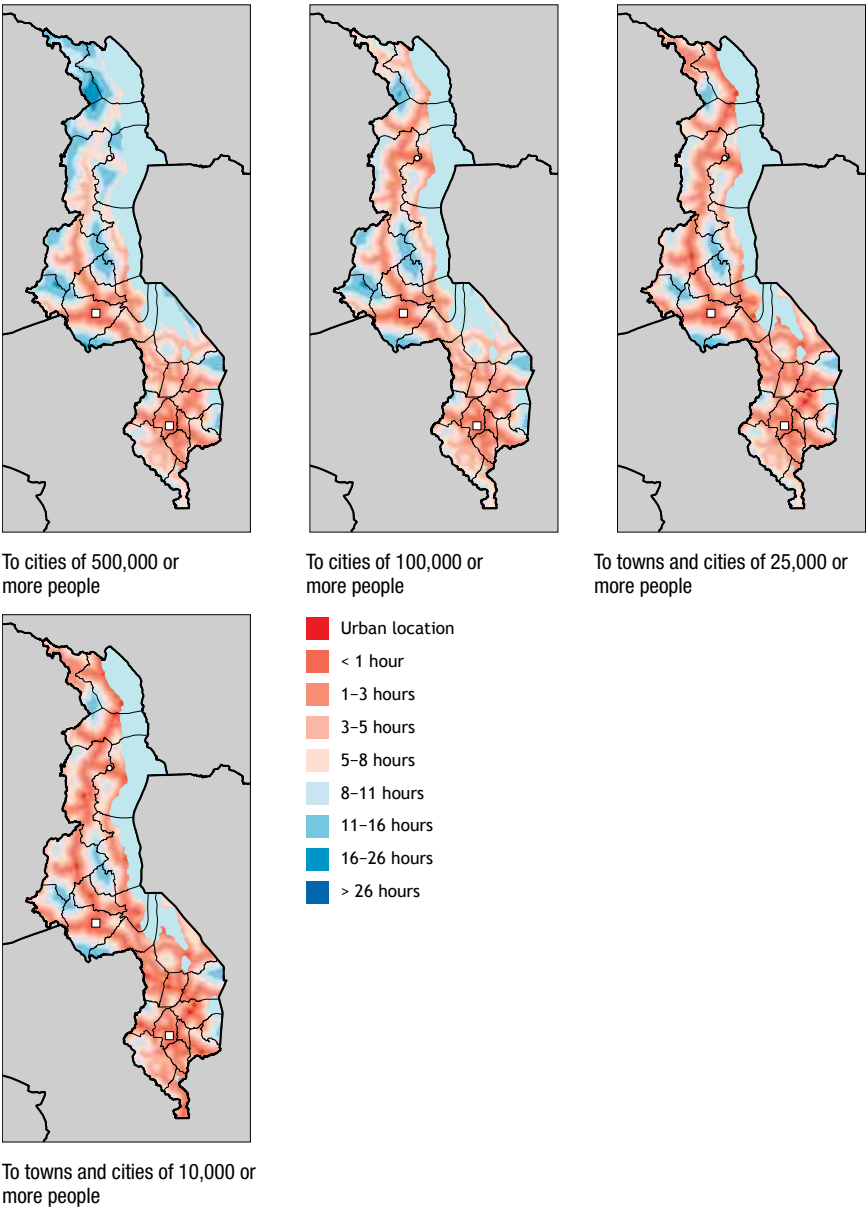
**FIGURE 5.7** Protected areas in Malawi, 2009

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).

Figure 5.8 shows the travel times to urban areas of various sizes, which provide potential markets for agricultural products. The importance of transport costs should be considered in policy planning and execution when considering 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 5.7.

Malawi has four major cities: Blantyre and Zomba in the south, Lilongwe in the center of the country, and Mzuzu in the north. Malawi also has the municipal towns of Luchenza and Mangochi in the south, Kasungu and Salima in the center, and Karonga in the north. There are more trading centers in the south, followed by the center; the north has the fewest. It follows, therefore, that in the northern part of the country, more people take longer than 11–16 hours to travel to big cities, which are largely found in the center and the south. The southern part of the country is more urbanized than the rest of the country.

**FIGURE 5.8** Travel time to urban areas of various sizes in Malawi, circa 2000



Source: Authors' calculations.

### Agriculture Overview

In Tables 5.3–5.5, the key agricultural commodities of Malawi are analyzed in terms of area harvested, value of production, and consumption of food commodities.

Maize is the staple foodcrop, but because of its low productivity, it is not surprising that the total acreage allocated to this food commodity is very large (Figure 5.9). The root and tuber crops (cassava and potatoes) have a high allocation, 362,000 hectares, while the legumes and pulses have a slightly higher allocation. Table 5.4 shows that the production value of root and tuber crops is significantly higher than that of cereals (maize and rice) and the commercial crops (tobacco and sugarcane). This could be in part because the value of cassava for home consumption might be overestimated. Table 5.5 reveals that the consumption of root and tuber crops supplements that of maize as a staple for the majority of households. The country has recently witnessed the increased growing of rice, which is an important staple and is exported to neighboring countries. It should be included in the basket of food security foods for the country.

**TABLE 5.3** Harvest area of leading agricultural commodities in Malawi, 2006–2008 (thousands of hectares)

Rank	Crop	Percent of total	Harvest area
	Total	100.0	3,389
1	Maize	45.0	1,525
2	Groundnuts	7.6	256
3	Beans	7.5	254
4	Potatoes	5.6	189
5	Cassava	5.1	173
6	Pigeon peas	4.7	160
7	Tobacco	4.1	139
8	Chickpeas	2.8	95
9	Cowpeas	2.4	80
10	Sorghum	2.2	73

Source: FAOSTAT (FAO 2010).

Note: All values are based on the three-year average for 2006–2008.

**TABLE 5.4** Value of production of leading agricultural commodities in Malawi, 2005–2007 (millions of US\$)

Rank	Crop	Percent of total	Value of production
	Total	100.0	2,541.8
1	Cassava	21.8	553.6
2	Maize	19.6	499.0
3	Potatoes	16.9	429.7
4	Sugarcane	6.9	174.4
5	Tobacco	4.5	114.5
6	Bananas	3.8	97.2
7	Groundnuts	3.7	94.8
8	Beans	3.5	88.1
9	Rice	2.5	64.7
10	Plantains	2.5	62.5

Source: FAOSTAT (FAO 2010).

Note: All values are based on the three-year average for 2005–2007. US\$ = US dollars.

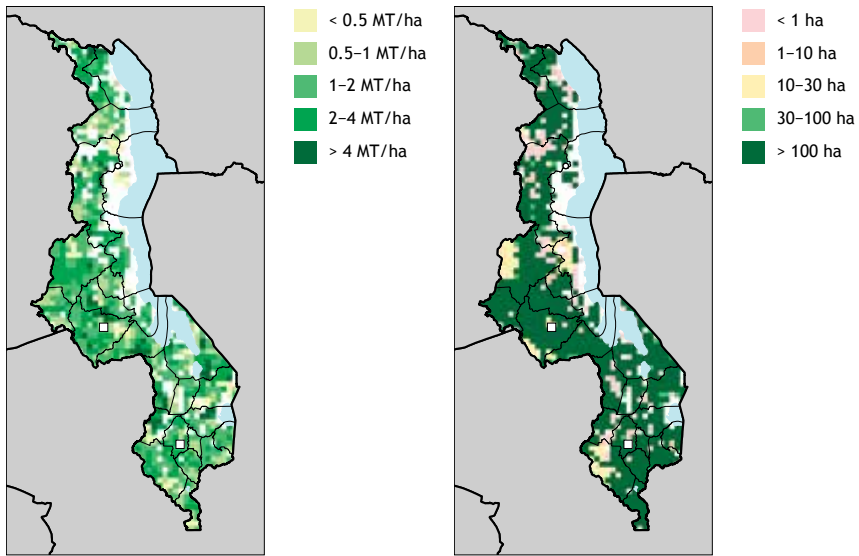
**TABLE 5.5** Consumption of leading food commodities in Malawi, 2003–2005 (thousands of metric tons)

Rank	Crop	Percent of total	Food consumption
	Total	100.0	6,237
1	Maize	26.1	1,631
2	Cassava	22.6	1,408
3	Potatoes	20.3	1,268
4	Bananas	5.0	312
5	Plantains	4.2	261
6	Other fruits	3.8	236
7	Other vegetables	3.2	198
8	Sugar	2.5	156
9	Fermented beverages	2.3	145
10	Other pulses	1.8	112

Source: FAOSTAT (FAO 2010).

Note: All values are based on the three-year average for 2003–2005.

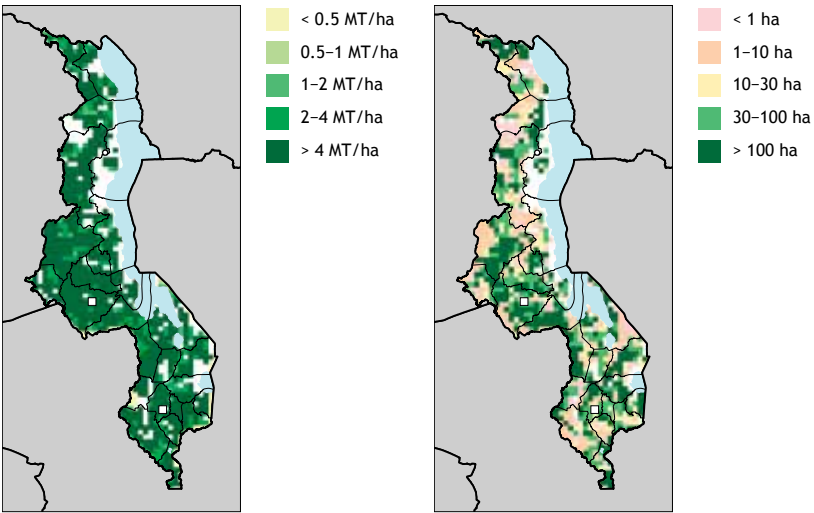
**FIGURE 5.9** Yield (metric tons per hectare) and harvest area density (hectares) for rainfed maize in Malawi, 2000



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

The estimated yield and growing areas for key crops are shown in Figures 5.9–5.13. The yields of rainfed maize in Malawi range from 1.5 metric tons per hectare to 3 metric tons per hectare (see Figure 5.9). These are comparatively low yields when compared to what is possible at research stations. Figure 5.10 shows that the yields of rainfed cassava in Malawi are over 10 metric tons per hectare in most areas. Most of the cassava is grown along the shores of lakes and in many other parts of Malawi, where it has recently been popularized as an important food security crop. The production of rainfed cotton is low (Figure 5.11), with yields ranging from 0.5 to 2 metric tons per hectare, whereas for groundnuts the yields are between 0.5 and 1 metric ton per hectare (Figure 5.12). The yields of rainfed beans in Malawi are generally low due to insect and pest infestations during the growing season (Figure 5.13). Thus yields as low as 0.25–1.0 metric ton per hectare are normal on most smallholder farms.

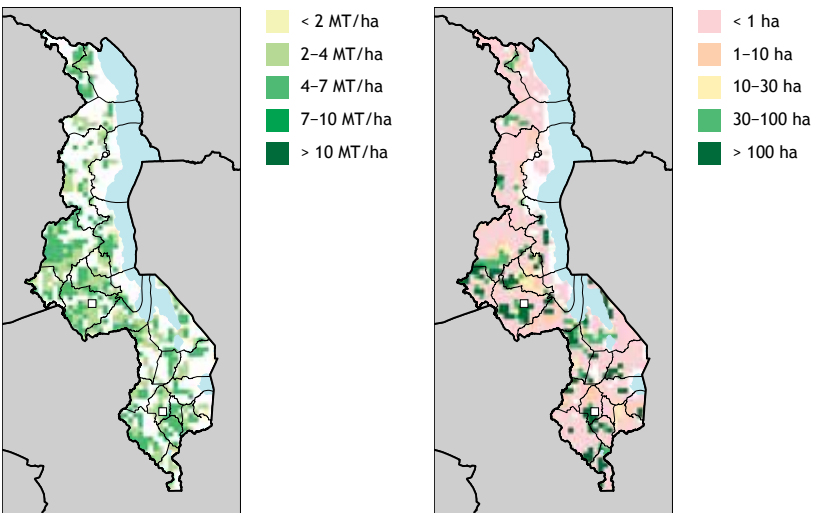
**FIGURE 5.10** Yield (metric tons per hectare) and harvest area density (hectares) for rainfed cassava in Malawi, 2000



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

Note: ha = hectare; MT/ha = metric tons per hectare.

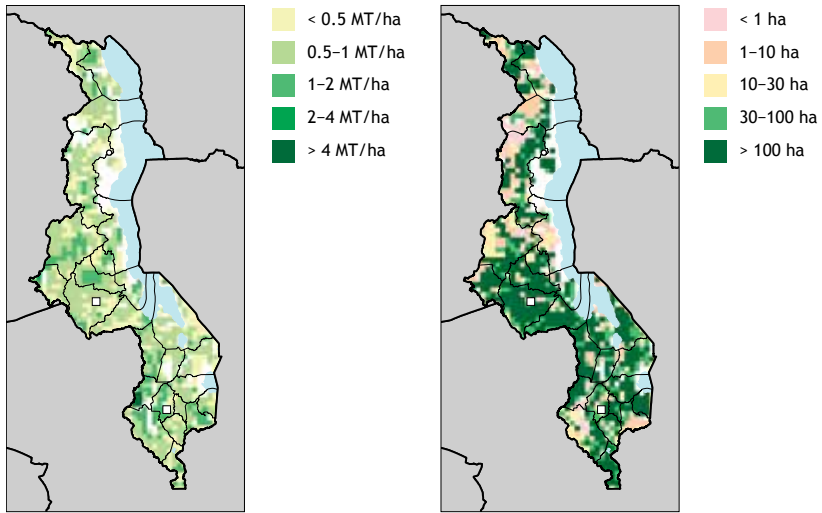
**FIGURE 5.11** Yield (metric tons per hectare) and harvest area density (hectares) for rainfed cotton in Malawi, 2000



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

Note: ha = hectare; MT/ha = metric tons per hectare.

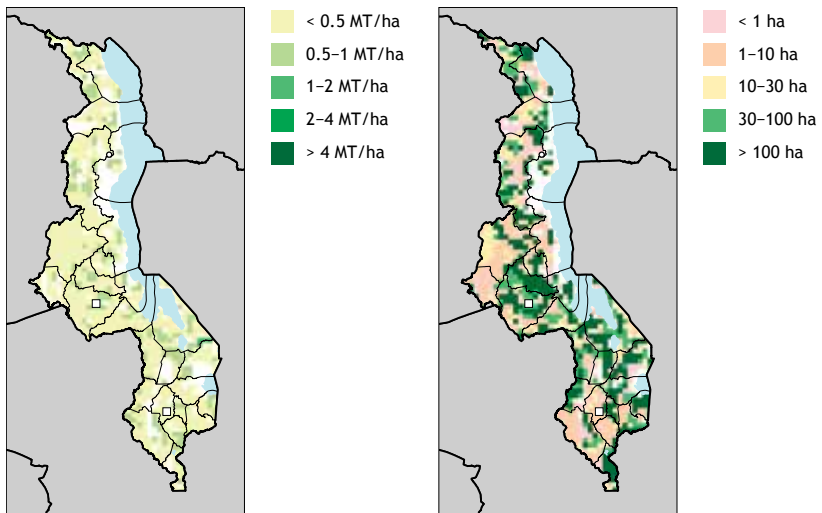
**FIGURE 5.12** Yield (metric tons per hectare) and harvest area density (hectares) for rainfed groundnuts in Malawi, 2000



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

Note: ha = hectare; MT/ha = metric tons per hectare.

**FIGURE 5.13** Yield (metric tons per hectare) and harvest area density (hectares) for rainfed beans in Malawi, 2000



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

Note: ha = hectare; MT/ha = metric tons per hectare.

## Scenarios for the Future

### Economic and Demographic Indicators

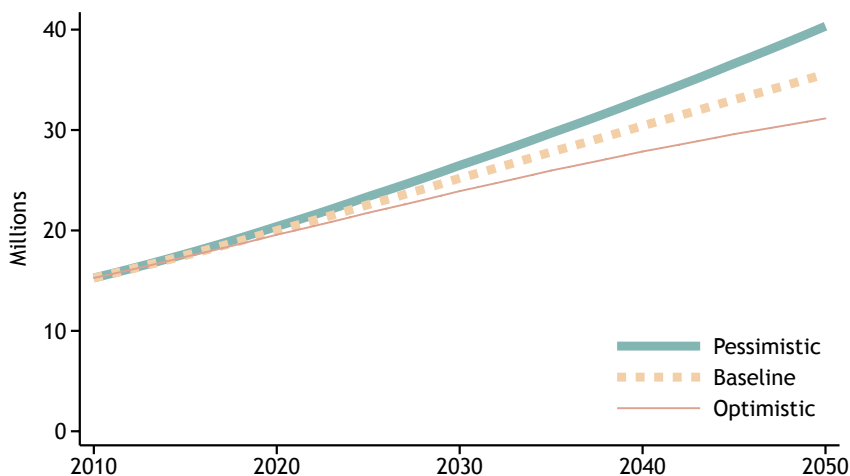
#### Population

The population projections by the UN Population Division (UNPOP 2009) through 2050 are shown in Figure 5.14. All three population projections, based on the high, medium, and low variants, show that Malawi's population is projected to increase significantly, doubling to 31 million people between 2010 and 2050 using the low variant and increasing to 40 million people using the high variant. These projections are reasons for concern and will pose major challenges for the country with its limited land area. For example, to avert hunger, food production will have to increase rapidly and efficiently, with many people moving out of agriculture to follow other livelihood endeavors. There will also be great pressure on the forests for fuelwood unless alternative energy sources are found and used. Managing population growth within acceptable limits consistent with the food resource base is a priority for the country. This entails investing in the education of girls and providing various incentives supportive of small family sizes.

#### Income

The analysis of income based on three scenarios of GDP per capita for Malawi is provided in Figure 5.15. The optimistic scenario projects an

**FIGURE 5.14** Population projections for Malawi, 2010–2050



Source: UNPOP (2009).

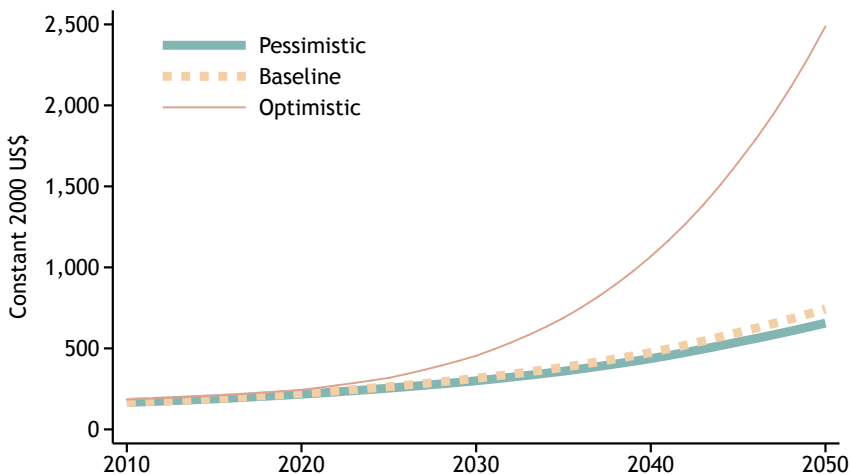
increase in GDP per capita to almost \$2,500 by 2050. Policymakers need to redouble their efforts to ensure that Malawi's population does not grow to the projected levels. In contrast, the pessimistic and baseline scenarios project that incomes will reach a much lower level by the year 2050, \$650 and \$740, respectively.

## Biophysical Analysis

### Climate Models

The precipitation changes projected for Malawi in the four climate models are indicated in Figure 5.16. The CNRM-CM3 and CSIRO Mark 3 models project that the country's mean annual precipitation will remain the same except in the CNRM model for the northern region, which will experience an increase of 50–100 millimeters by 2050. The ECHAM 5 model shows the mean annual precipitation decreasing in all of Malawi except the northern region. In contrast, the MIROC 3.2 model shows an increased mean annual precipitation level ranging from 200 to 400 millimeters for the northern and central

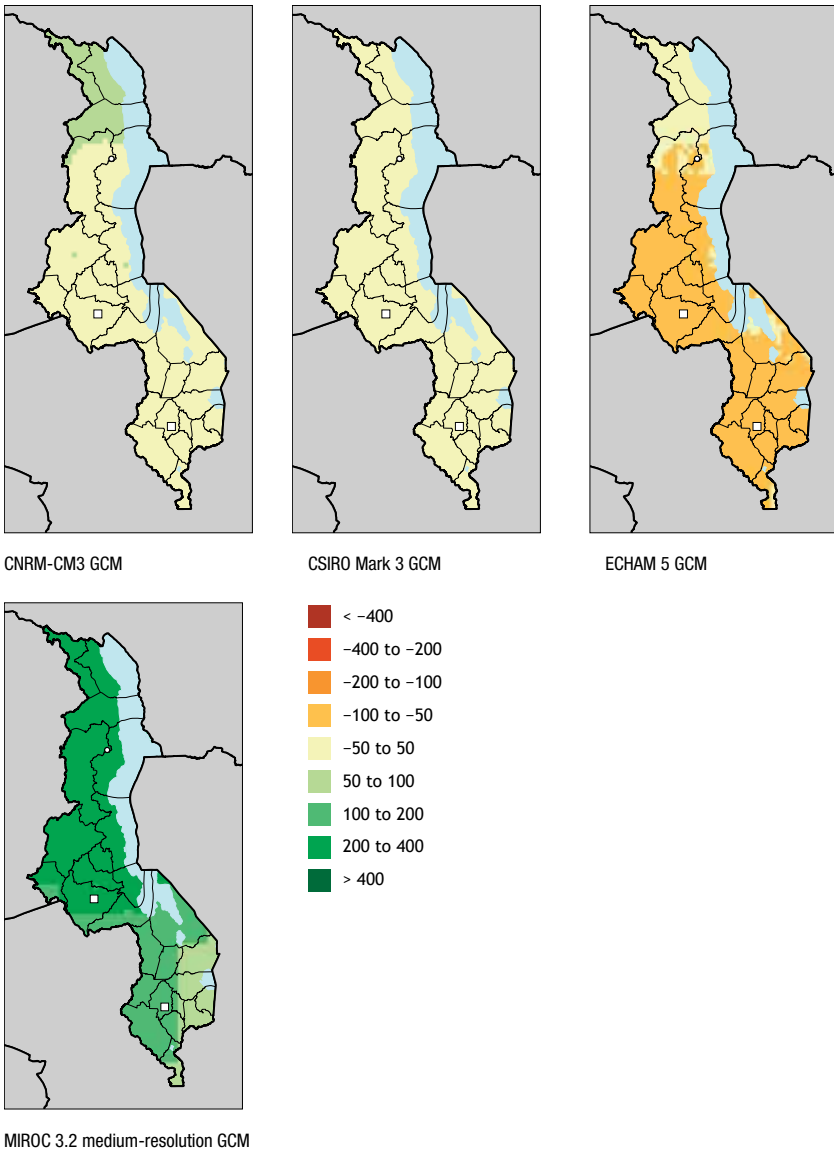
**FIGURE 5.15** Gross domestic product (GDP) per capita in Malawi, future scenarios, 2010–2050



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.

**FIGURE 5.16** Changes in mean annual precipitation in Malawi, 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 by the University of Tokyo Center for Climate System Research.

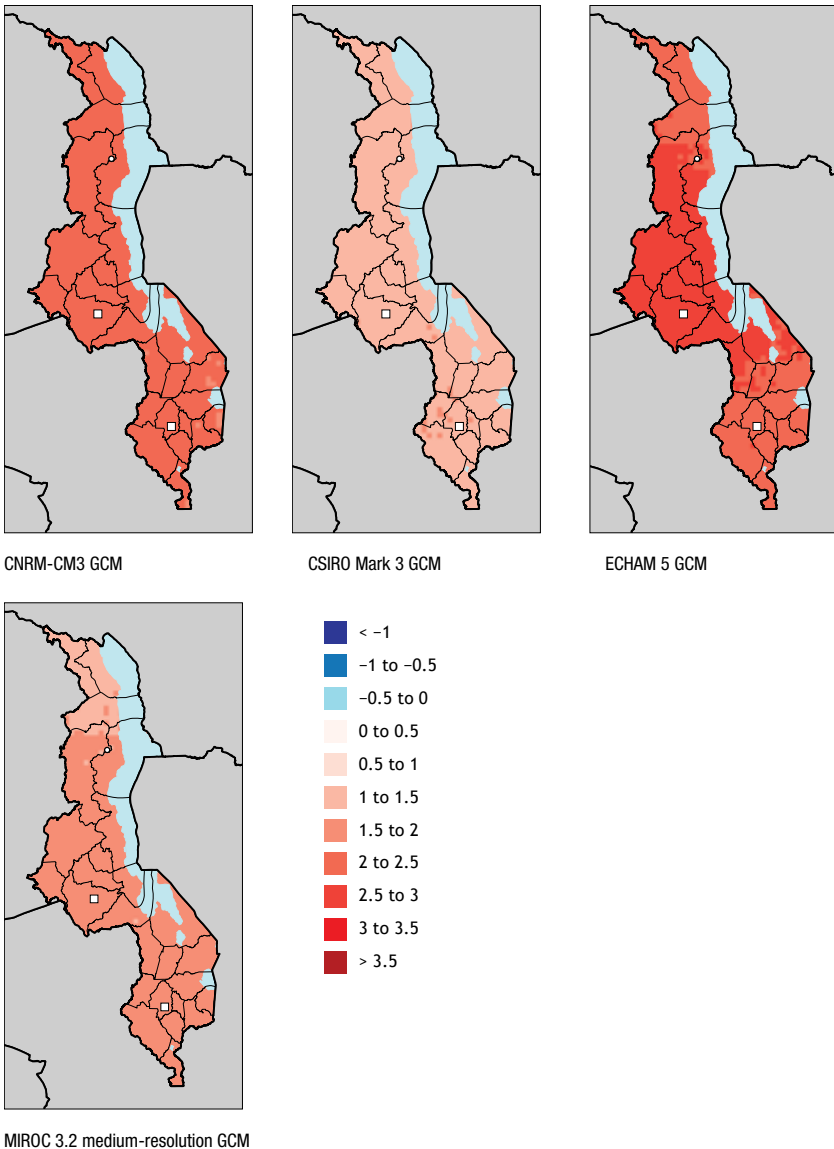
regions of Malawi and from 50 to 200 millimeters for most of the southern region by the year 2050. The precipitation maps highlight the uncertainties associated with modeling precipitation using GCMs.

Figure 5.17 shows projected annual changes in the mean maximum daily temperature for the warmest month in Malawi by 2050. The CSIRO Mark 3 model projects a relatively modest increase in temperature of between 1° and 1.5°C. The MIROC 3.2 model projects that for the northernmost part, but for the rest of the country it projects an increase of 1.5°–2°C. The CNRM-CM3 model predicts an even warmer future, with temperatures increasing in almost the entire country by 2°–2.5°C. But the ECHAM 5 model predicts the warmest future of all, with the temperature in the central part of Malawi to rise by 2.5°–3°C while that in the rest of the country is to rise by 2°–2.5°C. The projected increase in temperature would result in higher levels of evapotranspiration and reduced moisture, a problem particularly for crops and varieties that are not heat tolerant.

### **Crop Models**

The DSSAT crop modeling system was used to compare future yields by 2050 using four GCMs with the baseline yield (with an unchanged climate). Figure 5.18 shows rainfed maize yields declining by about 5–25 percent of baseline for most parts of the northern and central regions of Malawi in the CNRM-CM3 GCM; for most parts of the Shire Highlands in the south, yields are shown increasing by more than 25 percent of baseline by 2050. The CSIRO Mark 3 GCM shows a brighter prediction for maize in the northern and central regions, with most areas showing a gain in yield of 5–25 percent. The prediction is not as optimistic for the southern region. Although there are areas with projected yield gains of more than 25 percent, there are also large areas showing a 5–25 percent decline in rainfed maize yields. The ECHAM 5 GCM shows rainfed maize yields for most parts of Malawi decreasing by more than 25 percent of baseline, while the MIROC 3.2 GCM is similar in expectations to the CSIRO Mark 3 GCM. The ECHAM 5 GCM is the most pessimistic model, showing the greatest temperature increases and precipitation decreases of the four GCMs considered. It also reveals a reduction in rainfed maize yields, varying from 5 percent to more than 25 percent of baseline yields, except for Mwanza and Neno areas, where yield gains of greater than 25 percent of baseline yields are expected by 2050. The CSIRO model in Figure 5.18 shows significant gains in yields throughout most of the country.

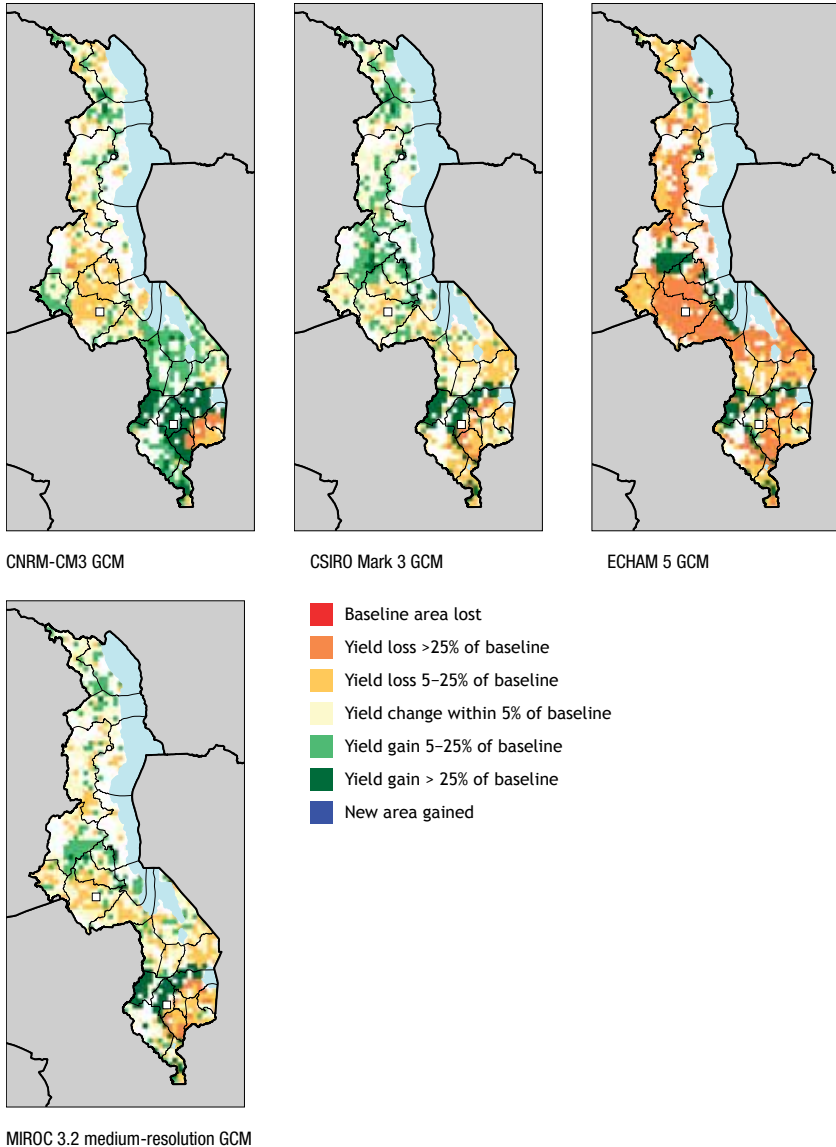
**FIGURE 5.17** Change in monthly mean maximum daily temperature in Malawi for the warmest month, 2000–2050, A1B scenario (°C)



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 by the University of Tokyo Center for Climate System Research.

**FIGURE 5.18** Yield change under climate change: Rainfed maize in Malawi, 2000–2050, A1B scenario



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

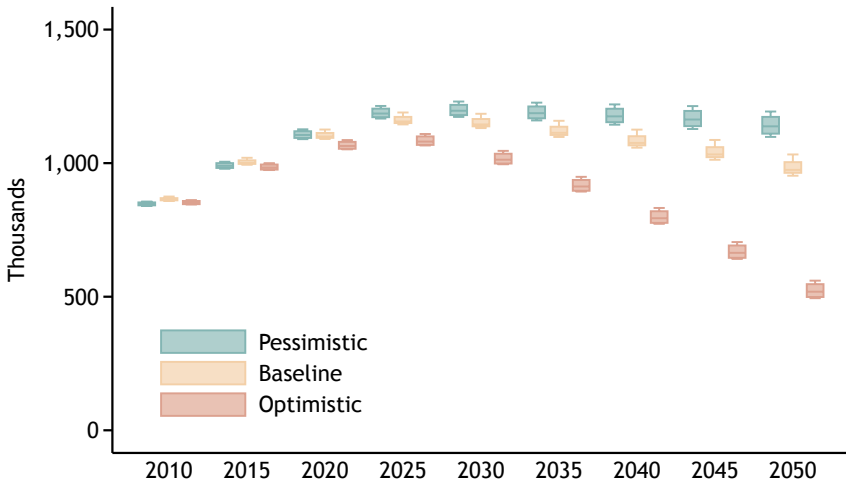
Notes: A1B = greenhouse gas emissions scenario that assumes fast economic growth, a population that peaks midcentury, and the development of new and efficient technologies, along with a balanced use of energy sources; CNRM-CM3 = National Meteorological Research Center—Climate Model 3; CSIRO = climate 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 by the University of Tokyo Center for Climate System Research.

### Vulnerability to Climate Change

The projected impact of future GDP and population scenarios on the number of malnourished children under age five is shown in Figure 5.19; Figure 5.20 shows the share of children who are malnourished. The pessimistic and baseline scenarios give similar estimates, topping out at around 1,150,000 in 2030. But the rise from around 850,000 in 2010 does not reflect an increase in the percentage of children malnourished, because the population will also be rising at a similar pace during those years. The optimistic scenario shows a steep decline in the numbers of malnourished children after 2025. The baseline scenario shows a slight decline after 2025, with the number of malnourished children under age five declining very little after 2030.

The decreased numbers of malnourished children are highly correlated with better caloric intake for the general population (Figure 5.21). The availability of kilocalories per capita remains the same under the three scenarios until 2030, when differences emerge. The higher-GDP, low-population scenario shows the availability of kilocalories per capita increasing to nearly 2,800 by 2050. The baseline and pessimistic scenarios show about

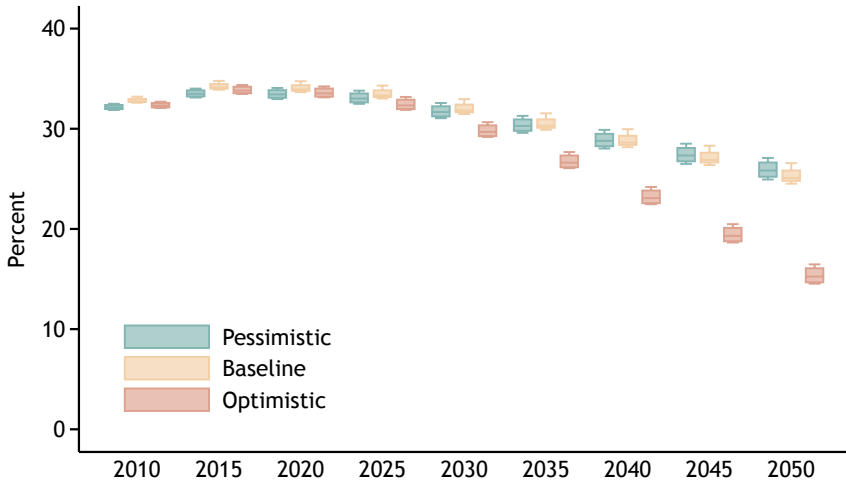
**FIGURE 5.19** Number of malnourished children under five years of age in Malawi in multiple income and climate scenarios, 2010–2050



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.

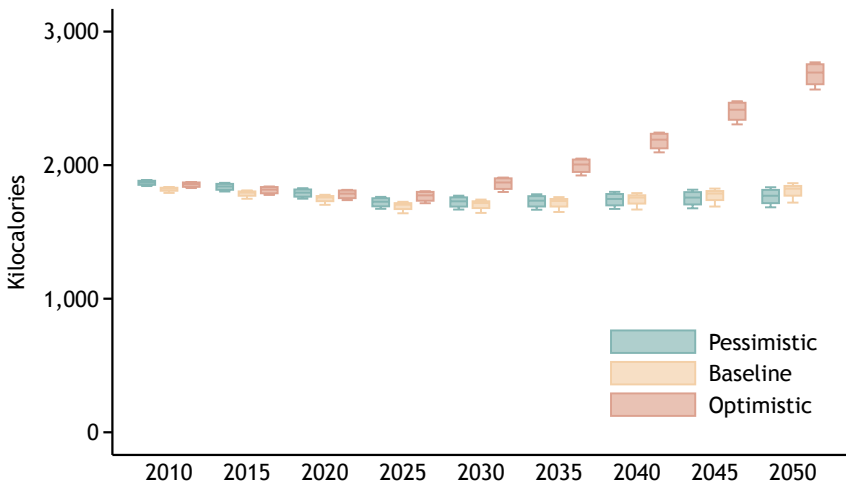
**FIGURE 5.20** Share of malnourished children under five years of age in Malawi in multiple income and climate scenarios, 2010–2050



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 5.21** Kilocalories per capita in Malawi in multiple income and climate scenarios, 2010–2050



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.

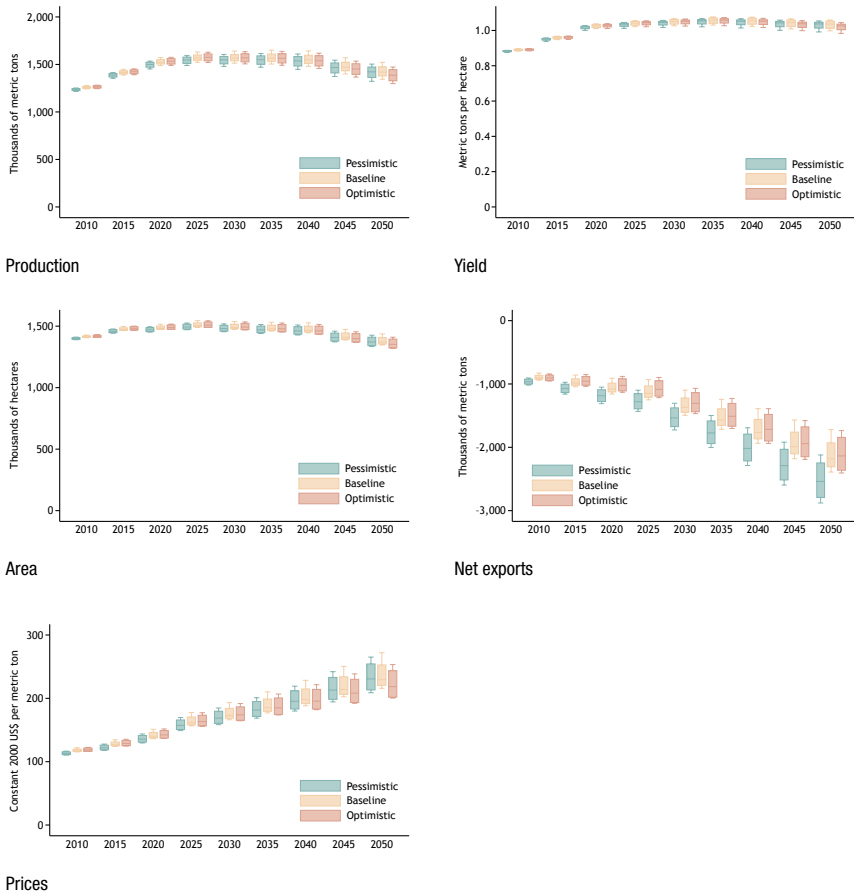
1,800 kilocalories per capita available in Malawi by the year 2050. In these two scenarios, the large price increases seem to negate the positive effects of the increases in income. Chapter 2, however, discusses the fact that the model's own-price elasticities for staple crops were set too high, amplifying the price effects. Nonetheless, the difference in outcomes between the optimistic scenario and the other two scenarios shows the importance of putting in place the right policies to control population growth and improve broad-based economic growth for Malawi.

### **Agricultural Outcomes**

The results in Figure 5.22 indicate that the total acreage allocated for the production of maize will remain almost the same in the three scenarios from 2010 to 2050. The maize yield will rise by over 15 percent between 2010 and 2030, then remain flat or decline slightly thereafter. Production will follow yield very closely. However, net exports will decrease considerably due to increased population growth by 2050, despite increased world prices for the commodity. It is very important for Malawi to ensure stable maize yields over the 40-year period to achieve stable production levels and meet food security needs. The production levels must be associated with an appropriate annual area for growing maize.

In Figure 5.23, the production of cassava and other roots and tubers and the associated yield per hectare are shown to increase from 2010 to 2050 in the three scenarios, with an increase in yield of almost 50 percent projected. However, there will be some drop in acreage and huge drops in net exports in the country by 2050 in all scenarios. Despite the increase in the world price of cassava and other roots and tuber crops, the model projects that Malawi will be importing these commodities. Malawi also needs to invest in growing and promoting cassava and other root crops in the food security chain. Increasing the yield potential will result in improved productivity during the 40-year period, irrespective of the scenarios.

In contrast with the production of maize and the tropical root crops, including cassava, cotton production over the 40-year period is projected to significantly increase (Figure 5.24), irrespective of the scenarios. The total production and yield per hectare for cotton will more than double by 2050 in the three scenarios, despite only a slight increase in the area dedicated to cotton due to land scarcity in Malawi. However, the net exports will more than triple

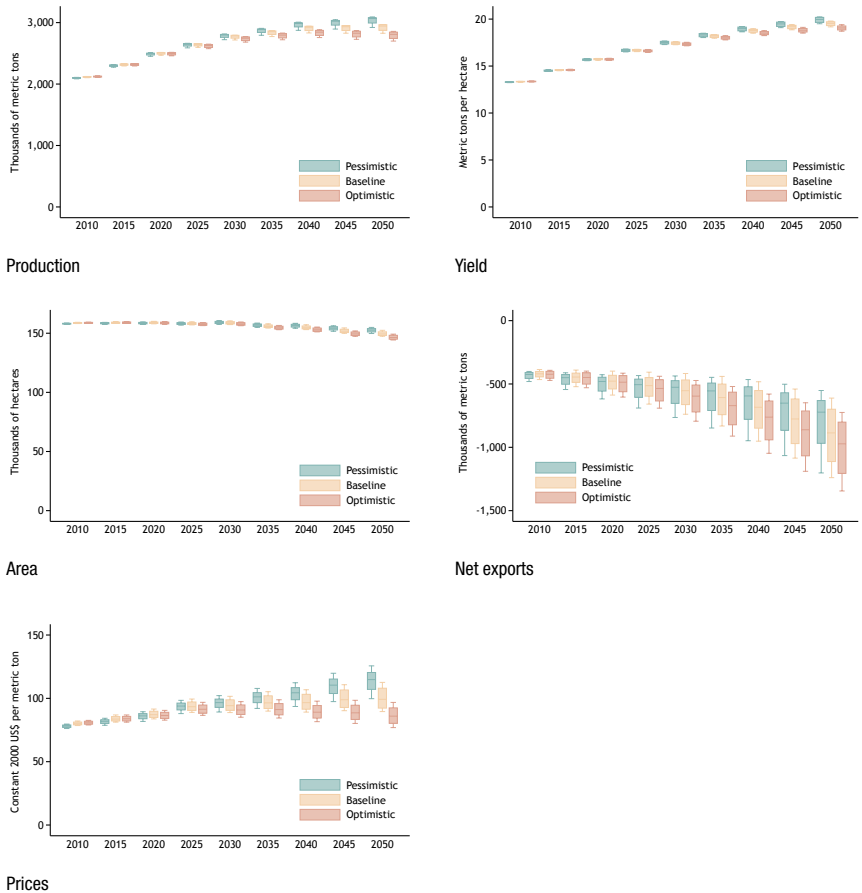
**FIGURE 5.22** Impact of changes in GDP and population on maize in Malawi, 2010–2050

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.

following the rising world prices of cotton, which will generate higher rates of foreign exchange through exports while keeping the area dedicated to cotton production fairly constant. This cash crop constitutes an important strategy for addressing the impact of climate change in Malawi. The country thus needs to intensify its cotton growing to generate increased foreign exchange earnings under the climate change conditions expected from now until 2050.

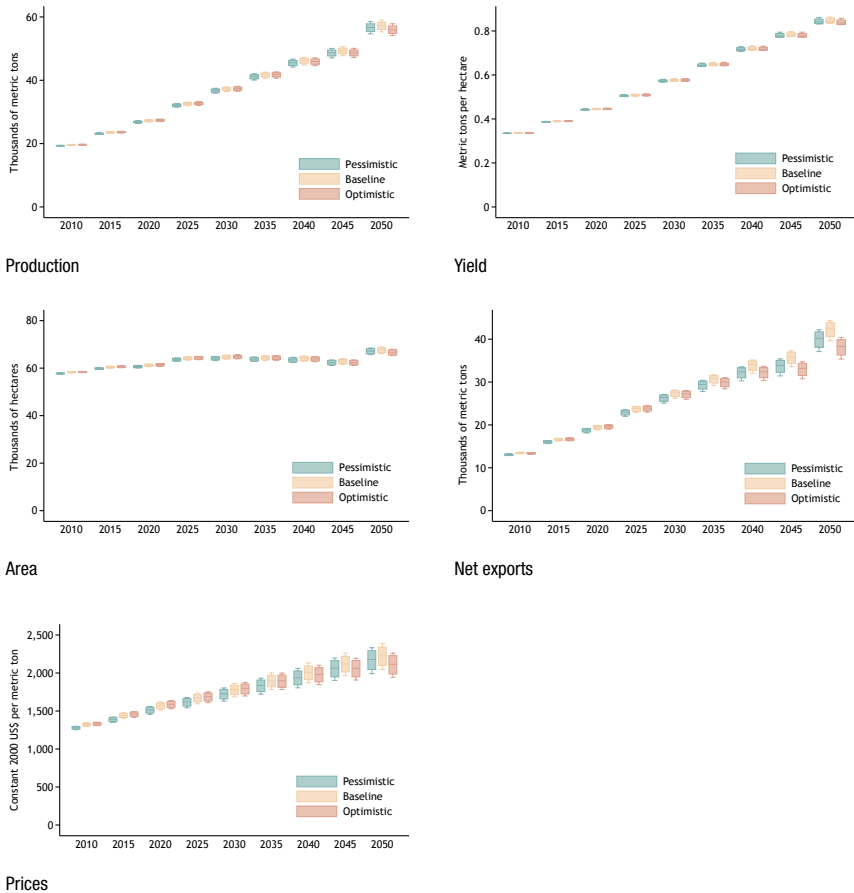
**FIGURE 5.23** Impact of changes in GDP and population on cassava in Malawi, 2010–2050



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.

It is evident from considering the three crop systems that the crops show different responses to climate change in Malawi. Given the country’s small landholdings and fast-growing population, the inclusion in the analysis of legumes and other valuable crops to show the impacts of climate change on them would offer various policy options. Further, the impact of climate change on other components of farming systems needs elucidation—for instance,

**FIGURE 5.24** Impact of changes in GDP and population on cotton in Malawi, 2010–2050

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.

how climate change influences the occurrence of pests and diseases that affect crop and livestock productivity.

### National Consultation in Malawi

A consultative workshop was held with stakeholders during the course of this study in Malawi. During this workshop, several issues were raised, as outlined in Table 5.6.

**TABLE 5.6** Climate change issues and recommendations from stakeholder consultations in Malawi

Issue	Observations	Recommendations
Policy on climate change	No policy on climate change exists; the National Adaptation Programme of Action and others policy instruments include some components on climate change.	Malawi needs a policy on climate change, and the current efforts by the United Nations Development Programme to this end should be fully encouraged.
	A policy on risk assessment for mitigating and adapting to climate change needs to be completed.	It is important that a plan be completed soon given the frequent episodes of climate change events.
	Risk assessment and management were included in the national Relief and Preparedness Plan but not developed. The plan is presently being developed.	
	The relationship between vulnerability and climate change definitions and their clear association should be elucidated.	Stakeholders and farming communities should be well informed about the relationship between the two terms.
	It is important to include the role of indigenous knowledge in combating climate change in adaptation policies.	The use and value of indigenous knowledge in combating climate change should be shared among the communities and strongly promoted and included in the policy framework.
Models	The data inputs into the models were not clear; such information is important to inform the outputs of the modeling.	Details on the input variables should be clearly provided and information on the reliability of the models included in the methodology section.
	The agriculture output predictions were restricted to a few crops; inclusion of more crops is required.	Future modeling should include more crops and be used to inform the site-specific recommendations.
	The model results do not seem to be site- and area-specific.	Modeling should ensure that each vulnerable site and area has interventions that are clear and implementable.

### **Strengthening Local Agricultural Innovation Systems in Malawi**

Institutions in Malawi are implementing various programs and projects aimed at reducing the vulnerabilities of communities to climate risks. These programs are contributing to (1) improving community resilience to climate change through the development of sustainable livelihoods, (2) restoring forests in the Upper Middle and Lower Shire Valley Catchments to reduce siltation and associated water flow problems, (3) improving agricultural production under erratic rains and changing climatic conditions, (4) enhancing

**TABLE 5.6** (Continued)

Issue	Observations	Recommendations
<b>Agriculture outcomes</b>		
Innovative coping strategies	Subsistence agriculture does not offer attractive opportunities for addressing impacts of climate change (i.e., adaptation measures). In the absence of mechanization, this sector would remain ineffective.	The government should proactively implement the Agriculture Sector–Wide Approach component on the commercialization of agriculture, including the Greenbelt Initiative; the medium- and large-scale farmers are likely to ensure food productivity and thus better food security. Mechanization of the agriculture sector should also be aggressively pursued.
	Site-specific associated risks are not known; this information would inform planning and the implementation of coping strategies dependent on the site and area in Malawi.	Malawi should quickly develop its policy on the risk assessment of climate change events.
Impact of climate change on farming systems	Climate change exacerbates outbreaks of diseases and pests that reduce crop yields; this was not included in assessing agriculture's vulnerability to climate change.	Inclusion of the effects of diseases and pests in the various scenarios on crop productivity and yields is important to show the true picture.
	Few crops were included as case studies.	The next exercise should be expanded to include other crops, such as legumes.
National capacity building	The modeling undertaken by the International Food Policy Research Institute and national consultants used only the outputs.	FANRPAN should support human capital development in modeling the various climate scenarios and thus provide better-informed policy advice.  Basic data inputs into the modeling should be shared with national partners, and these should include evidence-based experience in the use and handling of the models.

Source: Authors.

Note: FANRPAN = Food, Agriculture, and Natural Resources Policy Analysis Network.

Malawi's preparedness to cope with droughts and floods, and (5) improving climatic monitoring to enhance Malawi's early warning capabilities and decisionmaking and its sustainable use of Lake Malawi and Lake Shore area resources (Malawi, EAD 2006).

We briefly describe two projects that concentrate on knowledge and understanding of how various communities are adapting to climatic disasters in the realization that policy- and decisionmakers need to understand the context and strategies of farmers and other stakeholders in agriculture for coping and adapting to extreme climatic conditions. The diverse farming environments

and complexities affecting peoples' livelihoods require localized innovation to enhance and sustain agriculture productivity.

Several studies have been done on the risk that climate change poses to people's livelihoods in Malawi (Maro and Majule 2009). A study by ActionAID International (Phiri and Saka 2008) investigated the knowledge and strategies used by stakeholders in agricultural innovation systems in Chikhwawa and Salima to adapt to climate change and variability. It is interesting that communities in both studies are aware of the impacts of climate change. They have experienced both droughts and floods that have negatively affected crop growth and household livelihoods and have thus developed local adaptation strategies. The studies confirm that increased droughts and floods exacerbate poverty levels, leaving households trapped in a cycle of poverty and vulnerability. The two projects have catalyzed processes for two-way communication and engagement among stakeholders and have thus contributed to strengthening the capacities of farmers and other stakeholders to adapt to climate change.

### **Conclusions and Policy Recommendations**

Climate change continues to threaten the livelihoods and food security of many communities in Malawi. Poor communities, particularly women, girls, and the elderly, are most affected. Malawi, like other countries, experiences climate change and weather extremes that have an impact on the agriculture sector, affecting agricultural productivity and thus reducing food security and exacerbating chronic hunger.

The climate models used in this study have indicated various trends for which Malawi has to prepare. The population of the country is estimated to increase to 40 million by 2050 if the right policies are not put in place now. This population size will have serious repercussions for food security and livelihoods in such a small country as Malawi, especially for the most vulnerable people. The biophysical models are clear on one thing: Malawi will experience increased temperatures, ranging from 1° to 3.0°C (depending on the model). Higher temperatures will have negative effects on agriculture in the country. The models do not agree with each other regarding changes in annual precipitation. Two of the four models indicate that the mean annual precipitation will remain essentially the same; one model predicts a decline in precipitation and another predicts an increase. Increased precipitation, however, means that there will be an increased likelihood of floods in the most vulnerable areas of

the country, which can destroy crops, livestock, human life, and property. The crop models provide mixed trends in crop yields for maize; by 2050, two of the models show that most parts of the country are likely to experience yield reduction, while one of the models shows the exact opposite, and one had very mixed results. Therefore, expanding the diversification of crops to ones such as roots and tubers, rice, and nontraditional cash crops including cotton might be a strategy that offers greater security for the country. However, alternative strategies include investing in research and extension to find varieties of maize that are more heat tolerant and also possibly more drought tolerant than the varieties that are currently used.

Further, an analysis of existing policies reveals that Malawi has several policies that have a bearing on climate change; these have the potential of facilitating local adaptation efforts by communities. Their joint proactive implementation through the National Adaptation Plan for Action offers great opportunities for Malawi to adequately manage the threats and impacts of climate change. However, as of now the country does not have a policy on climate change, which should be a linchpin for implementing coherent programs; the present initiatives of the UN Development Programme and the government toward its development are timely.

Policymakers should consider doing the following:

1. Create an enabling policy environment for better management of the effects of climate change on the socioeconomic development of the country, including agriculture and sustainable livelihoods. Specifically, the country should
  - a. develop a clear policy and implementation plan on climate change;
  - b. develop a disaster risk policy and implementation plan that will inform better management of site-specific floods and droughts in Malawi;
  - c. implement the Agriculture Sector–Wide Approach component of agriculture commercialization;
  - d. include other crops in the modeling for a basket of wider choice; and
  - e. establish the relationship between vulnerability and climate change.
2. Enhance the capacity of rural communities to adapt to climate change. Such programs should include
  - a. expanding access to agricultural inputs,
  - b. facilitating smallholders' access to credit,
  - c. establishing a weather-based insurance program,

- d. establishing the capability of providing seasonal weather predictions,
  - e. expanding the quality and reach of extension services so that small-holder farmers will have technical assistance available to them more frequently,
  - f. increasing investment in agricultural research for the development and testing of plant varieties suitable to dealing with climate change threats, and
  - g. improving linkages with regional and international organizations regarding climate change adaptation and agricultural research and extension.
3. Strengthen the capacity and coordination of grassroots institutions such as the district, area, and village committees so that they can better provide support services to rural communities, which are the most affected by climate change events, especially during floods and droughts.

With the additional policies suggested here, Malawian farmers will be in a much better position to adapt to changes in the climate in coming decades.

## References

- Bartholome, E., and A. S. Belward. 2005. "GLC2000: A New Approach to Global Land Cover Mapping from Earth Observation Data." *International Journal of Remote Sensing* 26 (9): 1959–1977.
- CIESIN (Center for International Earth Science Information Network), Columbia University, IFPRI (International Food Policy Research Institute), World Bank, and CIAT (Centro Internacional de Agricultura Tropical). 2004. *Global Rural–Urban Mapping Project (GRUMP), Alpha Version: Population Density Grids*. Palisades, NY, US: Socioeconomic Data and Applications Center (SEDAC), Columbia University. <http://sedac.ciesin.columbia.edu/gpw>.
- FAO (Food and Agriculture Organization of the United Nations). 2010. FAOSTAT. Accessed December 22, 2010. <http://faostat.fao.org/site/573/default.aspx#ancor>.
- Haarstad, J. 2009. *Norwegian Environmental Action Plan—Baseline Study, 2009*. Oslo: Norwegian Agency for Development Cooperation. Accessed February 21, 2012. [www.norad.no/en/tools-and-publications/publications/](http://www.norad.no/en/tools-and-publications/publications/).
- IPCC (Intergovernmental Panel on Climate Change). 2007. "Regional Climate." In *Climate Change 2007: The Physical Science Basis*, chapter 11. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Geneva.

- IUCN (International Union for Conservation of Nature). 2010. "IUCN Red List of Threatened Species: Version 2010." Accessed March 12, 2012. [www.iucnredlist.org](http://www.iucnredlist.org).
- Jones, P. G., P. K. Thornton, and J. Heinke. 2009. *Generating Characteristic Daily Weather Data Using Downscaled Climate Model Data from the IPCC's Fourth Assessment*. Project report. Nairobi, Kenya: International Livestock Research Institute.
- Lehner, B., and P. Döll. 2004. "Development and Validation of a Global Database of Lakes, Reservoirs, and Wetlands." *Journal of Hydrology* 296 (1–4): 1–22.
- Malawi, EAD (Environmental Affairs Department). 2006. *National Adaptation Programme of Action (NAPA)*. Zomba: Government Press.
- Malawi, Ministry of Agriculture and Food Security. 2006. *Ministry of Agriculture and Food Security Strategic Plan*. Lilongwe.
- Malawi, Ministry of Economic Planning and Development. 2006. *National Policy on Early Childhood Development*. Lilongwe.
- Malawi, Ministry of Lands and Housing. 2002. *Malawi National Land Policy*. Lilongwe. Accessed March 22, 2011. [www.cepa.org.mw/documents/legislation/D\\_Malawi\\_National\\_Land\\_Policy\\_2002.pdf](http://www.cepa.org.mw/documents/legislation/D_Malawi_National_Land_Policy_2002.pdf).
- Malawi Government and World Bank. 2006. *Malawi Poverty and Vulnerability Assessment: Investing in Our Future*. Vol. 2. Lilongwe. Accessed May 12, 2011. [www.aec.msu.edu/fs2/mgt/caadp/malawi\\_pva\\_draft\\_052606\\_final\\_draft.pdf](http://www.aec.msu.edu/fs2/mgt/caadp/malawi_pva_draft_052606_final_draft.pdf).
- Malawi SDNP (Sustainable Development Network Programme). 1998. "State of Environment Report (SOER)." Accessed October 21, 2010. [www.sdn.org.mw/enviro/soe\\_report/chapter\\_4.html](http://www.sdn.org.mw/enviro/soe_report/chapter_4.html).
- Maro, P. S., and A. E. Majule, eds. 2009. *Strengthening Local Agricultural Innovations to Adapt to Climate Change in Botswana, Malawi, South Africa, and Tanzania*. Gaborone, Botswana: Southern African Development Community. Accessed March 3, 2012. [www.sadc.int/fanr/agricresearch/icart/inforesources/AdaptingtoClimateChange.pdf](http://www.sadc.int/fanr/agricresearch/icart/inforesources/AdaptingtoClimateChange.pdf).
- Millennium Ecosystem Assessment. 2005. *Ecosystems and Human Well-being: Synthesis*. Washington, DC: Island Press. <http://www.maweb.org/en/Global.aspx>.
- Nelson, G. C., M. W. Rosegrant, A. Palazzo, I. Gray, C. Ingersoll, R. Robertson, S. Tokgoz, et al. 2010. *Food Security, Farming, and Climate Change to 2050: Scenarios, Results, Policy Options*. Washington, DC: International Food Policy Research Institute.
- Phiri, I. M. G., and A. R. Saka. 2008. "The Impact of Changing Environmental Conditions on Vulnerable Communities of the Shire Valley, Southern Malawi." In *The Future of Drylands: International Scientific Conference on Desertification and Drylands Research, Tunis, Tunisia, 19–21 June 2006*, edited by C. Lee and T. Schaaf, chapter 7. New York: Springer-Verlag.

- UNEP (United Nations Environment Programme) and IUCN (International Union for Conservation of Nature). 2009. *World Database on Protected Areas (WDPA) Annual Release 2009*. Accessed January 8, 2011. <http://www.wdpa.org/protectedplanet.aspx>.
- UNPOP (United Nations Department of Economic and Social Affairs—Population Division). 2009. *World Population Prospects: The 2008 Revision*. New York. <http://esa.un.org/unpd/wpp/>.
- Wood, S., G. Hyman, U. Deichmann, E. Barona, R. Tenorio, Z. Guo, S. Castano, O. Rivera, E. Diaz, and J. Marin. 2010. “Sub-national Poverty Maps for the Developing World Using International Poverty Lines: Preliminary Data Release.” Accessed January 18, 2011. <http://povertymap.info> (password protected). Some also available at <http://labs.harvestchoice.org/2010/08/poverty-maps/>.
- World Bank. 2009. *World Development Indicators*. Washington, DC.
- . 2010. *The Costs of Agricultural Adaptation to Climate Change*. Washington, DC.
- You, L., and S. Wood. 2006. “An Entropy Approach to Spatial Disaggregation of Agricultural Production.” *Agricultural Systems* 90 (1–3): 329–347.
- You, L., S. Wood, and U. Wood-Sichra. 2006. “Generating Global Crop Distribution Maps: From Census to Grid.” Paper presented at the International Association of Agricultural Economists Conference in Brisbane, Australia, August 11–18.
- . 2009. “Generating Plausible Crop Distribution and Performance Maps for Sub-Saharan Africa Using a Spatially Disaggregated Data Fusion and Optimization Approach.” *Agricultural Systems* 99 (2–3): 126–140.