Chapter 7

KENYA

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Kenya is an ecologically diverse nation located on the Indian Ocean in East Africa. Most of the land is classified as arid or semiarid, yet at higher elevations lush montane forests are found. Kenya is home to the second-highest peak in Africa, glacier-capped Mount Kenya. Although agriculture is declining in importance in terms of gross domestic product (GDP), approximately 75 percent of the country's labor force is still devoted to agriculture. Because of this and because of Kenya's relatively slow growth in GDP per capita since 1980, adapting to the impact of climate change on agriculture is of critical importance to its population over the next 30 or 40 years.

In this chapter we review some national statistics that will help characterize the capacity of the population to adapt to climate change and describe Kenya's land base and current agricultural context. Then we show results of crop models that incorporate climate projections from recent global models. Finally, we incorporate those results into a global model for food and for agricultural supply and demand that takes into account demographic and economic projections for Kenya. Along the way, we identify areas of potential losses and gains.

The chapter draws heavily from the *National Irrigation Board Strategic Plan* (Kenya, Ministry of Water and Irrigation 2008), the *Kenya Agricultural Research Institute (KARI) Strategic Plan* (KARI 2009), the *Agricultural Sector Development Strategy* (Kenya 2010), the *National Climate Change Response Strategy* (Kenya, Ministry of Environment and Mineral Resources, 2010), the "Draft National Arid and Semi-Arid Lands Policy" (Kenya 2011a), the "Draft National Food and Nutrition Security Policy" (Kenya 2011b), and the "Draft National Irrigation Policy" (Kenya 2011c).

In the past decade or so, Kenya has developed policies, strategies, and programs in the agricultural and environment sectors with direct and indirect bearing on adaptation of the agricultural sector to climate change. The *National Climate Change Response Strategy* (NCCRS) (Kenya 2010) aims at mainstreaming climate change issues throughout all economic sectors and ensuring coordinated implementation of climate change mitigation and adaptation activities. The NCCRS also acknowledges the importance of effective communication, education, and public awareness programs in improving the resilience of communities and productive sectors for adaptation to climate change.

The Agriculture Sector Coordination Unit has developed the *Agricultural Sector Development Strategy* (Kenya, Ministry of Environment and Mineral Resources, 2010). The strategy has articulated subsector strategic focus around key themes that have a bearing on the adaptive response of the agricultural sector and all subsectors therein to the vulnerability occasioned by climate change. The Ministry of Environment and Mineral Resources, Office of the Prime Minister, and Ministry of Development of Northern Kenya and other Arid Lands have developed a five-year Natural Resources Management Program (2010–2014) whose overall objective is to contribute to reduttced poverty in the context of "Kenya Vision 2030" (Kenya 2007b) to safeguard the state of the environment and promote sustainable management of natural resources, including adaptation to climate change.

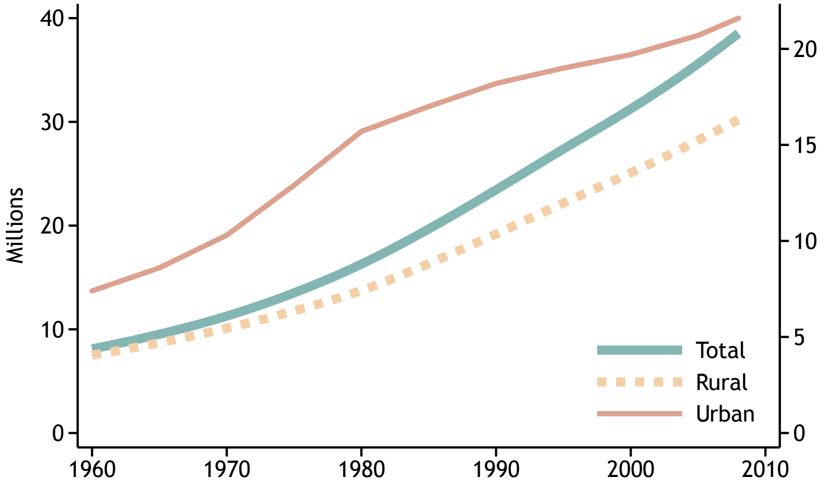
Review of the Current Situation and Trends

Economic and Demographic Indicators

Population

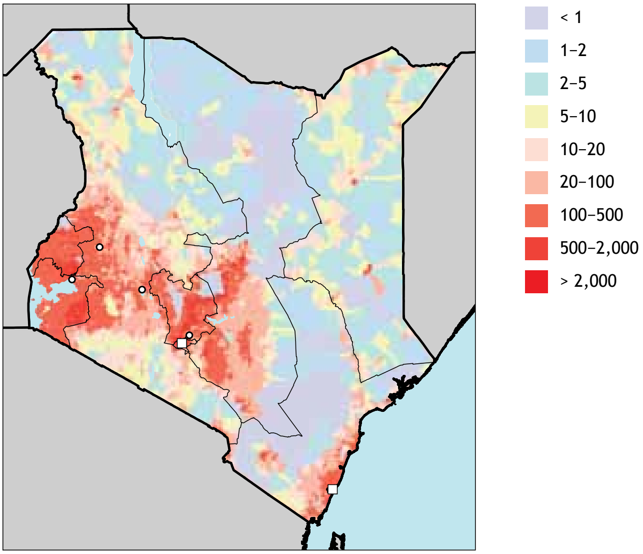
Figure 7.1 shows total and rural population counts (left axis) and the share of the urban population (right axis). The population trends and growth rates given in Figure 7.1 and Table 7.1 show a general upward trend in the urban, rural, and total populations, with the urban population rising from 14 percent in 1960 to 20 percent in 2008, while the total population increased from about 8 million people in 1960 to approximately 38 million in 2008. The rural population increased from approximately 7 million in 1960 to 30 million in 2008. From the population growth rates given in Table 7.1, we note that in all the four decades and eight years under study, the urban growth rate was higher than the rural growth rate, indicating a general trend of rural to urban migration or high relative urban child delivery rates over the period of analysis. There has also been a declining trend in growth rate over the temporal scale across all three categories of population. The highest urban growth rate was experienced in the first two decades. After that, the growth rates decreased between 1980 and 1999, only to rise marginally between 2000 and 2008. The total population growth rate took an upward trend in the first two decades

FIGURE 7.1 Population trends in Kenya: Total population, rural population, and percent urban, 1960–2008



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

FIGURE 7.2 Population distribution in Kenya, 2000 (persons per square kilometer)



Source: CIESIN et al. (2004).

TABLE 7.1 Population growth rates in Kenya, 1960–2008 (percent)

Decade	Total growth rate	Rural growth rate	Urban growth rate
1960–1969	3.3	3.0	6.6
1970–1979	3.7	3.1	7.9
1980–1989	3.7	3.4	5.2
1990–1999	2.9	2.7	3.7
2000–2008	2.6	2.3	3.8

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

under analysis, only to level off between 1980 and 1989, then decreased between 1990 and 2008. The rural population growth rate took on an upward trend in the first three decades, reaching its peak in 1989, and then assumed a downward trend thereafter until 2008.

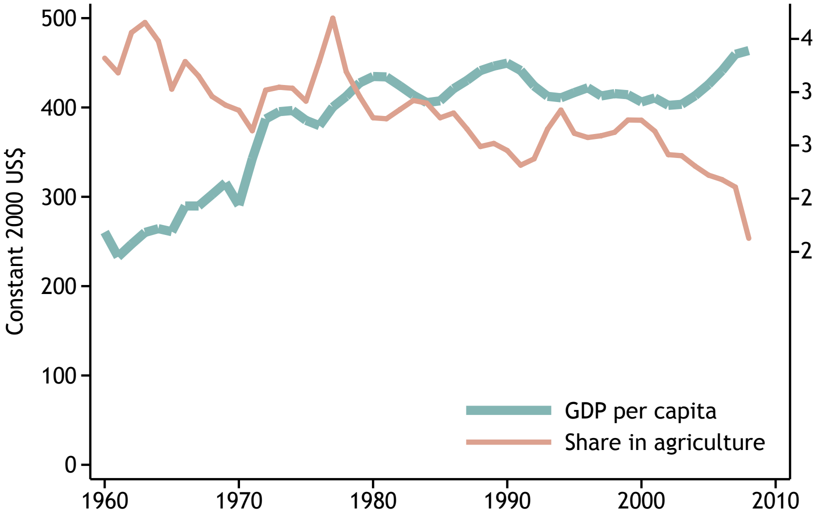
Figure 7.2 provides additional information concerning population density. A glance at this figure reveals a relatively high population density in agriculturally medium- to high-potential areas of central Kenya, the coastal strip, the Rift Valley, and western Kenya. The population density in the arid and semiarid upper parts of Eastern Province is between 1 and 2 persons per square kilometer. This can be partly explained by the pastoral lifestyle in the region.

Income

Figure 7.3 shows trends in GDP per capita and the proportion of GDP from agriculture. Agriculture is included as an indicator because it is vulnerable to the impacts of climate change and is a key indicator of the level of development of the country, whose mainstay economic activity is agriculture.

Generally, the graph shows a rapid upward trend in GDP per capita in the period between 1960 and 1990, increasing from approximately $260 in 1960 to around $450 some 30 years later. This was followed by a general decline until 2005 ($400). Since 2005, there has been an upward trend in GDP per capita. During the same period, the proportion of agriculture's contribution to GDP declined from approximately 40 percent in 1960 to near 20 percent around 2008, though the sudden drop from 26 percent in 2007 represents the impact of the 2008–2009 drought. A comparison of the trends of GDP per capita and the proportionate contribution of agriculture to GDP as given in Figure 7.3 clearly brings out the inverse relationship between growth in GDP and the proportionate contribution of agriculture to GDP. The only exception to the general trend was a short period in the second half of the 1970s when both GDP per capita and proportionate contribution of

FIGURE 7.3 Per capita GDP in Kenya (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.

agriculture to GDP concurrently assumed an upward trend. However, the scenario of the inverse relationship is well demonstrated in the period after the 2002 elections, where we observe a sharp decline in the proportionate contribution of agriculture to GDP as the general GDP per capita rose.

Vulnerability to Climate Change

Vulnerability is defined in many ways. According to one definition, vulnerability is the lack of ability to recover from a stress. In the agricultural sector, poor people are particularly vulnerable to the stresses of an uncertain climate. In this case, vulnerability means susceptibility to a negative outcome. The vulnerability of agriculture to climate change is considered its susceptibility to some form of natural hazard and is determined primarily by its capacity to respond to that hazard. Vulnerability is considered at many levels, ranging from the level of the individual household to national and regional levels.

The extent to which climate change may damage or harm the agricultural sector depends on the sector's sensitivity and ability to adapt to new conditions. The adaptive capacity of the agricultural sector to climate change in Kenya is low mainly due to limited economic resources for investment in more resilient production systems, low levels of technological development or adoption of developed technology, heavy reliance on rainfed agriculture, frequent droughts and floods, endemic crop and livestock diseases, frequent incidences of pest infestation, relatively high levels of postharvest losses, and the general poverty among the majority of smallholder producers. Adaptation of the agricultural sector to climate change will entail planned or automatic changes in processes, practices, or structures that minimize potential damage or take advantage of opportunities associated with changes in climate.

Table 7.2 provides data on indicators of vulnerability and resiliency to economic shocks that revolve around the level of education of the population and their literacy. Kenya's high enrollment rate in primary schools (112.6 percent) offers a critical means by which knowledge and sensitization on climate change issues and adaptation strategies could easily be communicated to a wider population. The high level of secondary schools enrollment (52.8 percent) and the high adult literacy rate (73.6 percent) offer other critical means for imparting knowledge and creating awareness on adaptation to climate change.

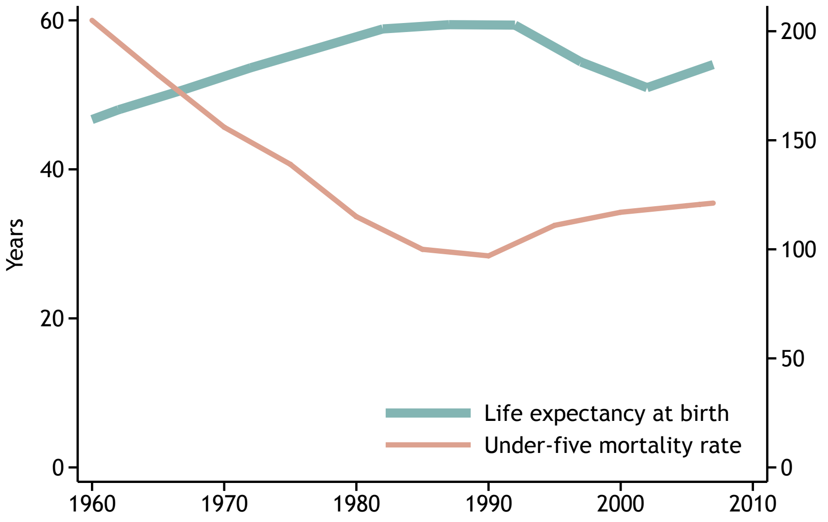
Figure 7.4 shows two noneconomic correlates of poverty, life expectancy and under-five mortality. A look at this figure reveals that life expectancy increased gradually in Kenya from 1960 up to the early 1980s, rising from the low level of about 48 years (1960) and leveling off at approximately 60 years (1980). This status was maintained until the early 1990s, when it started decreasing gradually to a minimum of about 50 years in 2002. Thereafter, it assumed an upward trend to approximately 55 years by 2008. The under-five mortality rate improved from the high of about 200 deaths per 1,000 in 1960 to a low of 100 deaths per 1,000 in 1990; thereafter it increased to approximately 130 deaths per 1,000 by 2008. The trends in Figure 7.4 show an inverse relationship between life expectancy at birth and under-five mortality rates over a temporal scale. The high rate of under-five mortality is associated

TABLE 7.2 Education and nutrition statistics for Kenya, 2000s

Indicator	Year	Percent
Primary school enrollment: Percent gross (three-year average)	2007	112.6
Secondary school enrollment: Percent gross (three-year average)	2007	52.8
Adult literacy rate	2000	73.6
Under-five malnutrition (weight for age)	2003	16.5

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

FIGURE 7.4 Well-being indicators in Kenya, 1960–2008

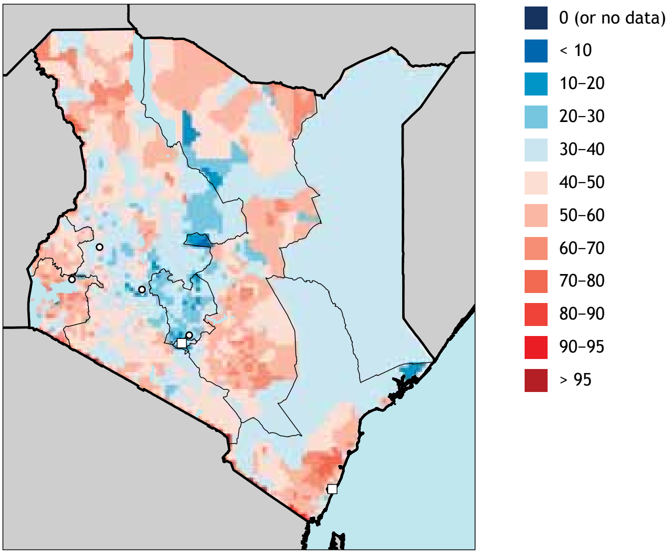


Source: *World Development Indicators* (World Bank 2009).

with malnutrition, among other factors. This implies that enhancing the resiliency of the agricultural sector to climate change could help mitigate malnutrition and thus reduce the high under-five mortality rates.

Figure 7.5 shows the proportion of the population living on less than $2 per day. The scenario in the figure reveals a situation in which between 40 and 70 percent of the population in Rift Valley, Eastern, and Nyanza Provinces and in the lower parts of Coast and Western Provinces live on less than $2 per day. In the semiarid North Eastern Province, the upper parts of Coast Province, and some parts of Rift Valley and Central Provinces, between 20 and 40 percent of the population live on less than $2 per day. In small sections of Central, Rift Valley, and Coast Provinces, between 10 and 20 percent of the population survive on less than $2 per day. In the metropolitan Nairobi Province, between 10 and 20 percent live on less than $2 per day. The spatial distribution of poverty seen in Figure 7.5 shows that proportionately fewer inhabitants of the predominantly pastoralist North Eastern Province, the upper Coast Province, and some parts of the upper Eastern and Rift Valley Provinces live on less than $2 compared to the agropastoralists in the southern parts of Eastern Province and the lower parts of Coast and Rift Valley Provinces and the agriculturalist and mixed farming inhabitants

FIGURE 7.5 Poverty in Kenya, 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.

of Nyanza and Western Provinces. Cash crop farming dominates Central Province and parts of Eastern Province neighboring Mount Kenya, which, together with the Metropolitan Nairobi Province, have the smallest proportion of their residents (between 10 and 30 percent) living on less than $2 per day.

Review of Land Use, Potential, and Limitations

Land Use Overview

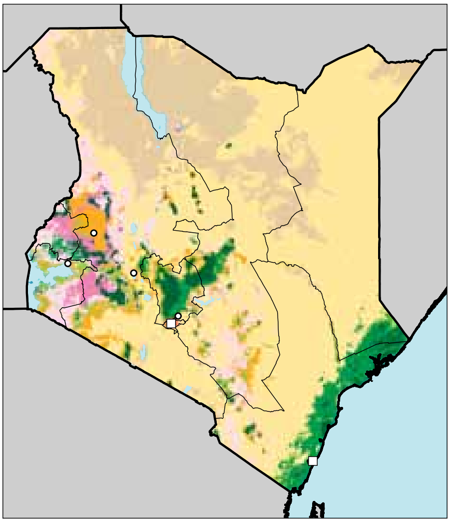
Land is an important factor of production because it provides the foundation for all other activities, such as agriculture, water distribution, settlement, tourism, wildlife management, forestry, and infrastructure development. Land issues are important to the social, economic, and political development of Kenya. Over the years, the administration and management of land in Kenya have been challenging because of the lack of a comprehensive national land policy, worsened by the existence of many land laws, some of which are conflicting. This has led to fragmentation of the land, breakdown in land administration, and disparities in land ownership. Other challenges include deterioration of land quality, squatting, landlessness, underuse and abandonment of agricultural land, tenure insecurity, and conflict. To address these challenges, the Government of Kenya has developed policies and legal and institutional reforms regarding the security of land tenure, land use and development, and sustainable conservation of the environment.

Figure 7.6 shows land cover and land use in Kenya as of 2000. The largest proportion of the country falls into two categories of land cover: (1) herbaceous cover, closed-open, and (2) sparse herbaceous or shrub cover. The two types of land cover are ideal for pastoralism involving sheep, goats, and camels, which characterizes the livelihoods of the arid and semiarid lands (ASALs) that cover 83 percent of the country's land area. Cultivated and managed areas are to be found in agriculturally high- to medium-potential areas of the country. Areas with tree cover of broadleaved evergreen or deciduous closed types are found in the five major water catchments, which also serve as the sources of major rivers in the country, dubbed "the five water towers," and along the coastal strip. The country's grain basket, Rift Valley and Western Provinces, is characterized by mosaic cover: cropland, trees, or other natural vegetation; cropland or shrubs; or grass.

Natural resources from wildlife and forestry in the protected areas play two basic roles in development: support to subsistence livelihoods, mainly as sources of firewood, and sources of development resources, mainly in the form of earnings received from the supply of goods and services to the tourism sector that is associated with wildlife. A major focus in the development and use of natural resources is to ensure their sustainability and the stability of the resource base. To achieve this objective, the Government of Kenya has developed policies and institutional and legal frameworks that aim at protecting, conserving, and managing forest and wildlife resources; strengthening forestry and wildlife research; promoting extension and training; and designing, supporting, and implementing forestry and wildlife flagship projects in Vision 2030. Notable among the policies and institutional and legal documents are a "Draft Forest Policy" (Kenya 2005) and a "Draft Wildlife Policy" (Kenya 2007a).

Figure 7.7 shows the locations of protected areas in Kenya, including national parks, water masses, game reserves, and forests. These locations provide important protection for fragile ecosystems, which also serve as sources of natural resources of economic importance such as freshwater and fuelwood, pastures for livestock and wildlife, and centers of attraction

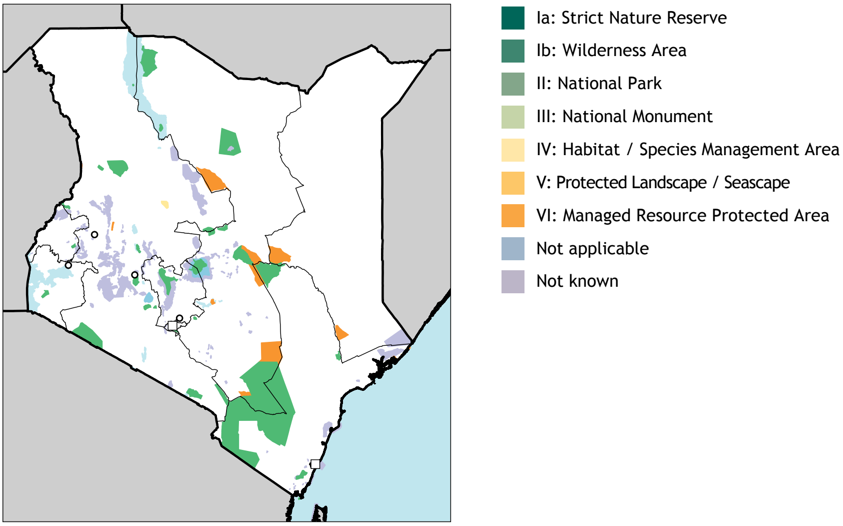
FIGURE 7.6 Land cover and land use in Kenya, 2000



- 🟩 Tree cover, broadleaved, evergreen
- 🟩 Tree cover, broadleaved, deciduous, closed
- 🟩 Tree cover, broadleaved, 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
- 🟨 Herbaceous cover, closed–open
- 🟫 Sparse herbaceous or sparse shrub cover
- 🟦 Regularly flooded shrub or herbaceous 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 (Bartholome and Belward 2005).

FIGURE 7.7 Protected areas in Kenya, 2009

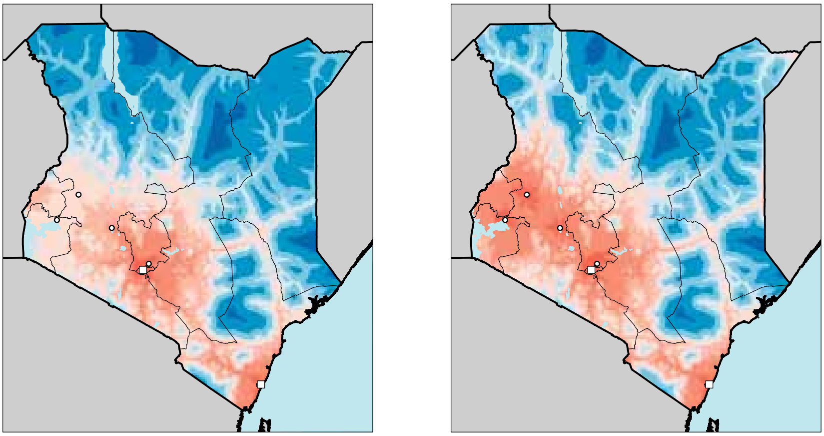


Sources: Protected areas are from the World Database on Protected Areas (UNEP and IUCN 2009). Water bodies are from the World Wildlife Federation's Global Lakes and Wetlands Database (Lehner and Döll 2004).

for service-oriented economic activities such as tourism. The main protected areas depicted in the figure include the country's national parks, namely Tsavo National Park, the Maasai Mara, Marsabit Game Reserve, Turkana Game Reserve, Meru National Park, and parts of Amboseli National Park. The International Union for the Conservation of Nature (IUCN) Category VI managed resource–protected areas include parts of Tsavo East, Samburu Game Reserve, and Tana River Game Reserve; other IUCN areas include those around Mount Kenya and Mount Elgon in the central and western parts of the country, respectively, the southern tip of the Kenya–Somalia border, Samburu in the midnorth region, and parts of South Rift. Water and biodiversity from protected areas can contribute to adaptation to climate change through interventions such as the use of irrigation agriculture and genetic materials from the wild in breeding for adaptation to the adverse effects of climate change. However, a majority of the country is not protected, which implies that species of ecological importance, including the endangered ones, that fall in such areas are susceptible to destructive human activities.

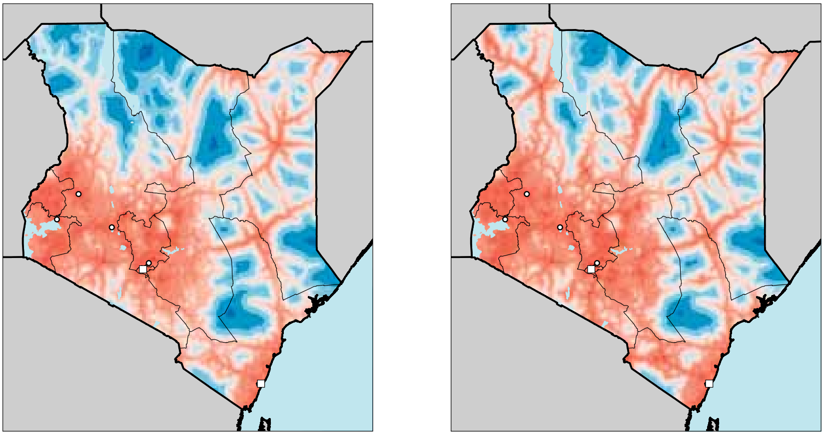
Figure 7.8 shows travel times to towns and cities of various sizes, which provide potential markets for agricultural products. Policymakers need to keep in mind the importance of transport costs when considering the

FIGURE 7.8 Travel time to urban areas of various sizes in Kenya, circa 2000



To cities of 500,000 or more people

To cities of 100,000 or more people



To towns and cities of 25,000 or more people

To towns and cities of 10,000 or more people

- 🟥 Urban location
- 🟥 < 1 hour
- 🟥 1–3 hours
- 🟧 3–5 hours
- 🟧 5–8 hours
- 🟦 8–11 hours
- 🟦 11–16 hours
- 🟦 16–26 hours
- 🟦 > 26 hours

Source: Authors' calculations.

potential for agricultural expansion. Fertile but unused land that is far from markets represents potential land for expansion only if transport infrastructure is provided and the land does not conflict with the preservation priorities shown in Figure 7.7. The resilience of the agricultural sector to shocks occasioned by climate change depends to a large extent on the availability of transport infrastructure. A glimpse at Figure 7.8 shows that farmers from agriculturally high- to medium-potential areas of Central, Rift Valley, Western, and Nyanza Provinces and some parts of Coast Province need less time to reach the more lucrative markets in towns with more than 100,000 inhabitants. The predominantly pastoralist communities in ASALs spend upward of 26 hours to reach such markets with their animals, under the assumptions used in the model, and possibly longer if the animals are herded to market. Towns with populations of between 10,000 and 25,000 inhabitants could easily be reached by both agricultural producers and pastoralists, because the time needed to reach them is in the range of 1–8 hours for most parts of the country.

Agriculture

Tables 7.3 and 7.4 show key agricultural commodities in terms of area harvested as a percentage of the total area harvested and value of production. Considering the area harvested and its contribution to overall food security, Table 7.3 reveals that maize and beans are the most important crops in Kenya, contributing 37.5 percent and 17.9 percent, respectively, of the harvested areas.

A look at Table 7.4 reveals that in terms of the value of the crops produced, maize, tea, and potatoes are the top three commodities, contributing 17.9 percent, 16.4 percent, and 8.8 percent, respectively, to the total value of crops produced, and are strategic to income generation from farming.

Figure 7.9 shows the estimated yield and harvest areas for rainfed maize. The picture given is one of low productivity, with areas such as Northern, North Eastern, and upper Coast Provinces producing less than 0.5 tons per hectare, though there are many areas throughout the country producing up to 4 tons per hectare, including areas near Lake Victoria, Mount Elgon, the central Kenya highlands, southwestern Coast Province, and even northernmost North Eastern Province. In terms of the land area sown with the crop, the model predicts a fairly high preference for maize production, with nearly half of the country committing from 30 to more than 100 hectares of land to the crop. The areas predicated to commit more than 100 hectares to maize include the traditional grain basket of northern Rift, Western, Central, and

TABLE 7.3 Harvest area of leading agricultural commodities in Kenya, 2006–2008 (thousands of hectares)

Rank	Crop	Percent of total	Harvest area
	Total	100.0	4,631
1	Maize	37.5	1,734
2	Beans	17.9	828
3	Pigeon peas	3.9	182
4	Coffee	3.5	163
5	Tea	3.3	151
6	Cowpeas	3.2	147
7	Sorghum	3.0	141
8	Wheat	2.7	127
9	Potatoes	2.6	119
10	Millet	2.3	106

Source: FAOSTAT (FAO 2010).

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

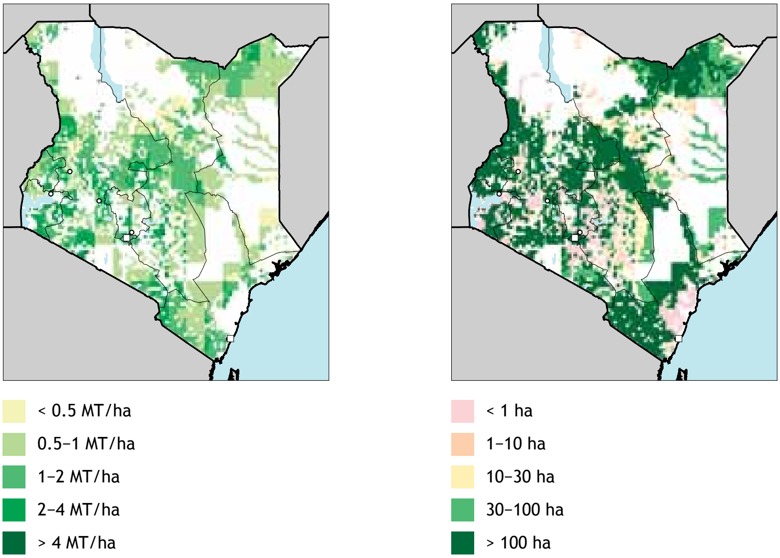
TABLE 7.4 Value of production for leading agricultural commodities in Kenya, 2005–2007 (millions of US$)

Rank	Crop	Percent of total	Value of production
	Total	100.0	3,650.7
1	Maize	17.9	651.7
2	Tea	16.4	597.6
3	Potatoes	8.8	321.2
4	Beans	6.7	243.3
5	Sugarcane	3.9	143.3
6	Cabbages and other brassicas	3.5	127.7
7	Pineapples	3.4	125.1
8	Coffee	3.1	114.0
9	Avocados	3.1	111.4
10	Tomatoes	3.0	109.1

Source: FAOSTAT (FAO 2010).

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

FIGURE 7.9 Yield (metric tons per hectare) and harvest area density (hectares) for rainfed maize in Kenya, 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.

southern Rift Provinces and the Central Kenya Highlands. The only exceptions in this category are areas on the border between Kenya and Ethiopia and the southwestern Coast Province. There is a clear positive correlation between areas willing to plant relatively large areas with maize and the productivity of the crop.

Figure 7.10 shows where rainfed beans are grown in Kenya, along with their productivity, which for the country averages around half a metric ton per hectare (FAO 2010).

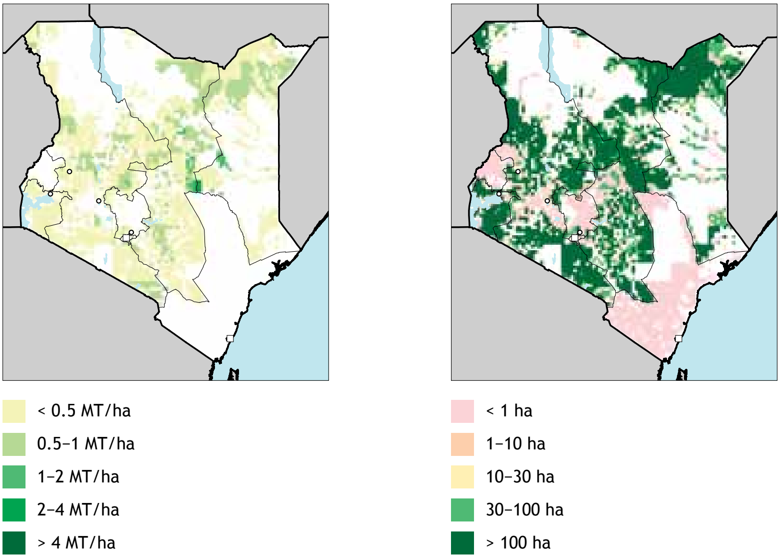
Scenarios for the Future

Economic and Demographic Indicators

Population

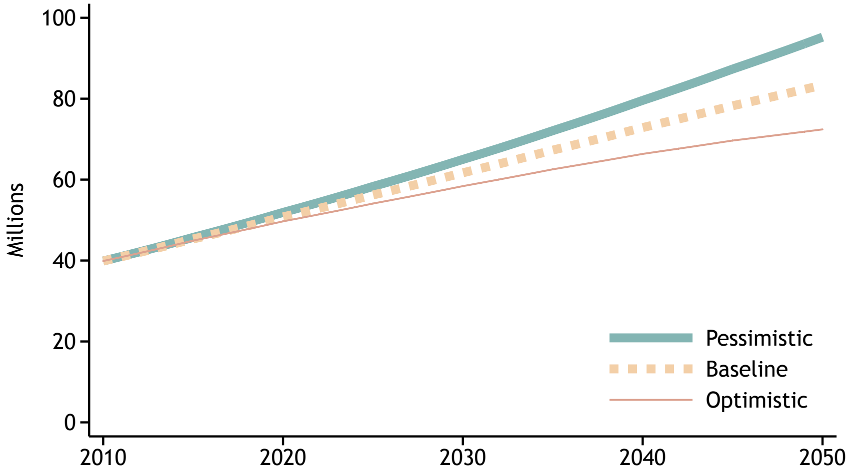
Figure 7.11 shows population projections for Kenya by the UN Population Division through the year 2050. Population projections predict a 150 percent increase between the base year and 2050 when the high-variant scenario

FIGURE 7.10 Yield (metric tons per hectare) and harvest area density (hectares) for rainfed beans in Kenya, 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 7.11 Population projections for Kenya, 2010–2050



Source: UNPOP (2009).

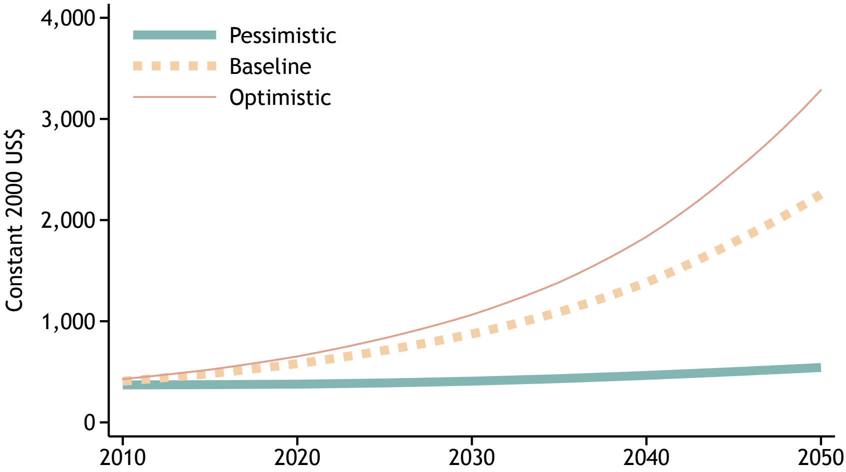
is considered, doubling of the population within the same period when the medium-variant scenario is considered, and an increase by 75 percent in the same period when the low-variant scenario is considered. The predictions from the three scenarios paint a picture of the likely pressure on productive resources if the country is challenged to remain food secure with increased numbers to feed.

Income

Figure 7.12 shows the three scenarios for GDP per capita used in this analysis. These are the result of combining three GDP projections with the three population projections of Figure 7.11 from the United Nations Population Division. The optimistic scenario combines high GDP with low population. The baseline scenario combines the medium GDP projection with the medium population projection. The pessimistic scenario combines the low GDP projection with the high population projection.

The emerging scenario is that the country will be able to achieve a high level of GDP per capita only if it embraces policies that will stimulate economic growth while concurrently checking high rates of population growth.

FIGURE 7.12 Gross domestic product (GDP) per capita in Kenya, 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.

The pessimistic scenario projects very slow growth in per capita GDP, which will increase by just under 50 percent between 2010 and 2050, rising to $543.

Biophysical Analysis

Climate Models

The data used in our analysis draws from four downscaled general circulation models (GCMs). Figure 7.13 shows projected precipitation changes under the four downscaled climate models, which were used with the A1B scenario.[1]

The CNRM-CM3 model predicts a significant reduction in annual rainfall in areas neighboring Lake Victoria, but elsewhere the story is more positive.[2] No change is anticipated for the Rift Valley. The model predicts a promising situation for the current ASALs of Coast, Eastern, and North Eastern Provinces, where there will be an increase of between 100 and 200 millimeters of precipitation. The CSIRO Mark 3 model predicts a change in rainfall for most of the country, with a very moderate increase around Turkana District and in the southwestern part of the country.

The predictions of the ECHAM 5 model are similar to those of the CSIRO Mark 3 model in that much of the country is projected to maintain the same rainfall as it has been receiving. Parts of the relatively dry mid to upper eastern, northwestern, and Lake Victoria region will benefit from gains of between 100 and 200 millimeters of precipitation. The MIROC 3.2 model presents the most optimistic scenario, predicting that nearly the entire country will experience an increase of between 100 and 300 millimeters of precipitation, with the extreme northern and southwestern parts of the country gaining most. The predictions of MIROC 3.2 forecast an era of enhanced resilience to the adverse effects of climate change.

Figure 7.14 shows changes in mean daily maximum temperature for the warmest month in Kenya. The CNRM-CM3 model predicts that the current agriculturally medium- to high-potential areas of the country and the northern

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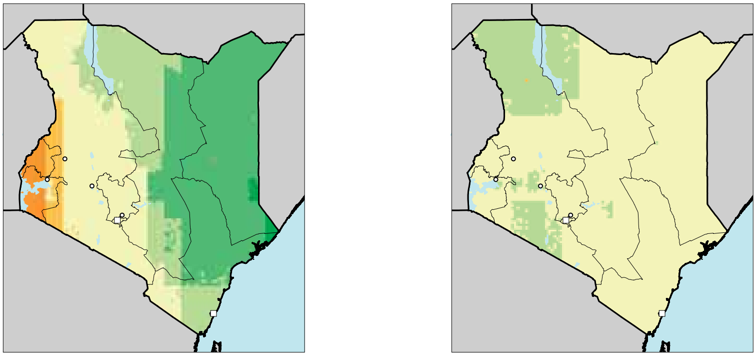
[1] The A1B scenario is a greenhouse gas emissions scenario that assumes fast economic growth, a population that peaks midcentury, and the development of new and efficient technologies, along with a balanced use of energy sources.

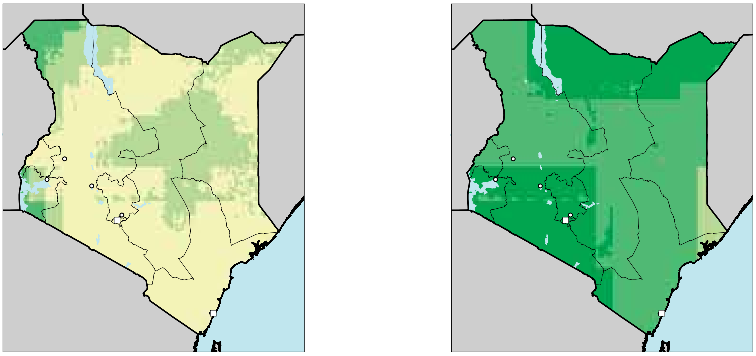
[2] CNRM-CM3 is National Meteorological Research Center–Climate Model 3. MIROC 3.2 is the Model for Interdisciplinary Research on Climate, developed at the University of Tokyo Center for Climate System Research. CSIRO Mark 3 is a climate model developed at the Australia Commonwealth Scientific and Industrial Research Organisation. ECHAM 5 is a fifth-generation climate model developed at the Max Planck Institute for Meteorology in Hamburg.

FIGURE 7.13 Changes in mean annual precipitation in Kenya, 2000–2050, A1B scenario (millimeters)



CNRM-CM3

CSIRO Mark 3



ECHAM 5

MIROC 3.2 medium-resolution

🟥 < −400

🟥 −400 to −200

🟧 −200 to −100

🟨 −100 to −50

🟨 −50 to 50

🟩 50 to 100

🟩 100 to 200

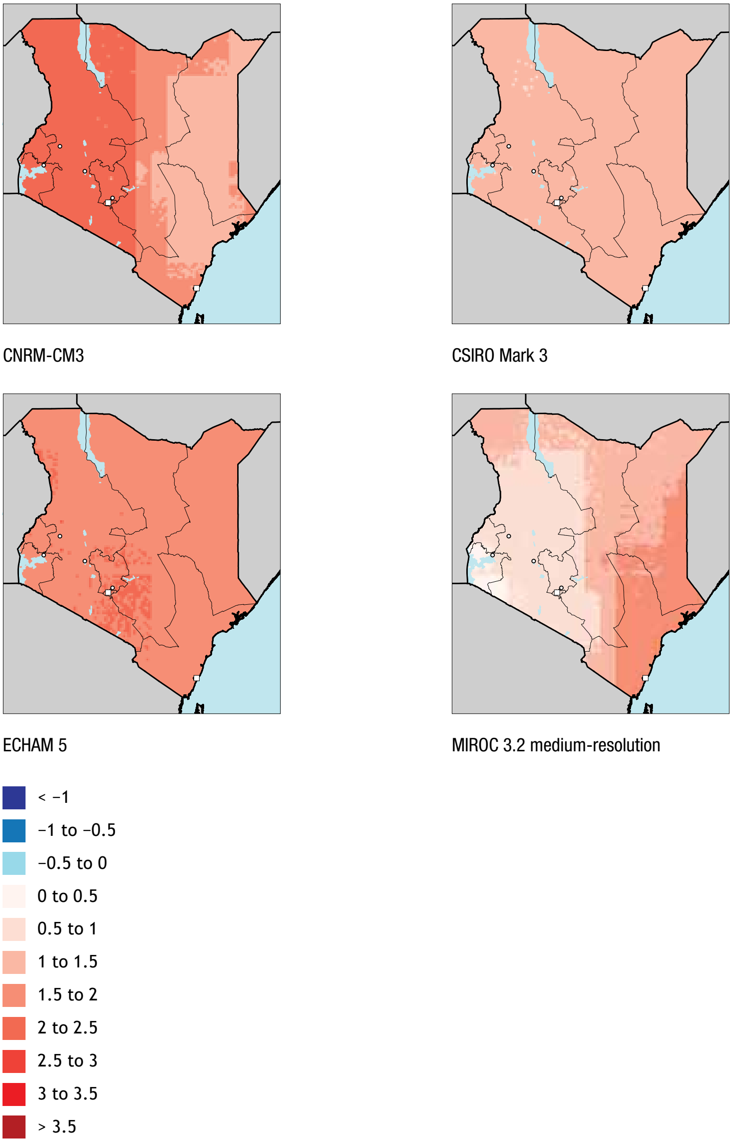
🟩 200 to 400

🟩 > 400

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 7.14 Changes in monthly mean maximum daily temperature in Kenya for the warmest month, 2000–2050, A1B scenario (°C)



CNRM-CM3

CSIRO Mark 3

ECHAM 5

MIROC 3.2 medium-resolution

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.

ASALs will experience a temperature increase of between 1.5° and 2.5°C over the prediction period. This is likely to lead to temperature stress, disease, an increase in pests, and high levels of evapotranspiration. The eastern part of the country will be affected less severely, with predicted temperature increases of between 1° and 1.5°C.

The CSIRO Mark 3 model predicts a fairly uniform increase in temperature of 1°–1.5°C across the country, while the ECHAM 5 model predicts a similar spatial spread but with a slightly higher increase in temperature of between 1.5° and 2°C, with small patches of the area experiencing an increase of between 2° and 2.5°C.

The MIROC 3.2 model predicts a situation in which most of the currently agriculturally medium- to high-potential areas will experience a marginal increase in temperature of between 0.5° and 1°C, while the easternmost part of the eastern, northeastern, and southern parts of Coast Province will experience increases of between 1° and 2°C, which is likely to result in heat stress.

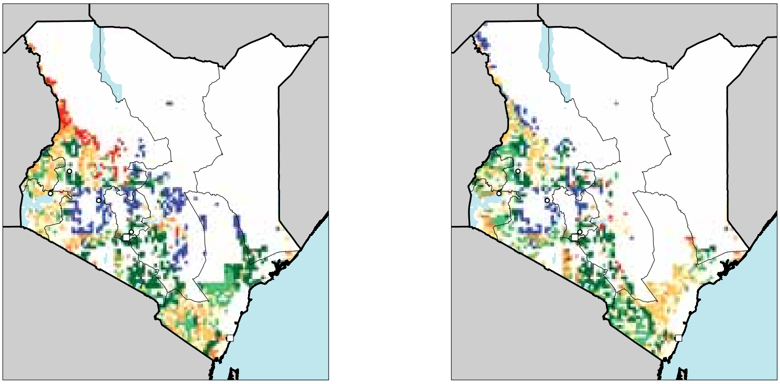
Crop Models

The Decision Support System for Agrotechnology Transfer (DSSAT) crop model was employed to compute yields under current temperature and precipitation regimes. The exercise was then repeated for future scenarios for the year 2050. For all locations, crop variety, soil, and management practices were held constant. The future yield results from DSSAT were then compared to the current or baseline yield results from DSSAT.

The output for key crops is mapped in Figures 7.15 and 7.16. The comparison is between the crop yields for 2050 with climate change and the yields with the 2000 climate. In Figure 7.15 we see the model predictions for rainfed maize. There is much variation between models, and in most models there is observable geographic variation within them as well. The MIROC 3.2 model is the most optimistic of the four, projecting yield increases in most areas, including large areas with a yield increase of more than 25 percent. The CNRM-CM3 GCM predicts loss of area in part of Rift Valley Province. These lost areas may be due to temperature rise. The ECHAM 5 GCM predicts a yield reduction in Coast Province of between 5 and 25 percent.

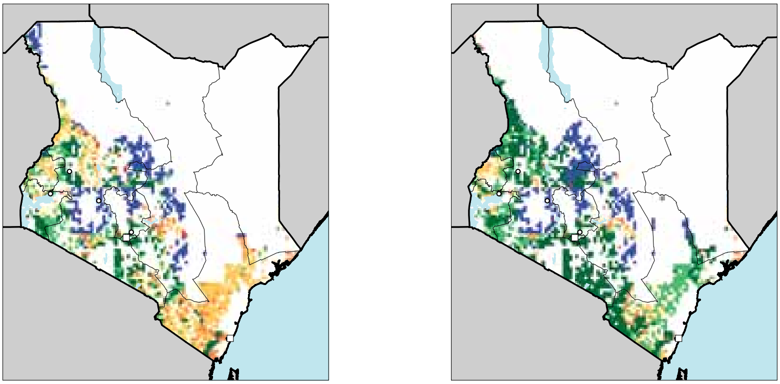
All models predict yield gains in areas that have not previously been able to cultivate maize. These are areas that were too dry for successful maize production. With new areas becoming available for maize cultivation, it seems important that policymakers consider encouraging people to cultivate maize in these areas sometime in the future. Some of these might be areas that are currently

FIGURE 7.15 Yield change under climate change: Rainfed maize in Kenya, 2000–2050, A1B scenario



CNRM-CM3

CSIRO Mark 3



ECHAM 5

MIROC 3.2 medium-resolution

🟥 Baseline area lost

🟧 Yield loss >25% of baseline

🟨 Yield loss 5–25% of baseline

⬜ Yield change within 5% of baseline

🟩 Yield gain 5–25% of baseline

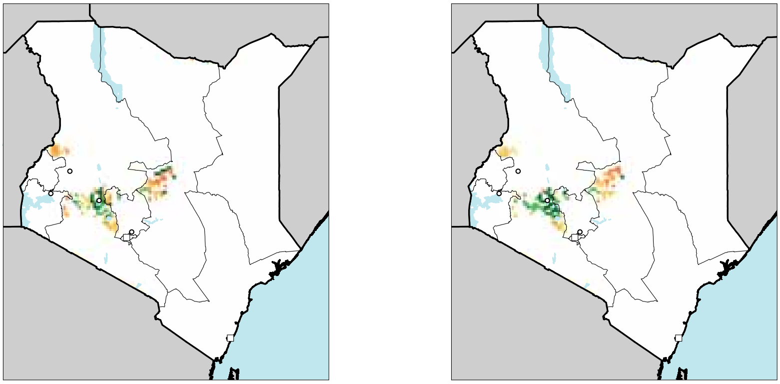
🟩 Yield gain > 25% of baseline

🟦 New area gained

Source: Authors' calculations.

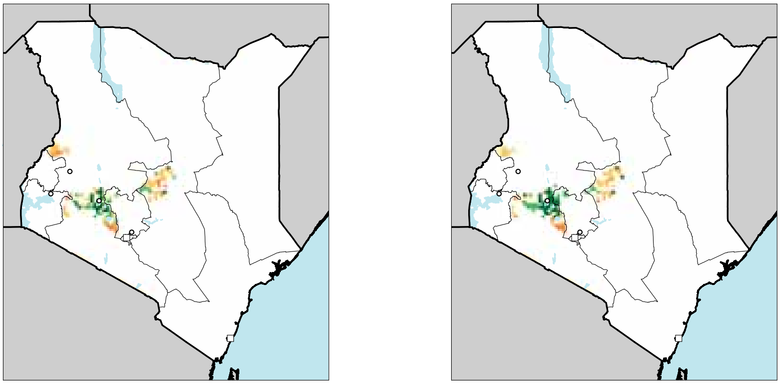
Notes: A1B = greenhouse gas emissions scenario that assumes fast economic growth, a population that peaks midcentury, and the development of new and efficient technologies, along with a balanced use of energy sources; CNRM-CM3 = National Meteorological Research Center–Climate Model 3; CSIRO = climate 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 7.16 Yield change under climate change: Rainfed wheat in Kenya, 2000–2050, A1B scenario



CNRM-CM3

CSIRO Mark 3



ECHAM 5

MIROC 3.2 medium-resolution

🟥 Baseline area lost

🟧 Yield loss >25% of baseline

🟨 Yield loss 5–25% of baseline

⬜ Yield change within 5% of baseline

🟩 Yield gain 5–25% of baseline

🟩 Yield gain > 25% of baseline

🟦 New area gained

Source: Authors' calculations.

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.

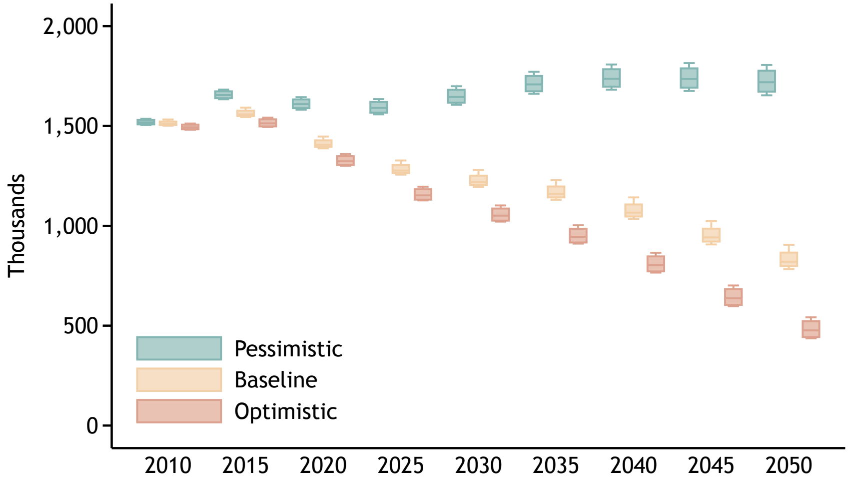
receiving precipitation that is not adequate to support maize production, like most of the ASALs. The point is that climate change may cause farmers to abandon some areas they are currently cultivating and move to new areas with a potential for maize production. Laws and procedures to facilitate such movement should be enacted in advance.

The yield change maps for wheat presented in Figure 7.16 are in general agreement, with losses predicted for the areas north of Mount Kenya and east of Mount Elgon. The four models also predict yield increases for wheat in a small area in Central Rift Valley neighboring Central Province. In general, the predictions show that maize will do better under climate change than will wheat.

Vulnerability

Figure 7.17 shows the impact of future GDP and population scenarios on the number of malnourished children under age five. Figure 7.18 shows the share of children who are malnourished. Under the pessimistic scenario, the number of malnourished children under age five increases to a maximum of 1.7 million by 2015 before gradually reducing to a minimum of 1.6 million, then gradually rising to a peak of 1.8 million by 2050. Under the baseline scenario, the

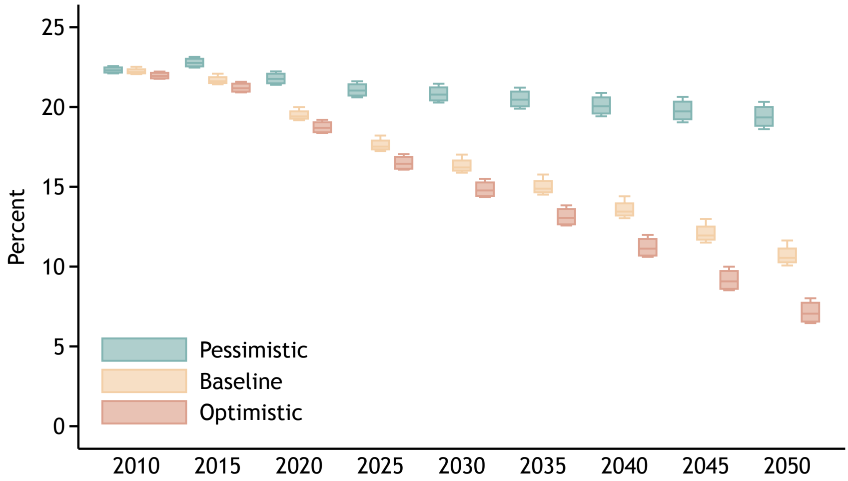
FIGURE 7.17 Number of malnourished children under five years of age in Kenya in multiple income and climate scenarios, 2010–2050



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 7.18 Share of malnourished children under five years of age in Kenya 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.

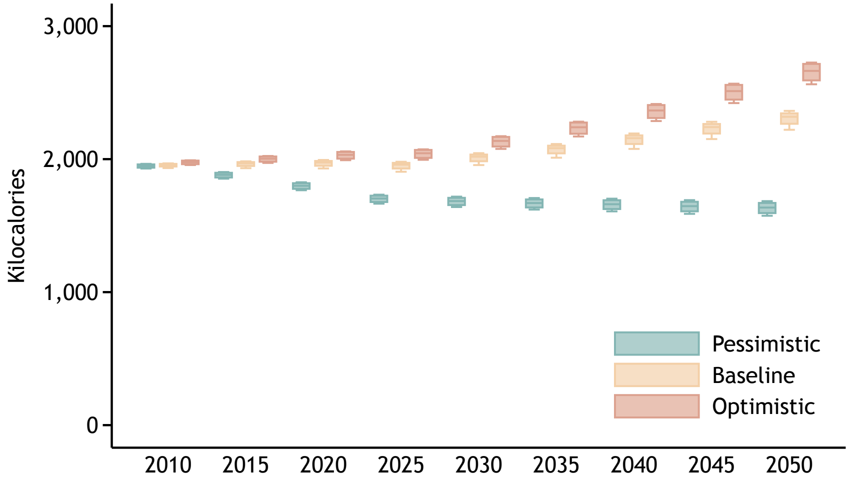
numbers will increase from 1.5 million to a peak of 1.6 million before declining across a temporal scale to a minimum of 0.8 million by 2050. Under the optimistic scenario, the numbers are predicted to decrease from a maximum of 1.5 million in 2010 to a minimum of 0.5 million by 2050. The share of malnourished children declines steadily because of population growth.

Figure 7.19 shows the kilocalories per capita available to each person in Kenya. A look at trends in available kilocalories per capita shows a slow downward trend under the pessimistic scenario. The available kilocalories decline from a high of 1,950 in 2010 to a low level of 1,650 in 2050. During this period, in the pessimistic scenario, the main staple, maize, almost doubles in price, while income rises less than 50 percent. When looking at both the optimistic and the baseline scenarios, mean calorie consumption rises slowly for the first 20 years, after which it assumes a relatively rapid upward trend up to 2050.

Agricultural Outcomes

Figure 7.20 shows simulation results of the impact of changes in GDP and population on maize in Kenya. A glance at Figure 7.20 reveals the following: (1) there is a gradual upward trend in the production of maize over time under

FIGURE 7.19 Kilocalories per capita in Kenya 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.

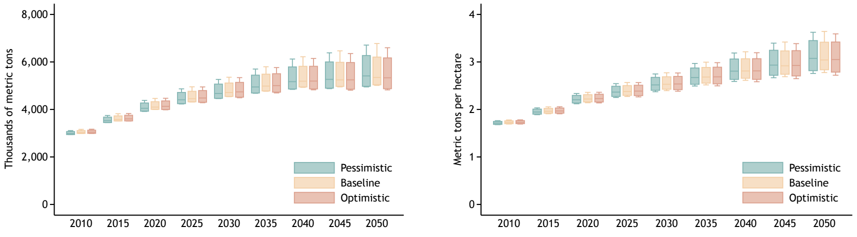
all three prediction scenarios; (2) the productivity of maize assumes an upward trend across the temporal scale for all three scenarios; (3) the area sown with maize rises slightly until around 2030, then declines to 2050, ending approximately where it began; (4) the variation between climate models is large for net exports, though we can at least say that the median rises to around 2025, then declines, but with 2050 levels slightly higher than those for 2010; and (5) the trend in the world price of maize assumes an upward trend across the temporal scale for all three scenarios.

Conclusions and Policy Recommendations

The trends in the contribution of agriculture to GDP in Kenya show that the overall importance of agriculture declined from 1960 to 2008. Nevertheless, it is still an important sector for the employment of many people and for keeping more people from slipping into poverty. These auxiliary roles of agriculture are likely to remain important for quite some time into the future.

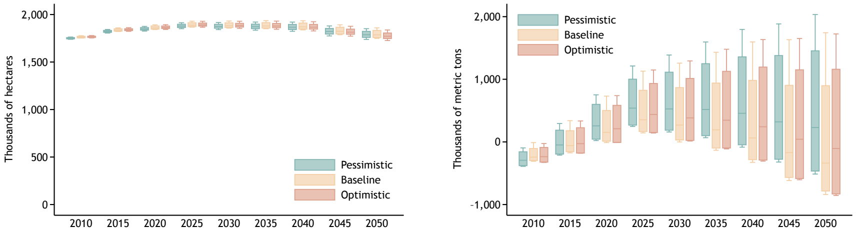
In the four climate models we used in this study, we noted significant differences between them and within them, geographically. The CNRM-CM3 model, for example, projects a much warmer future in the higher-productivity

FIGURE 7.20 Impact of changes in GDP and population on maize in Kenya, 2010–2050



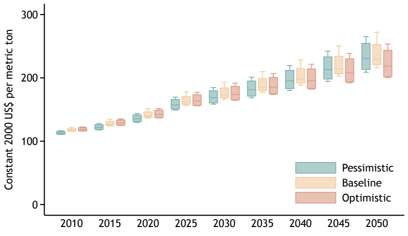
Production

Yield



Area

Net exports



Prices

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

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

areas of Kenya, with either little change in rainfall or a decline; meanwhile, the MIROC 3.2 model projects little temperature rise and a wetter future for Kenya, particularly in some of the higher-productivity areas. It is no surprise, then, that when they are used in crop models for rainfed maize, the results based on the CNRM-CRM3 model predicted yield reductions for large areas of Kenya and even a loss of some areas for the planting rainfed maize, while the results based on the MIROC 3.2 model predicted that there will be areas of yield increases, some quite large. Such differences between climate models suggest that policies aimed at helping farmers adapt to climate change must be flexible, easily reversible, and perhaps capable of offering differing regional solutions based on the different impacts of climate change across regions.

The International Model for Policy Analysis of Agricultural Commodities and Trade results, which takes into consideration technological improvements, projects an increase of around 80 percent in maize yield between 2010 and 2050, which seems to be a large enough increase to meet in-country demand for maize. Many assumptions were made to predict rates of technological improvements, and it is possible that if policymakers fail to sufficiently fund agricultural research institutions or extension agencies, the actualized rate of technological improvement will be slower, leading to slower growth in yield and to farmers' not producing enough food to meet demand.

In a rapidly changing climate, farmers cannot rely on traditional means of learning and transmitting knowledge. That is why research and extension are so important, not only to create new varieties or perhaps simply test internationally developed varieties but also to propagate the seeds and keep farmers informed of developments so that they can take advantage of them. The high enrollment rates in primary and secondary schools offer a critical means for sensitization of the population to adaptation to climate change in the agricultural sector. Furthermore, they suggest that farmers will be able to understand more complicated and varied messages from extension agents that will likely need to be presented to them as changes in climate become more apparent.

Although irrigation agriculture has the potential to serve as an important adaptive intervention against known and anticipated adverse effects of climate change, the situation in Kenya is such that irrigation accounts for only 1.7 percent of the total land area under agriculture, which calls for an upscaling of irrigation.

Stresses on the rural and agricultural sectors will be less severe if the population growth rate is slowed and the other sectors of the economy continue growing. This suggests a need for policies that encourage family planning, including educating adults and ensuring that girls receive opportunities for secondary education. It also suggests that there is a need for continued work on improving the business environment in Kenya so that manufacturing and services can thrive.

Yield improvements are contingent on farmers' having access to inputs at the lowest market prices possible and being able to sell their outputs at the highest possible prices. One of the important ways to help ensure such efficiencies is continued investment in infrastructure.

As this study has shown, farmers in Kenya can potentially thrive even with climate change. Their probability of success would be greatly enhanced with a supportive policy environment. Adopting the proposals just presented, or ones that are similar, will go a long way toward creating such an environment.

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