Chapter 7

SOUTH AFRICA

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In examining agricultural vulnerability to climate change in South Africa, we see that an important factor is the enormous existing socioeconomic disparity in access to resources, poverty levels, and capacities to adapt. Recent research results suggest that the South African farming sector is characterized by medium-level exposure risk, coupled with medium to high levels of social vulnerability (Gbetibouo and Ringler 2009).

South Africa is unique in southern Africa: from a climatological perspective, it has a steep rainfall gradient from west to east, as well as three different rainfall regimes; from a developmental perspective, it has a highly developed industrial and commercial infrastructure. Agricultural production is mostly commercial, with only 11 percent of the land arable—and much of that is located in marginally viable areas. Less than 20 percent of the country's production is from small-scale agriculture.

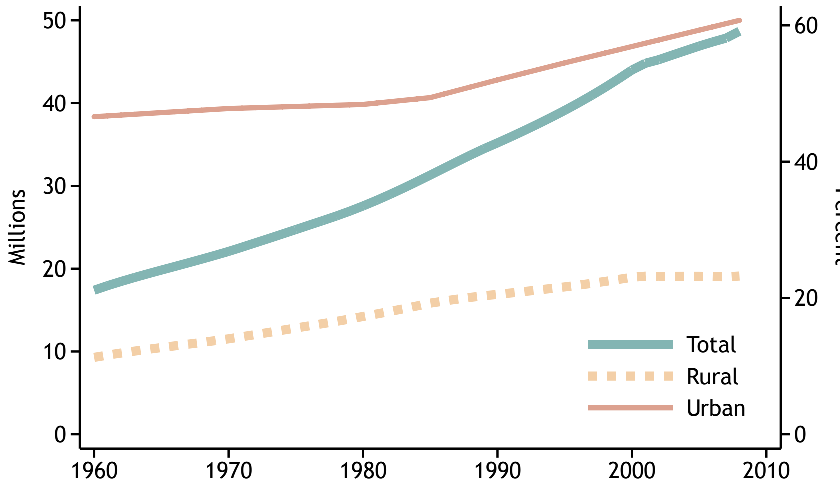
Review of Current Trends

Economic and Demographic Indicators

Population

Figure 7.1 shows trends for the total and rural populations of South Africa (left axis), as well as the share of the population that is urban (right axis). The figure provides additional information concerning rates of population growth. The graph shows that, although the total population is increasing steadily, the rate of growth decreased around 2000. This finding is backed up by the numbers in Table 7.1. The period 2000–2008 shows much slower growth than in previous periods, at 1.20 percent; this may be related to the fact that a population census was not taken during that period, but it may also reflect the impact of HIV/AIDS on mortality rates. Urban growth rates reflect increased trends toward urbanization. Although rural informal agriculture may be in decline,

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



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

urban agriculture may be increasing. The latter holds little potential for commercial production. Rural agriculture, when shifting from subsistence to commercial, would generally use less labor and more mechanization along with efficiencies of scale.

Figure 7.2 shows the geographic distribution of population in South Africa.

Income

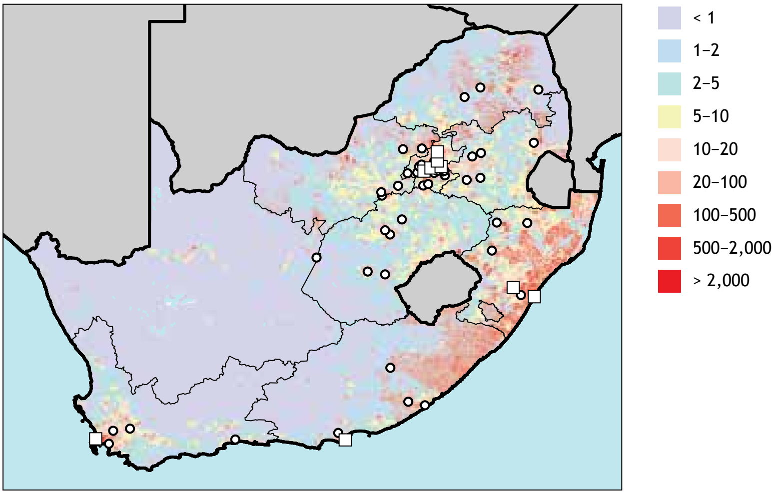
Figure 7.3 shows trends in gross domestic product (GDP) per capita and the proportion of GDP from agriculture. The decline in the contribution to GDP from agriculture reflects the increasing contributions from other sectors in the

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

Decade	Total growth rate	Rural growth rate	Urban growth rate
1960–1969	2.4	2.1	2.6
1970–1979	2.2	2.1	2.3
1980–1989	2.5	1.8	3.2
1990–1999	2.2	1.1	3.1
2000–2008	1.2	0.0	2.0

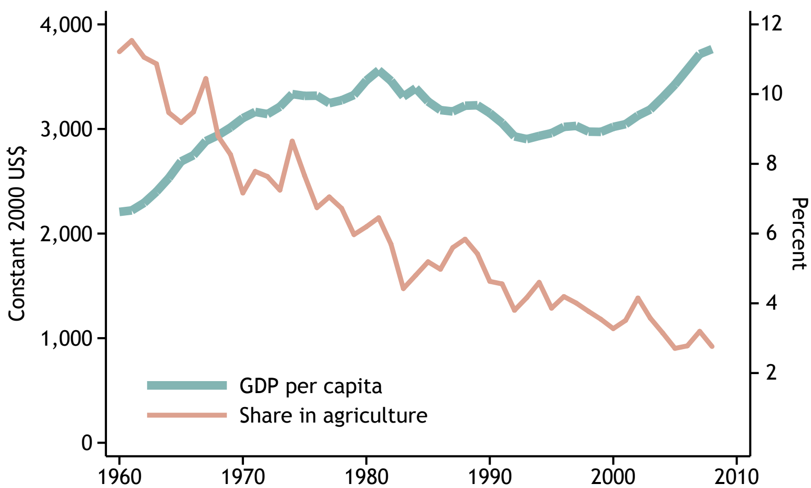
Source: *World Development Indicators* (World Bank 2009).

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



Source: CIESIN et al. (2004).

FIGURE 7.3 Per capita GDP in South Africa (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.

economy. The overall increase in GDP per capita since 1990 should indicate a growing improvement in personal well-being.

Vulnerability to Climate Change

Table 7.2 provides some data on indicators of a population's vulnerability or resiliency to economic shocks: level of education, literacy, and concentration of labor in poorer or less dynamic sectors. The figures for South Africa appear to indicate a healthy rate of literacy and education, but the values include a significant number of non-school-age learners currently in the education system. Similarly, although the adult literacy level appears high, it does not accurately reflect existing adult education levels. Although 65 percent of whites over 20 years old and 40 percent of ethnic Indians have completed at least high school, this figure is only 14 percent for black South Africans and 17 percent for the colored population.

Figure 7.4 shows two noneconomic correlates of poverty: life expectancy and under-five mortality. Life expectancy has decreased since 1990, and child mortality has also decreased. Figure 7.5 shows the HIV infection rate. This has influenced life expectancy. A positive sign is the leveling off of the rate of infection in the past decade.

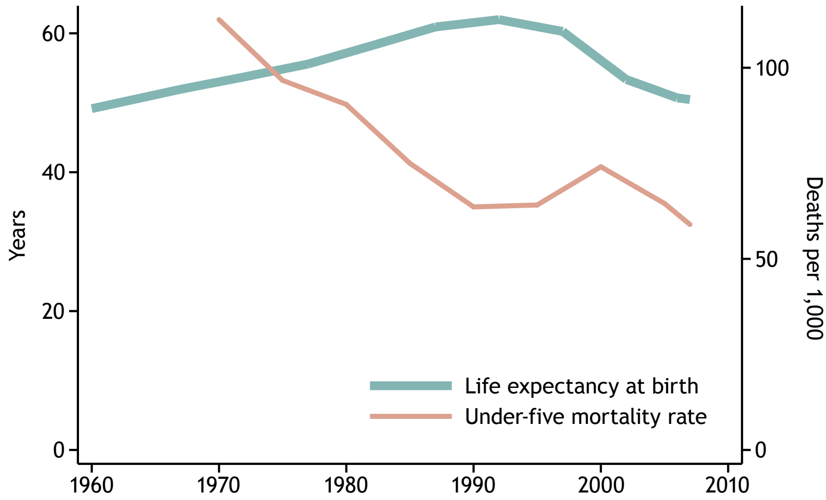
Figure 7.6 shows the distribution of the population living on less than $2 per day (the criterion for poverty). This indicator is based on actual income and ignores social grants and remittances. It is measured according to magisterial and provincial boundaries and does not reflect overall population density. It gives a good indication of the locations of the poorest members of the population, who reside mostly in rural areas. The World Bank (2012) calculates that 31.3 percent of the total population of South Africa was living on less than $2 per day in 2009 (2009 data measured at 2005 prices).

TABLE 7.2 Education and labor statistics for South Africa, 2007

Indicator	Year	Value (percent)
Primary school enrollment (percent gross, three-year average)	2007	102.5
Secondary school enrollment (percent gross, three-year average)	2007	97.1
Adult literacy rate (percent)	2007	88.0
Percent employed in agriculture	2007	8.8
Percent with vulnerable employment (own farm or temporary labor)	2007	2.7

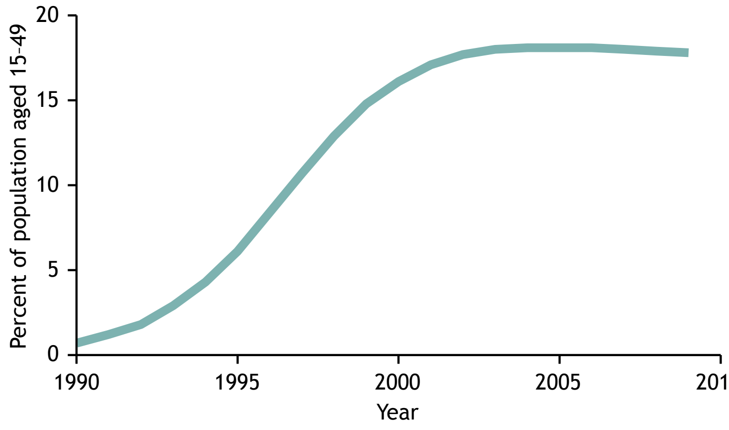
Source: *World Development Indicators* (World Bank 2009).

FIGURE 7.4 Well-being indicators in South Africa, 1960–2008: Life expectancy and under-five mortality rate



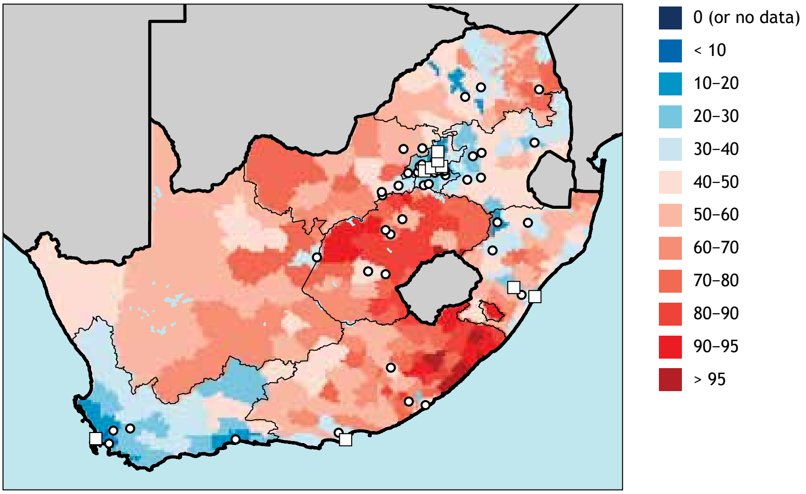
Source: *World Development Indicators* (World Bank 2009).

FIGURE 7.5 Well-being indicators in South Africa: Prevalence of HIV infection, 1990–2008



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

FIGURE 7.6 Poverty in South Africa, circa 2005 (percentage of population below US$2 per day)



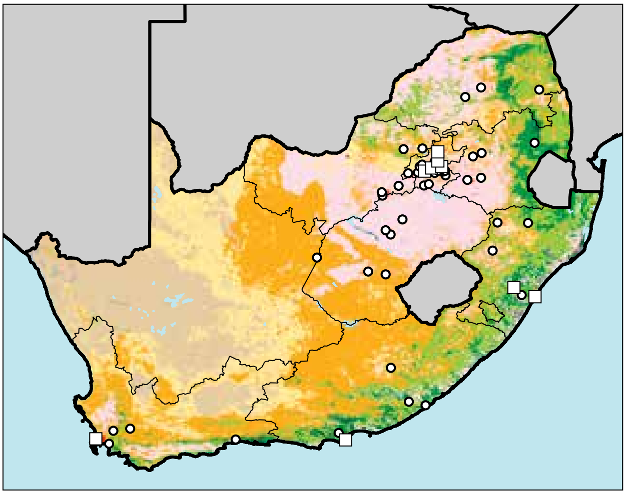
Source: Wood et al. (2010).
Note: Based on 2005 US$ (US dollars) and on purchasing power parity value.

Land Use Overview

Figure 7.7 shows the natural land cover and agricultural land use in South Africa as of 2000. The natural land cover has been mostly replaced by field crops, forests, and orchards where arable land is present; elsewhere, natural vegetation is used for grazing.

Figure 7.8 shows the locations of protected areas, including parks and reserves. These locations provide important protection for fragile environments, which may also be important for the tourism industry. South Africa enjoys the third-highest level of biodiversity in the world. Although the country covers only 2 percent of the world's land area, nearly 10 percent of the world's plant species and 7 percent of its reptiles, birds, and mammals are found there. South Africa's marine life is similarly diverse, partly as a result of the extreme contrast between the water masses on the east and west coasts. Over 10,000 plant and animal species—almost 15 percent of the coastal species known worldwide—are found in South African waters, with about 12 percent of these occurring nowhere else. By May 2008, about 5.9 percent of South Africa's land surface area was under formal conservation through the system of national and provincial protected areas, whereas approximately

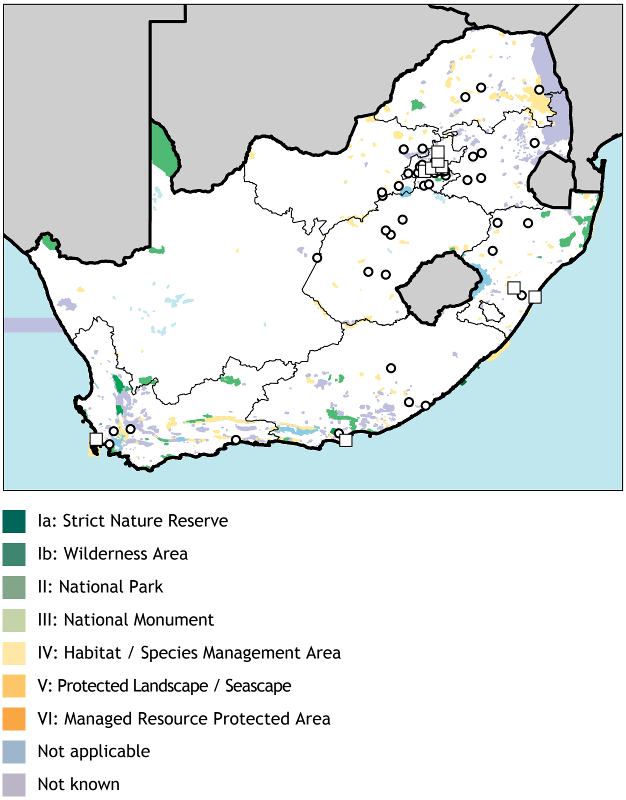
FIGURE 7.7 Land cover and land use in South Africa, 2000



- 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 South Africa, 2009

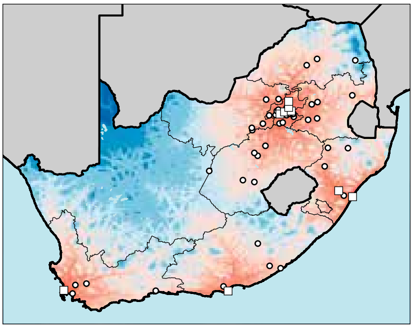


Sources: Protected areas are from the World Database on Protected Areas (UNEP and IUCN 2009). Water bodies are from the World Wildlife Fund's Global Lakes and Wetlands Database (Lehner and Döll 2004).

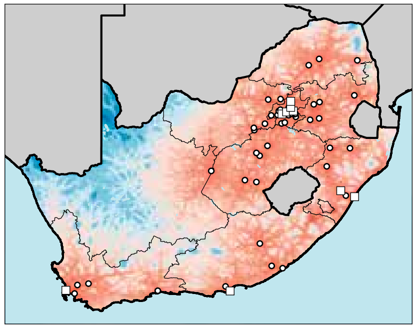
12 percent was under game farming and conservation management (South Africa Government Communications 2009).

Figure 7.9 shows travel times to urban areas of various sizes, which are potential markets for agricultural products as well as sources of agricultural inputs and consumer goods for farm households. The maps do not accurately convey the state of the roads or the terrain, which can be seriously inhibiting factors when attempting to transport goods to markets. The most remote area is the central Northern Cape Province, which has a population density of about 1–2 persons per square kilometer and is the least suitable for agriculture.

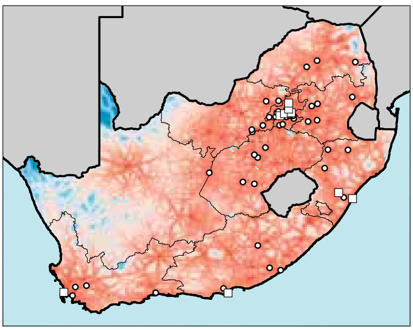
FIGURE 7.9 Travel time to urban areas of various sizes in South Africa, circa 2000



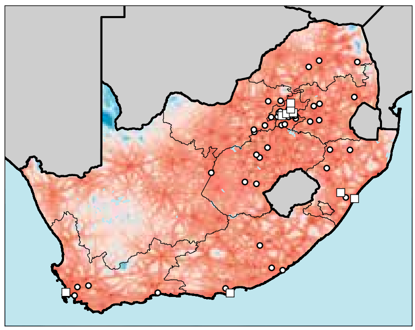
To cities of 500,000 or more people



To cities of 100,000 or more people



To towns and cities of 25,000 or more people



To towns and cities of 10,000 or more people

Source: Authors' calculations.

Agriculture Overview

About 8.5 million people are directly or indirectly dependent on agriculture for employment and income. The total contribution of agriculture to the economy increased from R38 billion (38 billion South African rand; US$1 ≈ R7) in 2002 to R68 billion in 2008. South Africa's dual agricultural economy comprises a well-developed commercial sector, an increasingly significant emerging sector, and a predominantly subsistence-oriented sector in the rural areas. Agricultural activities range from intensive export production (fruit, wine, and field crops) to mixed farming to cattle and sheep farming.

About 11 percent of South Africa's surface area is available for crop production, of which only 22 percent is high-potential arable land. About 1.5 percent of the country's agricultural land (1.3 million hectares) is under irrigation. About 81 percent of the total land area is farmed (crops and livestock included). However, only 70 percent of this area is suitable for grazing. Overgrazing and erosion diminish the carrying capacity of the veld and lead to land degradation. The most important limiting factor in agricultural production is water availability. Almost 50 percent of South Africa's available surface water is used for agricultural purposes.

Primary commercial agriculture contributes about 3 percent to South Africa's GDP and about 7 percent to its formal employment. However, due to strong backward and forward linkages to the economy, the agroindustrial sector is estimated to compose about 12 percent of GDP. Although the country has the potential to be self-sufficient in virtually all major agricultural products, the rate of growth in exports has been slower than that of imports.

Despite the farming industry's declining share in GDP, it remains vital to the economy and to the development and stability of the southern African region as a whole. Since 2005, agricultural exports have contributed, on average, about 7 percent of the total South African exports. Exports increased from 5 percent of agricultural production in 1988 to 38 percent in 2007; however, the growth in imports of processed goods is increasing even faster.

Major import products include wheat, rice, oil cakes, vegetable oils, and poultry meat. The estimated value of imports in 2008 was R38.4 billion, whereas exports totaled R44.3 billion in the same year. The largest export groups are wine, citrus, sugar, grapes, fruit juice, wool, and deciduous fruit, such as apples, pears, and quinces. Other important export products are avocados, pineapples, groundnuts, preserved fruit and nuts, maize (when a surplus is available), and hides and skins.

Owing to its geographic location, some parts of South Africa are prone to drought. At present, the country's agricultural sector experiences multiple stressors, including (but not limited to) variable rainfall, widespread poverty, environmental degradation, uncertainties surrounding land transfer and transformation, limited access to capital and markets, inadequate infrastructure and technology, and HIV/AIDS. Climate change—superimposed on all these other stressors—is anticipated to exacerbate these issues. With low adaptive capacity, throughout the value chain the South African agricultural sector is highly vulnerable to the effects of climate change and the anticipated increase in climate variability.

The Fourth Assessment Report of the Intergovernmental Panel on Climate Change states that "agricultural production and food security (including access to food) in many African countries and regions are likely to be severely compromised by climate change and climate variability" (Boko et al. 2007, 435). Because most of the arable land in South Africa is rainfed, increasing rainfall variability—widely projected under climate change conditions—would threaten the livelihoods of people who depend on rainfed agriculture, increasing the percentage of the population suffering from hunger and undernourishment.

Farmers, both subsistence and commercial, have developed varied strategies to cope with the current climate variability in South Africa. These strategies, however, may not be sufficient to cope with climatic changes of the future (Boko et al. 2007). In an effort to address issues related to climate change in the agricultural sector, the Department of Agriculture, Forestry, and Fisheries has developed the Climate Change Sector Plan and Climate Change Programme to ensure a sustainable, profitable agricultural sector. The plan is a response to the South African National Climate Change Response Strategy as well as the cabinet's mandated action plans calling for individual plans for all sectors. Research on the impact of climate change on agricultural production is being supported to allow policymakers to better understand and plan for likely impacts. Climate change vulnerability, mitigation, and adaptation are three key concepts that are of critical importance to agriculture.

Regardless of any impacts of climate change in South Africa, agriculture is already affected by droughts, floods, cyclones, and veld fires, among other natural hazards. The losses resulting from these impacts can be minimized by strengthening the early warning system for all natural hazards. The system communicates early warning information in the form of monthly advisories and daily extreme weather warnings to the sector for disaster risk reduction, mitigation, and preparedness in accordance with the Disaster Management Act of 2002 (Republic of South Africa, Presidency 2003). Climate variability means that drought episodes are fairly regular and are interspersed with flooding episodes, resulting in lower average agricultural yields.

TABLE 7.3 Value of production of leading agricultural commodities in South Africa, 2000 and 2008 (millions of US$)

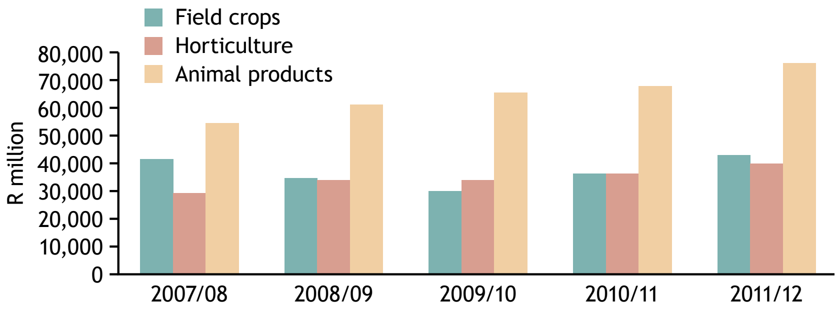
	Production	
Commodity	2000	2008
Total	8,455	15,855
Indigenous cattle meat	1,284	1,580
Indigenous chicken meat	954	1,135
Maize	919	1,004
Grapes	674	831
Cows' milk, whole, fresh	646	771
Sugarcane	495	425
Hen eggs, in shell	241	371
Wheat	363	320
Indigenous pig meat	105	299
Oranges	205	267
Potatoes	214	264
Apples	164	221
Sunflower seed	133	205
Indigenous sheep meat	105	167
Tomatoes	95	128
Pears	87	95
Onions, dry	60	91
Wool, greasy	88	75
Groundnuts	60	74
Peaches and nectarines	79	73

Source: FAOSTAT (FAO 2010).
Note: US$ = US dollars.

Table 7.3 shows key agricultural commodities in terms of their monetary value. The value of maize as a crop is eclipsed only by the value of protein in the form of poultry. Sugarcane and wheat are the other rainfed crops that show high values; irrigated crops such as fruits and vegetables are also significant. Most livestock are fed either from natural pastures or from grains, increasing the monetary value of the latter in the food chain.

Figure 7.10 shows that the contributions of animal products, horticultural products, and field crops to the total gross value of agricultural production are

FIGURE 7.10 Value of production of agricultural commodities by type in South Africa, 2007/2008–2011/2012

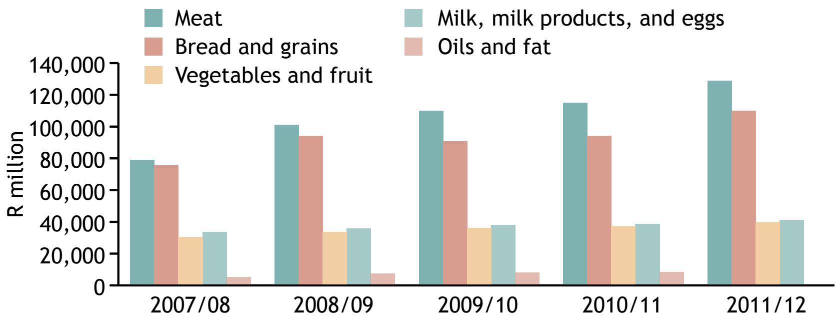


Source: Republic of South Africa, DAFF (2013).

51.3 percent, 25.7 percent, and 23.0 percent, respectively. The poultry meat industry made the largest contribution, at 18.2 percent, followed by cattle and calves slaughtered, at 11.2 percent, and maize, at 10.9 percent.

The consumption expenditure on food for the year 2009/10 shows a 2.29 percent increase over the previous year at R338,875 million compared to R331,300 million (Figure 7.11). The steadily increasing demand for meat reflects a growing trend; the increasing grain requirement for feed coincides with a recent decrease in human grain consumption.

FIGURE 7.11 Gross value of food consumption expenditure in South Africa, 2007/2008–2011/2012



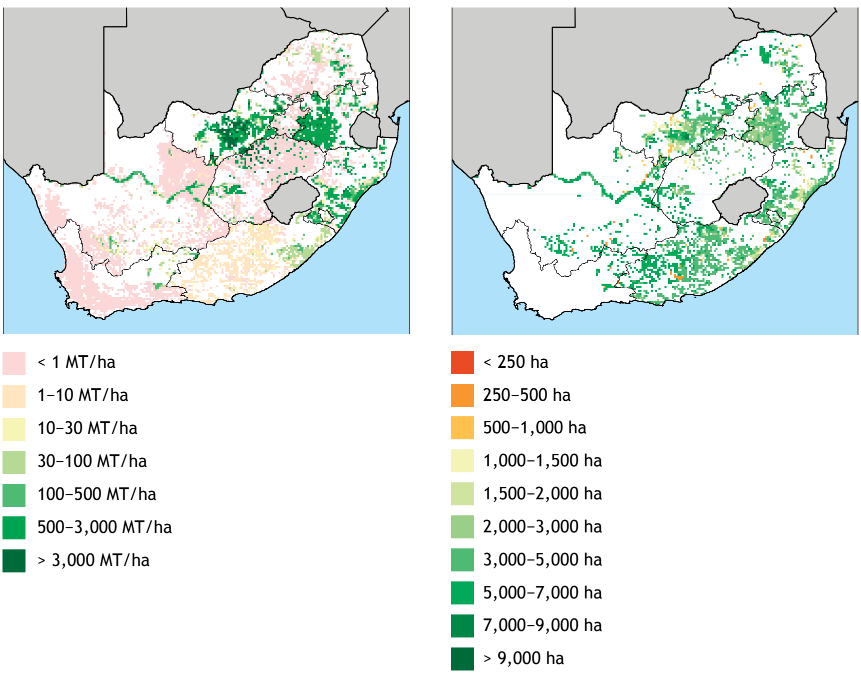
Source: Republic of South Africa, DAFF (2013).

Note: R = South African rand; US$1 ≈ R7.

Maize

Maize (*Zea mays* L.) is South Africa's most important field and grain crop (Figure 7.12). Approximately 10–16 kilograms of grain are produced for every millimeter of rainfall or irrigation water "consumed" by the maize plant; in essence, this means that each maize plant will have used around 250 liters of water by maturity (Du Plessis 2003). Maize is the staple food for most of South Africa's people. The crop provides the basic household requirements of subsistence and emerging farmers, and any excess production is sold to supplement household income (Republic of South Africa, NDA 2005). The maize industry is also an important foreign exchange earner through exports of maize and maize products. The consumption requirement of maize for South Africa is around 8.7 million tons per year—around 4.8 million tons for white maize and around 3.9 million tons for yellow maize—as it is the most important feed ingredient in the beef, dairy, and poultry industries.

FIGURE 7.12 Yield (metric tons per hectare) and harvest area density (hectares) for maize in South Africa, 2005



Sources: 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.

Maize is produced in South Africa by around 9,000 commercial farmers and provides direct employment to a workforce of around 130,000. In addition, tens of thousands of people are employed in the various industries relying on maize as a raw material (mainly for milling and stock feeds). Maize is generally planted from October to December, depending on regional and seasonal rainfall and temperature patterns—for example, as soon as sufficient soil moisture has accumulated (about 25 millimeters over a five-day period) or when soil temperatures are high enough for germination (when minimum temperatures of 10°–15°C have been maintained for a week) (Republic of South Africa, NDA 2005).

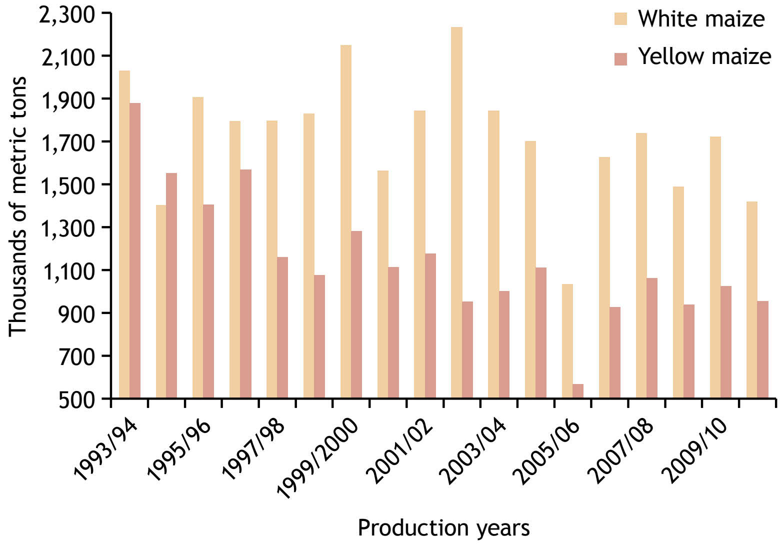
As a warm-weather crop, maize requires daily mean temperatures above 22°C: the ideal is a January mean between 19° and 24°C. The maximum temperature that can be reached before heat-related yield reductions are incurred is around 32°C. Frost can damage maize at all growth stages, and generally a frostfree period of 120–140 days is required to prevent damage. Maize can be produced in areas with a mean annual precipitation as low as 350 millimeters, but ideal rainfall levels are 450–600 millimeters during the growing season (Republic of South Africa, NDA 2005). Sustained production depends on an even distribution of rainfall throughout the growing season (Republic of South Africa, NDA 2005), but rainfall is particularly critical during the flowering season, when soil water stress reduces yields more than during other growth phases.

In the decade 1995/1996–2004/2005, maize yields in South Africa fluctuated between 2.16 and 3.04 tons per hectare, depending primarily on climatic conditions. Under irrigation, yields average 6.05 tons per hectare, with the highest yields in the Northern Cape (6.76 tons per hectare), Free State (6.31 tons per hectare), and Mpumalanga Provinces (6.27 tons per hectare) (Statistics South Africa 2002; Schulze and Walker 2007). It seems that the total area planted with maize is slowly decreasing, whereas it seems that production is increasing (Figures 7.13 and 7.14). This reflects the increasing efficiency and technological advances within the industry as well as the (mostly) favorable climatic conditions over the past decade.

Wheat

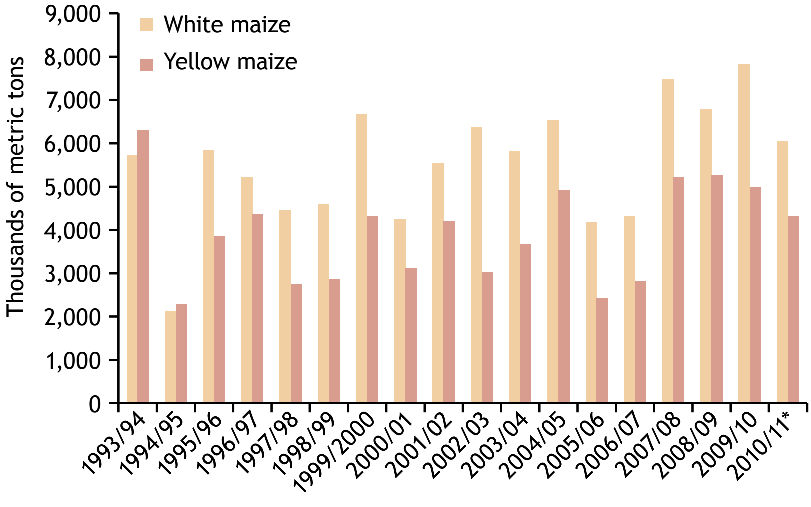
The Western Cape and Free State Provinces typically produce three quarters of the South African wheat crop (Figure 7.15). Approximately 85 percent of the total wheat area is cultivated under rainfed conditions, whereas the other 15 percent is irrigated. Most wheat produced in the Western Cape is

FIGURE 7.13 Area planted with maize, South Africa, 1993/1994–2010/2011 (thousands of hectares)



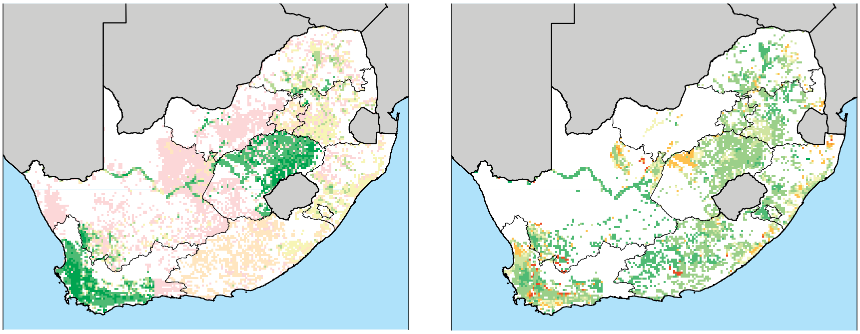
Source: Grain SA (2010).

FIGURE 7.14 Maize production, South Africa, 1993/1994–2010/2011 (thousands of metric tons)



Source: Grain SA (2010).
Note: * = preliminary estimates.

FIGURE 7.15 Yield (metric tons per hectare) and harvest area density (hectares) for wheat in South Africa, 2005



< 1 MT/ha
1–10 MT/ha
10–30 MT/ha
30–100 MT/ha
100–500 MT/ha
500–3,000 MT/ha
> 3,000 MT/ha

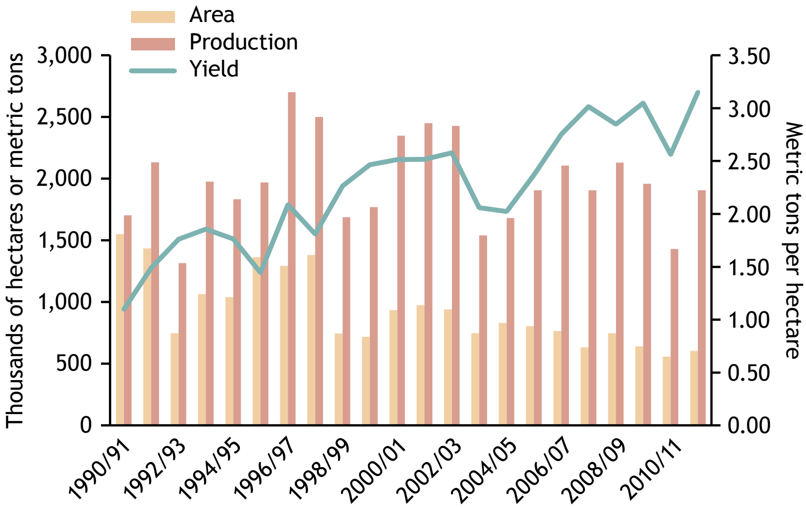
< 250 ha
250–500 ha
500–1,000 ha
1,000–1,500 ha
1,500–2,000 ha
2,000–3,000 ha
3,000–5,000 ha
5,000–7,000 ha
7,000–9,000 ha
> 9,000 ha

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.

under rainfall conditions; the southwestern part of the Western Cape is one of the most important wheat-producing regions in South Africa. Unsteady and erratic rainfall in the Western Cape often produces wide variations in wheat yields and quality. Accordingly, South Africa could produce a surplus of wheat during years with very good rainfall, but it experiences shortages of wheat in most years. The planted areas are decreasing (Figure 7.16), and, though yields are increasing, total production cannot cope with increased demand.

Critics say that the shortage of wheat supply is due to a combination of factors, primarily the government's decision to open up the domestic market to global forces. But transport and infrastructure problems also make it costly for farmers to use the railways to export their product. In any case, South Africa may face a growing food crisis if a decline in domestic wheat production threatens to escalate food prices.

FIGURE 7.16 Area planted, production, and yields for wheat in South Africa, 1990/1991–2010/2011

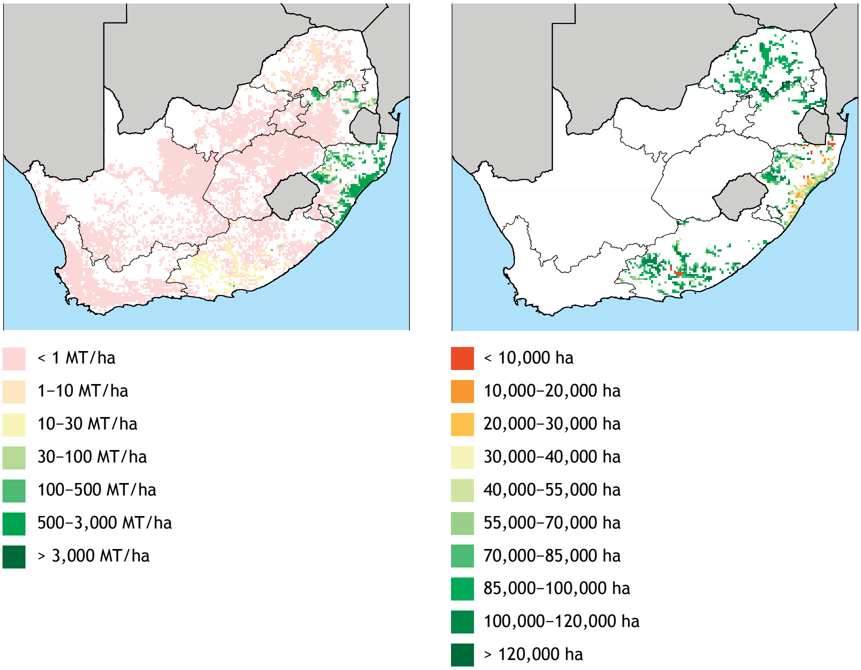


Source: Republic of South Africa, DAFF (2013).

Sugar

South Africa is ranked 13th in the world as a producer of sugarcane (*Saccharum officinarum*) (South Africa Government Communications 2005). The sugar industry in South Africa employs 85,000 people directly as well as 265,000 indirectly (for example, in the fertilizer, fuel, chemical, transport, food, and services sectors); an additional 1 million jobs are dependent on the sugar industry. The industry contributes approximately R2.0 billion annually to foreign exchange earnings. Sugarcane makes up approximately 15 percent of the gross value of the country's agricultural production and approximately 4.5 percent of its total agricultural production by tonnage. Sugarcane is grown by nearly 50,000 registered producers: 2,000 large-scale growers (average farm size 165 hectares) produce about 78 percent of the total crop; about 47,000 small-scale growers farm 2.0–2.5 hectares, on average, and produce 12 percent of the total crop. The remaining 10 percent is produced by milling companies with their own estates (Republic of South Africa, DAFF 2011). Annual production varies from 19–23 million tons, depending largely on climatic conditions. From this tonnage, around 2,500,000 tons of sugar is produced per season, of which half is marketed in South Africa and the remainder exported to markets in Africa, the Middle East, North America, and Asia. Some 95 percent of the sugarcane crop is fertilized, accounting for 18 percent

FIGURE 7.17 Yield (kilograms per hectare) and harvest area density (hectares) for sugarcane in South Africa, 2005



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.

of the fertilizer used in the country (FAO 2005a). The average cane yield is 51 tons per hectare per year (FAO 2005a). Dryland yields, however, vary considerably from year to year (Figure 7.17) (Schulze, Hull, and Maharaj 2007).

Irrigation

The total runoff per year from South African rivers is estimated at approximately 51,100 million cubic meters, but because of variable flow and high evaporation, only 30,000 million cubic meters can be economically used. The total potential groundwater delivery is estimated at 12,000 million cubic meters, of which only 5,400 million cubic meters can be readily retrieved. The estimated total water used in South Africa during 2000 was 22,500 million cubic meters.

The irrigation sector uses approximately 50 percent of the total water consumed. Groundwater irrigates 24 percent of the irrigable area, whereas surface water (from rain, rivers, dams, and canals) irrigates 76 percent. South Africa

TABLE 7.4 Distribution of irrigated area in South Africa, by province, 1999 (hectares)

Province	Commercial irrigation, permanent	Commercial irrigation, temporary	Area equipped for irrigation, total
South Africa, total	416,753	1,081,257	1,498,010
Eastern	11,070	179,995	191,065
Free State	46	68,764	68,810
Gauteng	18	16,330	16,348
KwaZulu-Natal	2,747	131,974	134,722
Mpumalanga	18,498	116,977	135,475
North West	706	114,094	114,801
Northern Cape	34,759	130,181	164,940
Northern	58,704	160,617	219,321
Western Cape	290,204	162,325	452,529

Source: FAO (2005b).

has three major rivers—the Vaal, Orange, and Limpopo—and many irrigation schemes have been developed on or near these rivers or their tributaries. Approximately 1.5 million hectares are under irrigation, amounting to 7.2 percent of the total arable land in South Africa. Table 7.4 summarizes the amount of irrigation available by province.

Scenarios for the Future

Economic and Demographic Indicators

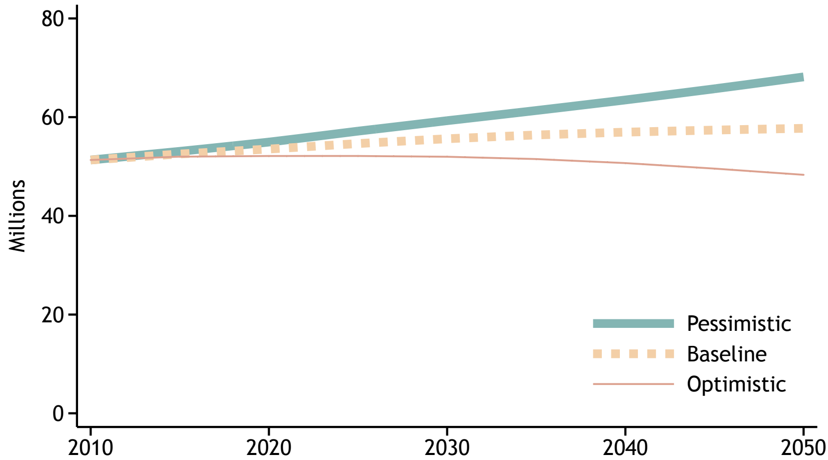
Population

Figure 7.18 shows population projections by the UN Population Division through 2050. The low variant reflects an increase in HIV/AIDS–related deaths, as well as a reduction in the population growth rate. The medium variant is most likely, showing a small annual increase over the next 40 years.

Income

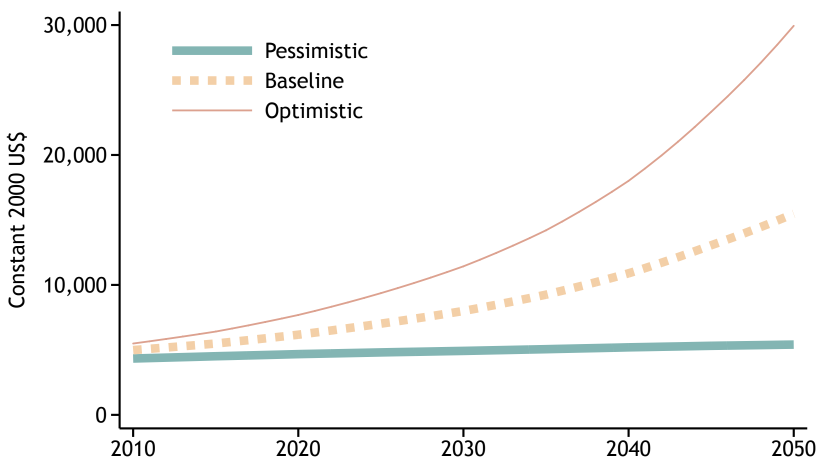
Figure 7.19 shows the three scenarios for GDP per capita used for this study. These result from combining three World Bank GDP projections with the three population projections of Figure 7.18, from United Nations population statistics: the optimistic scenario combines high GDP with low population, the baseline scenario combines the medium GDP projection with the medium

FIGURE 7.18 Population projections for South Africa, 2010–2050



Source: UNPOP (2009).

FIGURE 7.19 Gross domestic product (GDP) per capita in South Africa, 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.

population projection, and the pessimistic scenario combines the low GDP projection with the high population projection.

The worst-case scenario would assume negative trends in South Africa's political, economic, and health situations, combined with rapid population growth. The baseline scenario assumes constant growth rates for GDP and population and is more likely. The optimistic scenario reflects constant GDP growth along with a declining rate of population growth.

Biophysical Analysis

Climate Models

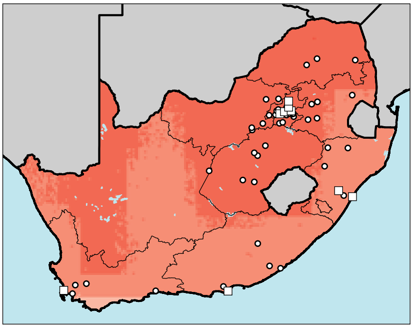
The latest downscaled scenarios from the Climate Systems Analysis Group were examined to find trends in the potential change in precipitation through 2050 (Republic of South Africa, DST 2011). The study uses nine general circulation models (GCMs) downscaled to a 25-kilometer grid resolution over South Africa. Note that downscaling is especially important for South Africa because the GCMs that are not downscaled fail to adequately capture the detailed spatial gradients and strong topographical forcing that are important determinants of South Africa's climate. The downscaled applications in the study focused on scenario SRES A2, a moderately high-emission scenario that envisions a heterogeneous world with an increasing global population and regionally oriented economic growth.[1]

The study shows that the models are in general agreement for September through November, with much of the country, particularly the eastern half, projected to become wetter (there is a range of wetness projected, with 10 millimeters of rain per month the approximate median). December through February is projected to be drier, particularly in the northeast, though the models are far from unanimous. Finally, the other quarterly projections show little change, on average, though they tend to lean toward predicting that it will be slightly wetter, with March through May predicted to be wetter toward the center of the country and June through August predicted to be wetter toward the east. We also note that in all quarters the lower southwestern coast of the Western Cape is projected to receive less rainfall.

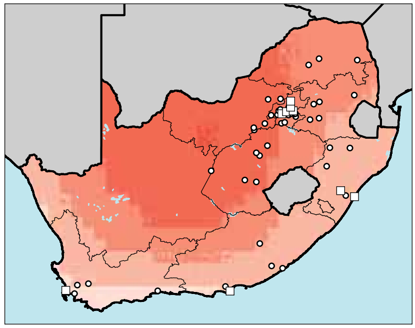
Figure 7.20 shows changes in mean daily maximum temperature for the warmest month, with each map representing the outcome of a different GCM

1 SRES is the Special Report on Emissions Scenarios, a report by the Intergovernmental Panel on Climate Change (IPCC 2000).

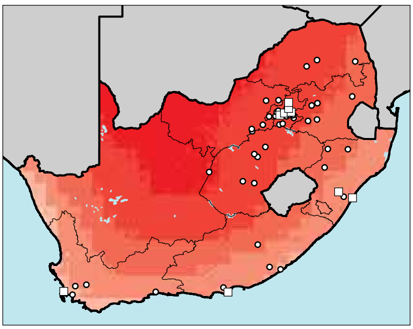
FIGURE 7.20 Change in monthly mean maximum daily temperature in South Africa for the warmest month, 2000–2050, A1B scenario (°C)



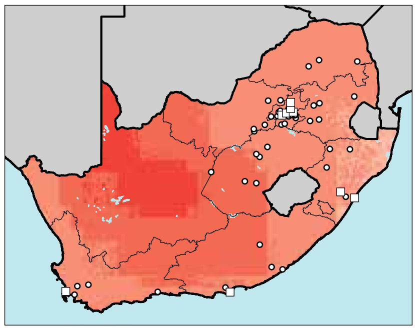
CNRM-CM3 GCM



CSIRO Mark 3 GCM



ECHAM 5 GCM



MIROC 3.2 medium-resolution GCM

- < −1
- −1 to −0.5
- −0.5 to 0
- 0 to 0.5
- 0.5 to 1
- 1 to 1.5
- 1.5 to 2
- 2 to 2.5
- 2.5 to 3
- 3 to 3.5
- > 3.5

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.

(four GCMs were used).[2] Of the four GCMs, the ECHAM 5 model predicts the hottest future, with the temperatures of at least half the country projected to increase by over 2.5°C and some areas well over 3°C. The coolest future is found in the projection of the CSRIO Mark 3 GCM, with most of the country seeing an increase of less than 2°C.

Climate Summary

Temperatures across the country have increased in the historical past and are seen to be increasing throughout the 21st century. The warming is expected to be greatest in the interior of the country and less along the coast. Assuming a moderate to high level of growth in greenhouse gas concentrations, by mid-century the coast is likely to warm by around 1°C and the interior by around 3°C.

Rainfall changes are expected to be regionally complex, especially in areas of strong topographical variation. In general, several trends emerge from the models. There are indications that the east coast will be wetter in summer and the west coast drier; the southwest of the country will experience drier conditions in both summer and winter. The west–east pattern of precipitation seems stable across the range of models and is physically consistent with the circulation changes; nevertheless, there is notable uncertainty about the magnitude of the response. There are indications that rainfall intensity is likely to increase—that is, even without an increase in total rainfall, the intensity is likely to be greater when it does rain. Evaporation is likely to increase due to higher temperatures. This is likely to increase the drought potential (as defined by the response of available soil moisture and available free water)—possibly even if the total rainfall of a region increases.

Crop Models

We used the Decision Support Software for Agrotechnology Transfer crop model to compute yields under current temperature and precipitation regimes and compare them to those for the year 2050 using the temperatures and precipitation levels projected. The output for key crops is mapped in Figures 7.21 (maize) and 7.22 (wheat).

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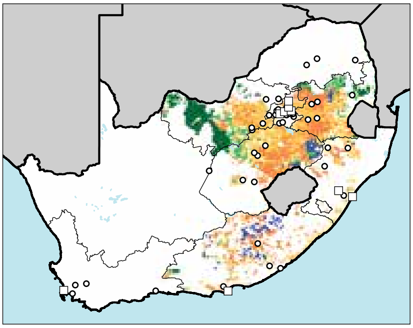
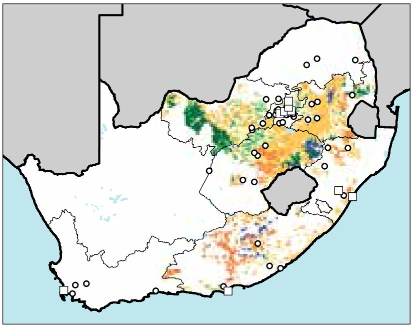
2 CNRM-CM3 is National Meteorological Research Center–Climate Model 3. CSIRO is a climate model developed at the Australia Commonwealth Scientific and Industrial Research Organisation. ECHAM 5 is a fifth-generation climate model developed at the Max Planck Institute for Meteorology in Hamburg. MIROC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

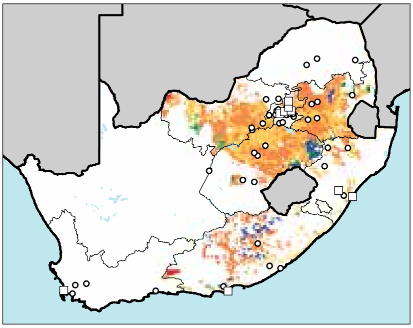
FIGURE 7.21 Yield change under climate change: Rainfed maize in South Africa, 2000–2050, A1B scenario



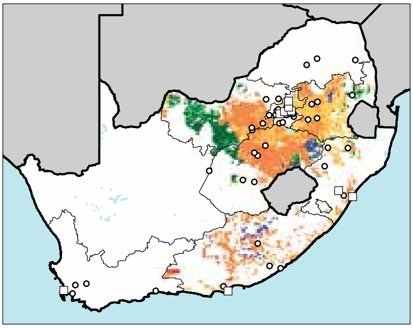
CNRM-CM3 GCM



CSIRO Mark 3 GCM



ECHAM 5 GCM



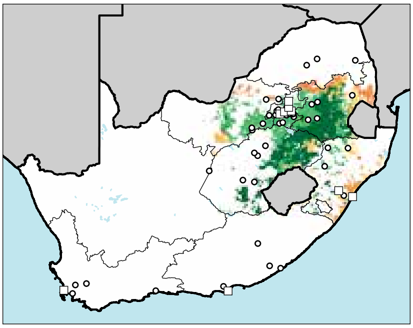
MIROC 3.2 medium-resolution GCM

- 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

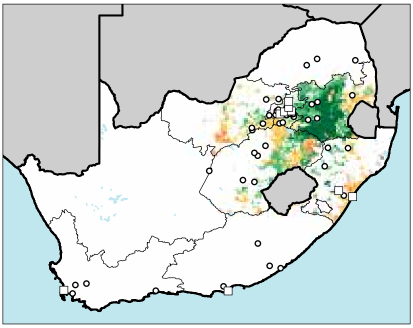
Source: Authors' calculations based on Jones, Thornton, and Heinke (2009).

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.

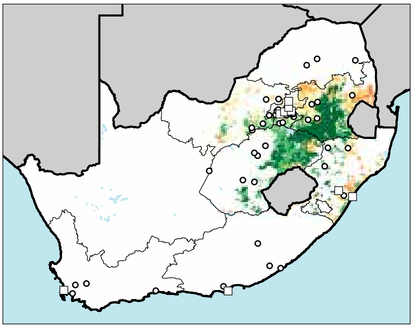
FIGURE 7.22 Yield change under climate change: Rainfed wheat in South Africa (excluding Western Cape), 2000–2050, A1B scenario



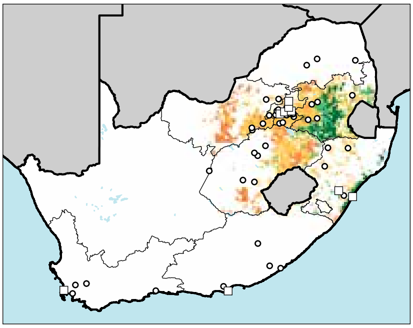
CNRM-CM3 GCM



CSIRO Mark 3 GCM



ECHAM 5 GCM



MIROC 3.2 medium-resolution GCM

- 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 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.

For maize, the areas that are projected to suffer significant losses are located in the medium- to high-yielding areas, and thus climate change would have fundamental impacts on food production. The possibly improved yields will be in areas that are currently marginal. Three of the four GCMs show areas of significant yield increases in North West Province. All models show significant losses in Free State. However, there are some areas in Free State that will be able to grow maize that have not been able to under the current climate. Some such areas also exist in Eastern Cape. These areas are likely ones that were previously too cold to grow maize.

Three out of four GCMs show large areas of increased wheat yield in Free State and Mpumalanga. However, in scenarios showing likely decreases in rainfall, yields are seriously under threat in the Western Cape region. Unfortunately, we failed to assess the yield changes in the Western Cape in our crop model.

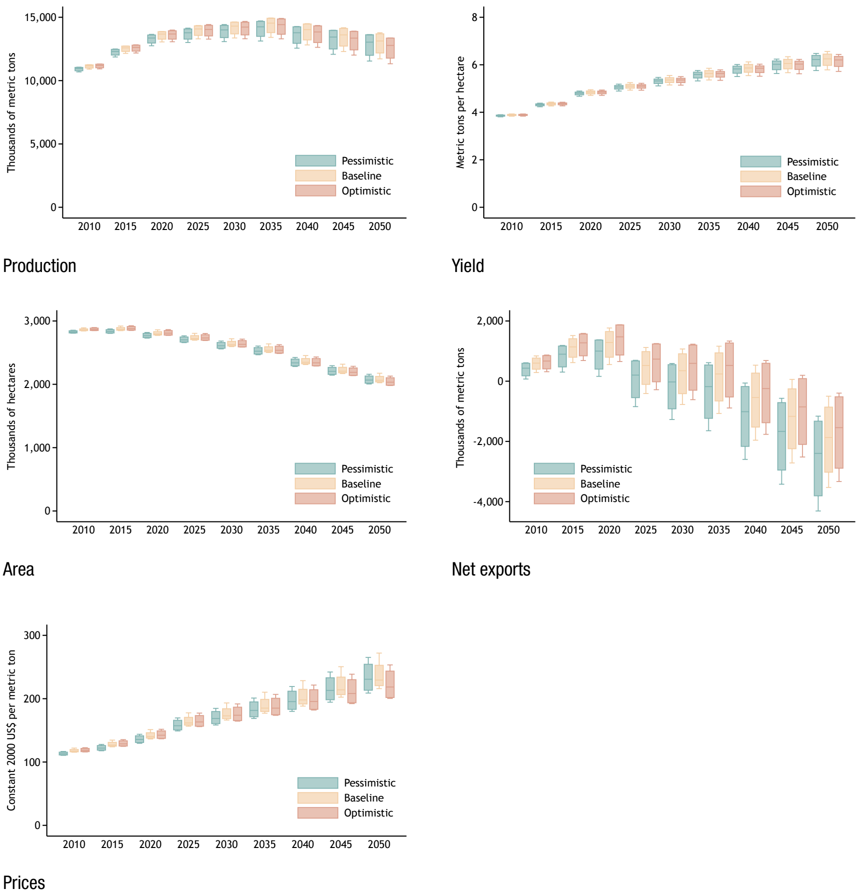
Agricultural Outcomes

Figures 7.23 and 7.24 show simulation results from the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) associated with key agricultural crops in South Africa. Each featured crop has five graphs: production, yield, area, net exports, and world price. The simulations represent the three GDP and population scenarios—each modeled with the four GCMs—hence the box-and-whisker plots indicating the range of outcomes under different climate change models (25th percentile, median, and 75th percentile).

These maps show a continued trend of smaller planting areas for maize, with higher yields and total production at first but after 2035 succumbing to the decline in planted area. Exports are projected to increase through 2020 and afterward to decline to the point that South Africa will become a net importer of maize. It is cause for concern that total production is shown to decline—more dramatically if the scenario's increases in yield do not materialize. Thus climate change is seen to have an anticipated impact on the security of the country's maize supply, especially during years of extreme weather.

The model did not compute yield changes for wheat in the Western Cape, but it appears likely that any increases in production will be offset by expected losses in this region due to increased temperatures and lower levels of rainfall.

FIGURE 7.23 Impact of changes in GDP and population on maize in South Africa, 2010–2050



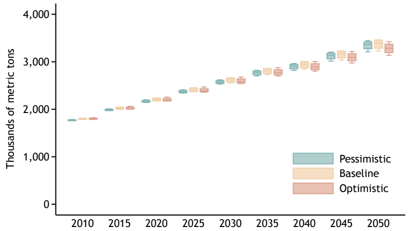
Source: Based on analysis conducted for Nelson et al. (2010).

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.

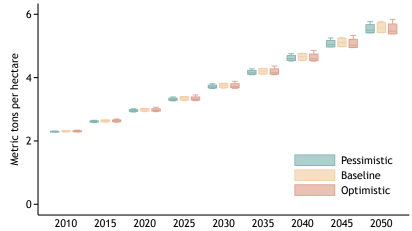
The increase in the world price will insulate South Africa against external pressure as long as domestic production is adequate to supply the demand, which seems unlikely given the divergence of production and consumption since 2001 (Figure 7.25).

Sugarcane appears to be the most resilient of the field crops to climate change (Figure 7.26). The crop's yield and area are both projected to increase, though its yield will increase by a higher percentage, and production will

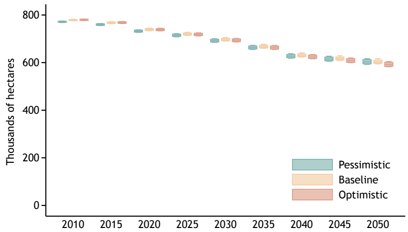
FIGURE 7.24 Impact of changes in GDP and population on wheat in South Africa, 2010–2050



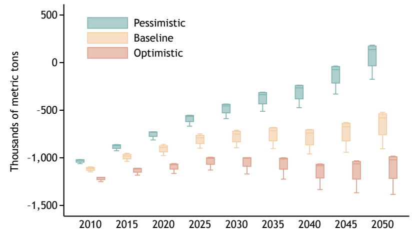
Production



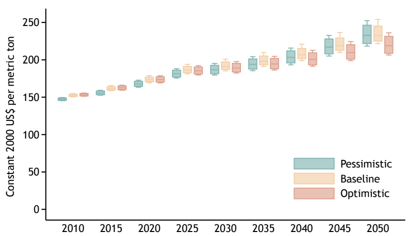
Yield



Area



Net exports



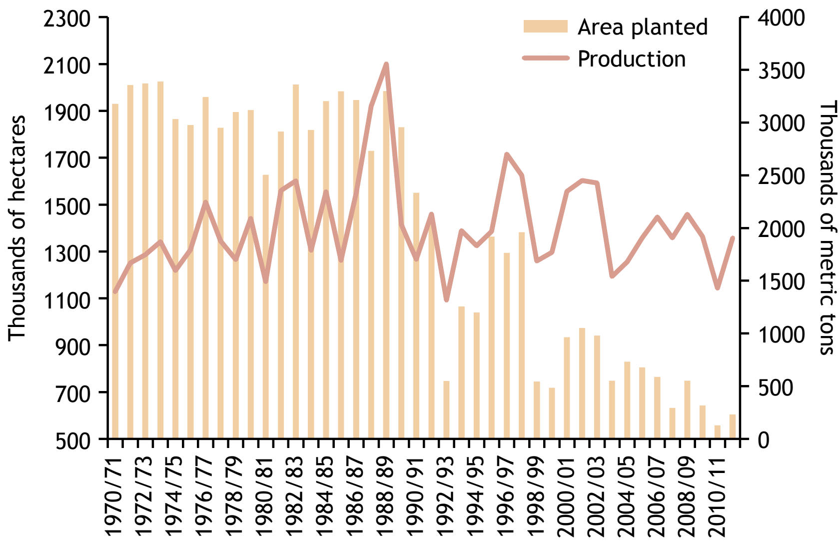
Prices

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.

increase. Sugarcane farmers normally burn off the bagasse after harvest; this dangerous practice has to be carefully monitored to prevent runaway fires that can damage productive crops. Increases in temperature stand to increase this risk, as well the risk of veld fires, which may also damage sugar plantations. Increased rainfall, especially if more intense, may leave fields soggy or flooded. This will make it very difficult for machinery to access the crops for harvesting on both sloped and level ground.

FIGURE 7.25 Trends in wheat production and area planted in South Africa, 1970/1971–2011/2012



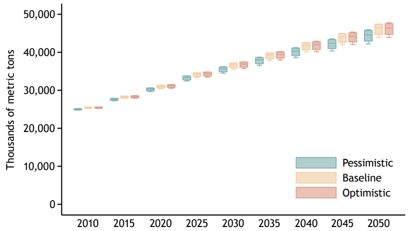
Source: USDA, FAS (2012).

Vulnerability to Climate Change

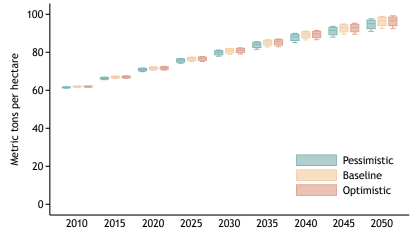
In addition to agricultural predictions, IMPACT also produces scenarios of the number of malnourished children under the age of five, as well as the available kilocalories per capita. Figure 7.27 shows the impact of future GDP and population scenarios on the number of malnourished children under age five in South Africa; Figure 7.28 shows the share of these children. After increases in the short term, levels drop off in all scenarios. In the baseline case, the number of malnourished children drops below the current level by 2035 (and by 2030 under the optimistic scenario). This outcome assumes the improved distribution and availability of food and an increase in food security (or in welfare infrastructure).

Figure 7.29 shows the kilocalories per capita available in South Africa. Because no dramatic increase in available nutrients is projected, the decline in malnourished children may be driven instead by a decline in the birth rate, resulting in fewer children under age five as a percentage of the population.

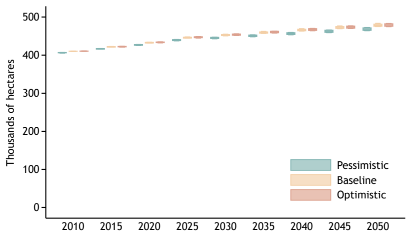
FIGURE 7.26 Impact of changes in GDP and population on sugarcane in South Africa, 2010–2050



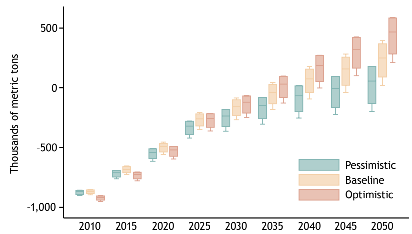
Production



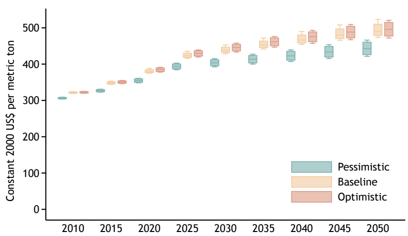
Yield



Area



Net exports



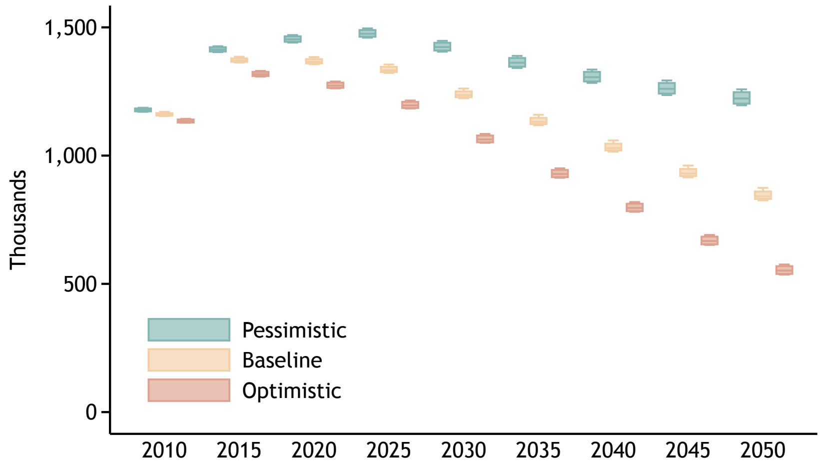
Sugar prices

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.

It is of concern that the pessimistic scenario shows a 20 percent reduction in kilocalories per capita. This reflects the negative impact of the large projected staple price increases, whereas GDP per capita in this scenario increases only modestly.

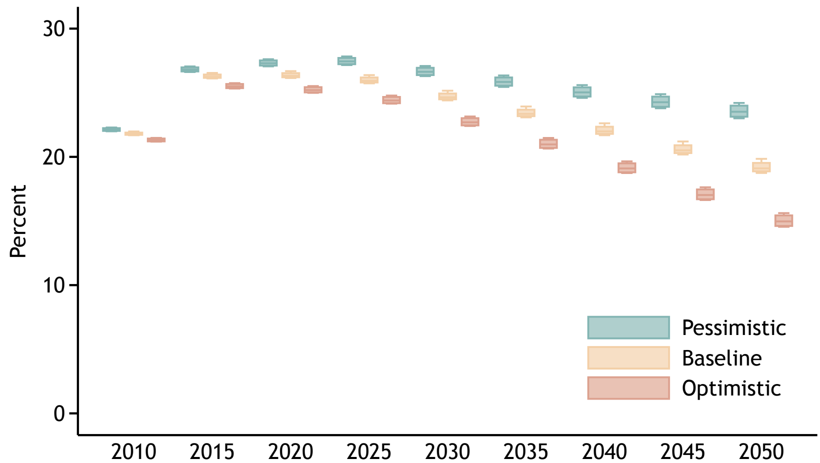
FIGURE 7.27 Number of malnourished children under five years of age in South Africa in multiple income and climate scenarios, 2010–2050



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.

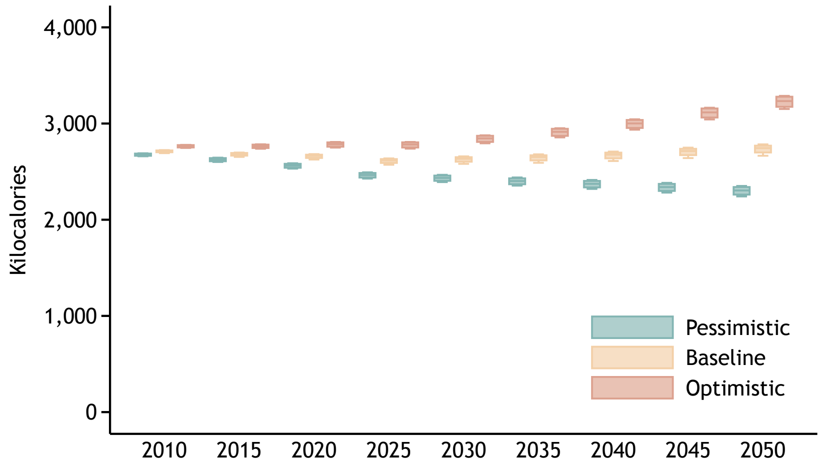
FIGURE 7.28 Share of malnourished children under five years of age in South Africa in multiple income and climate scenarios, 2010–2050



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 7.29 Kilocalories per capita in South Africa 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.

Conclusions and Policy Recommendations

In this chapter we have used statistical information from various sectors and aspects of the South African society, economy, and natural environment to assess the vulnerability of the country's agriculture to the impacts of climate change. The chapter represents a useful, though not comprehensive, source of information for analysis by interested stakeholders, sector role players, and policymakers.

Agricultural production in South Africa is mainly commercial and thus less vulnerable to the impacts of climate change than other parts of the region, because adapting to climate change is, in most cases, worth the extra investment required. Resilience is a function of economic well-being; in a wealthier country, the government has more resources to assess vulnerabilities and to create and implement adaptive mechanisms, thereby increasing the resilience of even the poorest citizens.

The most vulnerable sector in agriculture was found to be that of poor farmers, including subsistence and even emerging farmers. These producers are more dependent than others on weather and climate conditions on a daily basis to provide them with basic foodstuffs and enable them to achieve a degree of food security. However, commercial agriculture provides the food for the majority of South Africans; here, too, shifts in climate patterns, growing regions, and market prices would have a major influence on plantings, yields, and total production.

It is clear that climate change will have two major impacts. First, average temperatures will increase. Higher minimum temperatures will have impacts on cold storage, frost frequency, and pest life cycles but will have the advantage of opening up areas to the cultivation of specific crops where it was previously too cold. Higher maximum temperatures will cause more extremely hot days, with increased evaporation, more days of soils drying out, and increased refrigeration requirements for fresh produce. In general, every day of 2050 is likely to be, on average, 2°C warmer than at current temperature levels. This will have severe impacts on seasonal cycles, suitable growing areas, and the way crops grow.

Second, the nature of rainfall patterns within seasons will change in both intensity and frequency. This will affect runoff, water availability, the length of dry spells, and the replenishment of groundwater. Agriculture will need to adapt to changes in the areas suitable for specific crops. Especially vulnerable will be crops that require longer-term investments in, for example, orchards, vineyards, and irrigation systems.

The future of agriculture in South Africa can be made more resilient by a more secure supply of water, specifically through irrigation. However, the country has few rivers and thus few opportunities for dam building. Increased temperatures will mean generally drier conditions. Groundwater will need to be replenished through rainfall and will be under increasing demand, not only from all forms of agriculture but also from the domestic, industrial, and mining sectors.

In the case of rangelands, the main threat to grazing will be from the effects on trees of CO_2 fertilization, which will increase the size of the root systems of trees and shrubs. On the other hand, Scheiter and Higgins (2009) point out that temperature-driven factors might favor grasses.

The implications of climate change for policy are enormous. More than ever, planning, management, and conservation of water resources will become vital for the sustainability of agriculture. The demands on fresh water for mining and industry, as well as for domestic use, must be tempered with the use of recycled, gray, or even brown water sources. Agriculture is generally already using water efficiently because it represents a significant input cost; more judicious uses can still be encouraged by wise application of tariffs and allocations.

In addition, the expansion of agriculture for previously disadvantaged groups needs to be well planned, accompanied by sufficient support to allow the growth of sustainable farming units and an increase in well-being for all farmers. Increased urbanization will leave fewer people working on the land, but this is a manageable outcome. Experience has shown that agriculture can be very efficient with a core of committed and knowledgeable farmers.

For highly vulnerable regions, such as KwaZulu-Natal, Limpopo, and the Eastern Cape, it will be essential to develop policies that do the following:

- Encourage the effective management of environmental resources (soil, water, and natural vegetation) through holistic and sustainable agricultural practices.
- Stimulate agricultural intensification and diversification. Marginal agriculture should be avoided and alternative livelihood incomes sought in degraded areas.
- In the small-scale sector, facilitate increased access to markets and participation in them.
- Develop rural infrastructure to uplift desperately poor and vulnerable communities, especially because these are the most highly vulnerable to climate change.

The main recommendation of this chapter is that decisionmakers, policymakers, and water users be educated regarding the implications of climate change on agriculture. Specific vulnerabilities need to be identified and addressed through adaptation frameworks and actions in order to build resilience and guarantee food security for the country. Because vulnerability to climate change is highly variable according to region, policymakers should tailor policies to local conditions (Gbetibouo and Ringler 2009).

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