Chapter 1

OVERVIEW

Sepo Hachigonta, Gerald C. Nelson, Timothy S. Thomas, and Lindiwe Majele Sibanda

According to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) (Le Treut et al. 2007, 96), climate is defined as average weather over a period of time, ranging from months to millions of years. Climate is usually described in terms of the mean and variability of temperature, precipitation, and wind. The IPCC defines an extreme climate event as an event that is rare within its statistical reference distribution at a particular place.

Extreme weather events (such as droughts, floods, and changes in the frequency and intensity of dry spells) already negatively affect agriculture in most parts of Africa. Higher temperatures tend to reduce yields of crops by reducing soil moisture content and the length of the growing season, and in most places they tend to encourage weed and pest proliferation. Greater variations in precipitation patterns increase the likelihood of crop failures and long-run production declines (Nelson et al. 2009).

There is a growing concern that climate change will intensify existing agricultural problems in developing countries, where communities are directly dependent on the natural environment and are underresourced to adequately adapt to extreme changes in climate (Meinke et al. 2006; Ziervogel et al. 2008). This is particularly true for those communities that rely on rainfed agriculture for their livelihoods. Some of the projected climate change impacts are

- direct—on crops and livestock productivity,
- indirect—on availability and prices of food, both domestic and in international markets, and
- indirect—on income generated from agricultural production at farm and national levels.

This monograph builds on previous research that focused on regional and global effects of climate change, including Nelson et al. (2009, 2010) and ADB and IFPRI (2009). This chapter provides a regional overview for southern Africa. Eight chapters look at the effects of climate change on eight countries in southern Africa: Botswana, Lesotho, Malawi, Mozambique, South Africa, Swaziland, Zambia, and Zimbabwe.

The main objective of this study is to analyze the range of plausible impacts of climate change by the year 2050, focusing almost entirely on crops. We use both crop models and global partial equilibrium models, informed by four different climate models and three socioeconomic scenarios. In some of the chapters on countries in which the livestock sector is important, we highlight some key aspects of this sector using secondary literature. We discuss agricultural adaptation options throughout this monograph.

Our goal is to provide policymakers and others concerned with climate change, agriculture, and food policy with guidance on the range of the impacts of climate change and some information as to how climate change might affect various regions differently. We provide some suggestions for policies that could most help each country prepare for the future impacts of climate change.

There is, inherently, significant uncertainty about how to model the way these effects play out over the surface of the earth. It is thus important to review the tools used to generate outputs in this monograph.

- Global circulation models (GCMs) depict the physics and chemistry of the atmosphere and its interactions with oceans and the land surface. Several GCMs have been developed independently around the world, and four have been used for this analysis: CNRM-CM3, CSIRO Mark 3, ECHAM 5, and MIROC 3.2 (see details on these GCMs in the methodology chapter).[1]
- Integrated assessment models (IAMs) simulate the interactions between humans and their surroundings, including industrial activities, transportation, and agriculture and other land uses, to estimate the emissions of various greenhouse gases (including carbon dioxide, methane, and nitrous oxide, the most influential). Several independent IAMs exist as well.
- The emissions simulation results of the IAMs are made available to the GCMs as inputs that alter atmospheric chemistry. The end result is a set of estimates of precipitation and temperature values around the globe, usually at two-degree intervals (about 200 kilometers at the equator).

1 CNRM-CM3 is National Meteorological Research Center–Climate Model 3. 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. MIROC 3.2 is the Model for Interdisciplinary Research on Climate, developed at the University of Tokyo Center for Climate System Research.

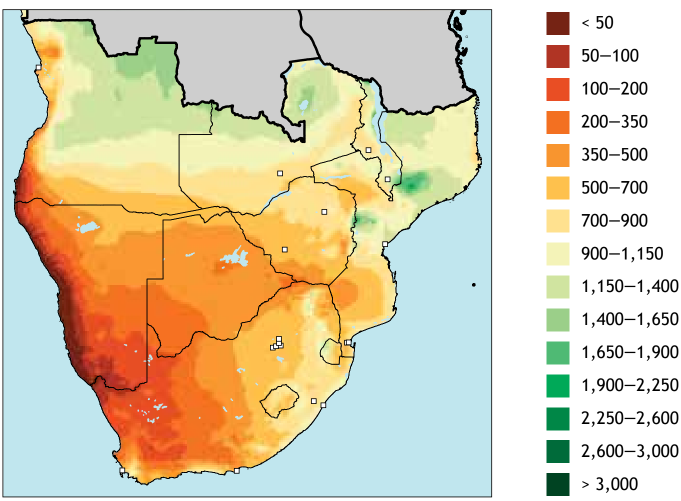
Review of Current Trends

Climate and Agriculture of Southern Africa

Figure 1.1 shows the annual precipitation distribution for southern Africa in the early part of the 21st century. The humid (or semihumid) areas in the northern parts of Angola, Zambia, Mozambique, and Malawi receive the highest rainfall during the summer season, which lasts from October to March. The high precipitation over these areas is partly associated with the southward migration of rainfall systems from the north, such as the Intertropical Convergence Zone. A reduced amount of precipitation is observed south of the region, especially over the southwest arid regions of southern Africa. The distribution of rainfall, both within the season (intraseasonal) and over years, is subject to high variability, with some regions often having their peak season extended or reduced (Reason, Hachigonta, and Phaladi 2005).

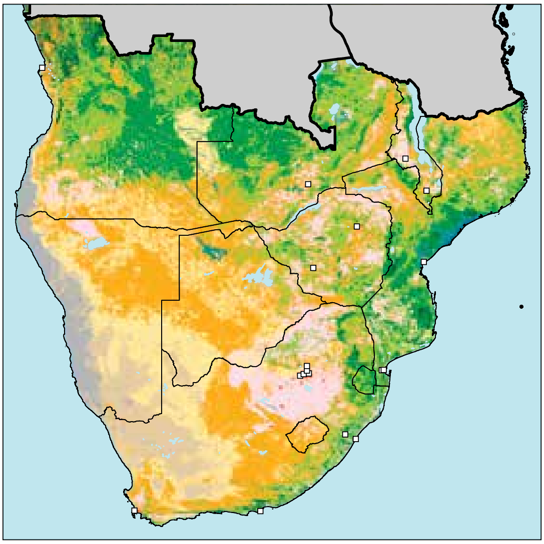
The region has a very diverse vegetation cover. The arid western parts (referred to as "sparse" and "open" grasslands in Figure 1.2) have little crop farming activity. The largest croplands are observed in the Free State province of South Africa. Southern Zambia, Zimbabwe, and Limpopo Province of South Africa have occasional patches of cropland. Some countries in the region have relatively small crop sectors due to unfavorable climatic

FIGURE 1.1 Annual average precipitation in southern Africa, 1950–2000 (millimeters per year)



Source: WorldClim version 1.4 (Hijmans et al. 2005).

FIGURE 1.2 Land cover and land use in southern 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).

conditions, as is the case with Botswana and Namibia, though the livestock sector is very important in both.

Agriculture remains the primary source of employment and income for most of the rural population of the Southern Africa Development Community (SADC). In Malawi, about 39 percent of the gross domestic product (GDP) is from agriculture (FAO 2005). In Zimbabwe, an estimated 80 percent of the population directly depends on agriculture; of this over 60 percent are small-scale farmers (NOAA 2002; Raes et al. 2004). In Zambia, agriculture contributes about 18 percent of GDP; small-scale farmers contribute about 60 percent of farming outputs, and a large share of production is maize (ODI 2002). South Africa has a dual agricultural system, including both well-developed commercial farming and more subsistence-based production in the deep rural areas; agriculture contributes about 3 percent to South Africa's GDP (South Africa, GCIS 2009).

The region as a whole has more than 50 percent of its agricultural land allocated to cereals, with maize (the main staple crop) accounting for more than 40 percent of the total harvested area (Table 1.1). South Africa is the largest maize producer in the region, mainly due to the contribution of irrigated farmlands, followed by Zimbabwe. Namibia, Swaziland, and Botswana have the smallest areas in maize.

TABLE 1.1 Average harvest area of leading agricultural commodities in southern Africa, 2006–2008 (hectares)

Country	Maize	Millet	Rice (paddy)	Sorghum	Wheat
Total	9,199,950	988,690	250,235	848,518	811,903
Angola	1,113,333	358,333	13,333	0	2,467
Botswana	52,333	1,033	0	25,833	383
Lesotho	166,990	0	0	36,739	25,519
Malawi	1,525,050	43,452	57,749	73,115	1,713
Mozambique	1,471,333	59,000	163,333	342,000	1,967
Namibia	21,635	245,267	0	20,000	2,189
South Africa	2,461,082	21,000	1,400	65,317	716,500
Swaziland	47,264	0	50	1,000	213
Zambia	711,330	44,688	14,119	24,950	18,549
Zimbabwe	1,629,600	215,917	250	259,564	42,403

Source: FAOSTAT (FAO 2010).

Millet and sorghum are also important crops, especially in the drier areas. Some countries, such as Botswana and Lesotho, cannot meet their national demand for maize and sorghum through domestic production; the large deficits are traditionally met by imports from South Africa. Zimbabwe and Angola have the highest yield of millet per hectare; sorghum is mostly grown in Mozambique. Most maize production over the region is rainfed, except in South Africa, which has high yields from irrigated areas in the central region of the country (Figure 1.3). Wheat is produced mainly under irrigation in South Africa and Zimbabwe (UNEP 2009). South Africa has by far the highest yield per hectare of wheat in the region, averaging more than four tons (see Figure 1.3).

Demographic and Economic Indicators

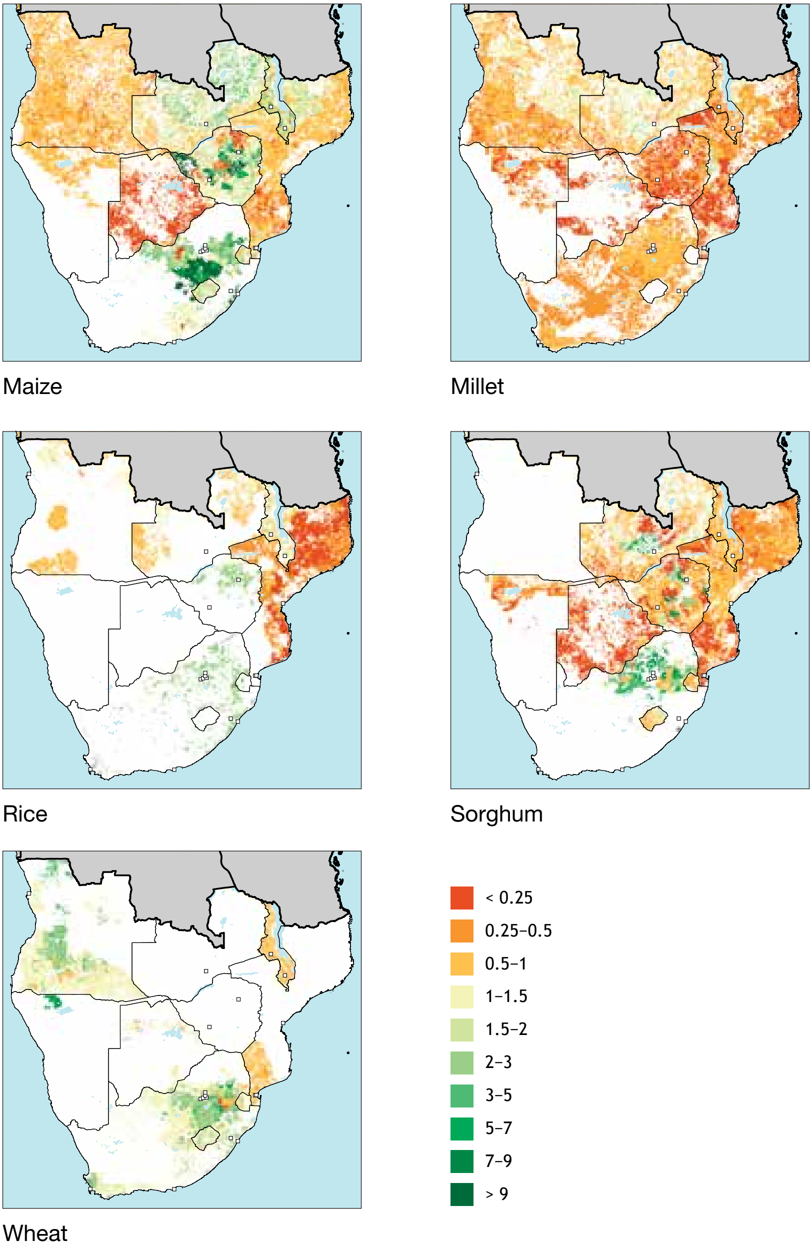
Population

Rapid population growth in southern Africa will likely increase its vulnerability to the effects of climate change. In addition, other demographic trends—such as urbanization in coastal areas and encroachment of populations into ecologically marginal areas—can exacerbate climate risks (Jiang and Hardee 2009).

In 2008, southern Africa had an estimated population of 135 million people (Table 1.2). South Africa alone represents over 35 percent of southern Africa's population and 73 percent of the GDP of the region; Swaziland represents less than 1 percent of the SADC population and less than 1 percent of regional GDP (UNEP 2009). As can be seen in Table 1.2, Angola has had the greatest increase in population in southern Africa during the past two decades, followed by Zambia. The smallest amount of growth was in Zimbabwe: after a sharp increase in population (between 3.3 and 3.7 percent) from 1980 to 2000, its growth declined to 1.9 percent in the 1990s and 0.0 between 2000 and 2008 (World Bank 2009). The absence of population growth in Zimbabwe during the past decade can be attributed to the country's weakened economy and the resulting emigration to neighboring countries and overseas; approximately 3–4 million Zimbabweans migrated during the past decade, mainly to South Africa, Botswana, and Britain (Ploch 2010).

The urban growth rate in southern Africa has exceeded that of the rural population. The greatest decadal urban population increase was in Angola and Mozambique, where it increased by about 10 percent between 1988 and 2008. The highest rural growth rate was in Zambia, at 4.2 percent from

FIGURE 1.3 Yields for the main rainfed crops in southern Africa, 2000 (metric tons per hectare)



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

TABLE 1.2 Population of southern Africa, annualized growth rate, and urban growth rate, 1988 and 2008

Country	Total population (millions)		Annualized growth rate, 1988–2008 (%)	Urban growth rate, 1988–2008 (%)
	1988	2008		
Total	88.03	135.05	2.7	5.1
Angola	10.09	18.02	3.9	10.0
Botswana	1.29	1.90	2.4	7.3
Lesotho	1.55	2.02	1.5	7.5
Malawi	8.65	14.28	3.3	9.3
Mozambique	13.33	21.78	3.2	10.9
Namibia	1.30	2.11	3.1	6.1
South Africa	33.73	48.69	2.2	3.6
Swaziland	0.80	1.17	2.3	3.3
Zambia	7.45	12.62	3.5	2.4
Zimbabwe	9.84	12.46	1.3	3.4

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

1988 to 2008. During the postindependence era, countries in southern Africa have rapidly urbanized. Rural–urban migration is a response to differences in economic opportunities and incomes between the towns and the rural areas.

Income

With the exception of Zambia (which shows a decrease) and Zimbabwe (for which no data were available for 2008), the southern African countries included here had increases in per capita GDP from 1988 to 2008 (Table 1.3). During this period, Mozambique had the highest rate of growth in GDP as a result of its recovery from civil war. Botswana had the second-highest rate of growth in GDP per capita in SADC, which is also reflected in its reduced poverty level, which declined from 47 percent in 1993/1994 to 30 percent in 2002/2003. However, the gains in GDP per capita and poverty reduction for most SADC countries have fallen short of the targets of the United Nations (UN) Millennium Development Goals—especially the requirement to halve both extreme poverty and hunger by 2015.

Zambia's GDP per capita started to decline rapidly between 1975 and 1999, reaching its lowest level in the mid-1990s (World Bank 2009). This decline can be attributed to several factors: nationalization (which brought much of the economic base under Zambian government management),

TABLE 1.3 Income of southern Africans (GDP per capita and share of GDP from agriculture), 1988 and 2008

Country	GDP per capita (constant 2000 US$)		Rate of GDP growth, 1988–2008 (%)	Share of GDP from agriculture (%)	
	1988	2008		1988	2008
Angola	838	1,357	3.1	16	10
Botswana	2,183	4,440	5.2	6	2
Lesotho	308	525	3.5	25	7
Malawi	134	165	1.1	50	34
Mozambique	174	365	5.5	43	28
Namibia	1,912	2,692	2.0	12	8
South Africa	3,223	3,764	2.5	6	3
Swaziland	1,039	1,559	0.8	16	8
Zambia	413	387	–0.3	17	21
Zimbabwe	608	n.a.	n.a.	16	n.a.

Source: *World Development Indicators* (World Bank 2009).
Note: GDP = gross domestic product; n.a. = not available; US$ = US dollars.

fluctuations in copper prices, and the mass closure of most mines and industries due to the economic liberalization policy of the mid-1990s. Since 2000, Zambia has seen a steady increase in GDP per capita, reaching almost $400 in 2008 (see Table 1.3).

Table 1.3 shows the decreasing contribution of agriculture to GDP, with Lesotho showing the highest percentage reduction over the past two decades. The agricultural sector in Lesotho accounted for less than 10 percent of GDP in 2008, even though agriculture is the primary source of income for more than half of the population (LVAC 2008).

Well-being indicators

Generally, the past two decades show a declining regional under-five mortality rate (Table 1.4). This might be attributed to improved health services and access to health services in most countries, especially in the rural areas, with their special challenges in addressing medical needs. Although the under-five mortality rate shows a positive change over the past two decades, the rates remain far worse than those of most other countries in the world. Life expectancy at birth, in fact, declined significantly over the past two decades in most countries in the region; one factor in this decrease is the high incidence of HIV/AIDS.

The availability of transport infrastructure influences access to markets and vulnerability to food scarcity (Paavola 2003). The region's transport

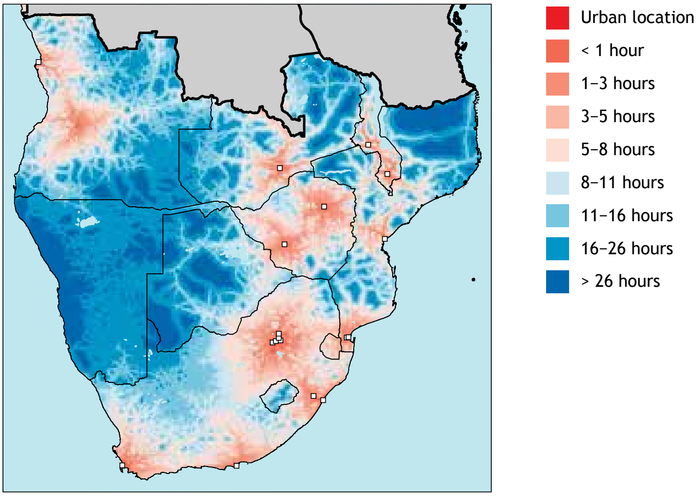
TABLE 1.4 Under-five mortality and life expectancy at birth in southern Africa, 1988 and 2008

	Under-five mortality (deaths per 1,000)		Life expectancy at birth (years)	
Country	1988	2008	1988	2008
Angola	257	158	42	47
Botswana	57	40	63	51
Lesotho	102	84	59	43
Malawi	209	110	49	48
Mozambique	200	168	44	42
Namibia	87	67	62	53
South Africa	63	59	62	51
Swaziland	96	91	60	46
Zambia	163	170	51	45
Zimbabwe	95	90	60	44

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

infrastructure is generally good in urban areas, as reflected in the short travel times between cities of more than 500,000 people. However, most of the rural districts are poorly accessible (Figure 1.4). South Africa, Swaziland, and Zimbabwe have the shortest travel times, whereas Namibia has the longest.

FIGURE 1.4 Travel time to cities of 500,000 or more people in southern Africa, circa 2000



Source: Authors' calculations.

Regional Future Scenarios

Population

Continuing population growth in developing countries will worsen food insecurity over the region (IPCC 2007). Table 1.5 shows the outcomes for southern Africa by 2050 for the three population scenarios mentioned earlier. The low variant reflects an increase in HIV/AIDS-related deaths as well as a reduction in the birth rate. The median (baseline) variant is most likely, showing small annual increases over the next 40 years; the overall result, however, is an increase of 70 percent. The projections assume that the standard of living, life expectancy, and nutritional status of the population will be improved.

The population projections for southern Africa show varying growth rates for different countries. Overall, the regional population is shown increasing by about 70 percent (from 142 million to about 241 million) by 2050 under the median-variant scenario. Based on UN estimates, the highest rate of population growth by 2050 is shown for Angola, Malawi, Mozambique, and Zambia.

Income

Table 1.6 shows the three GDP per capita scenarios used for this study. These are the result of combining three sets of GDP projections with the three population projections from the UN Population Division. The optimistic scenario

TABLE 1.5 Projected population in southern Africa, 2010–2050 (millions)

		2050		
Country	2010	Low variant	Median variant	High variant
Angola	18,993	37,224	42,267	47,675
Botswana	1,978	2,335	2,758	3,220
Lesotho	2,084	2,056	2,491	2,970
Malawi	15,692	32,019	36,575	41,456
Mozambique	23,406	38,268	44,148	50,480
Namibia	2,212	3,076	3,588	4,141
South Africa	50,492	47,536	56,802	67,051
Swaziland	1,202	1,463	1,749	2,061
Zambia	13,257	25,302	28,957	32,870
Zimbabwe	12,644	18,930	22,178	25,731

Source: UNPOP (2009).

TABLE 1.6 GDP per capita scenarios for southern Africa, 2010–2050 (constant 2000 US$)

		2050		
Country	2010	Pessimistic	Baseline	Optimistic
Angola	877	3,548	4,002	8,378
Botswana	5,353	3,686	25,628	48,646
Lesotho	645	1,850	3,166	6,279
Malawi	166	656	744	2,488
Mozambique	327	1,186	1,812	2,885
Namibia	2,754	4,082	14,239	26,654
South Africa	4,987	5,409	15,473	29,941
Swaziland	1,717	2,709	8,026	15,455
Zambia	502	1,791	2,454	4,254
Zimbabwe	523	1,326	1,539	5,296

Source: 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).
Notes: Entries in the 2010 column are for the baseline scenario. GDP = gross domestic product; US$ = US dollars.

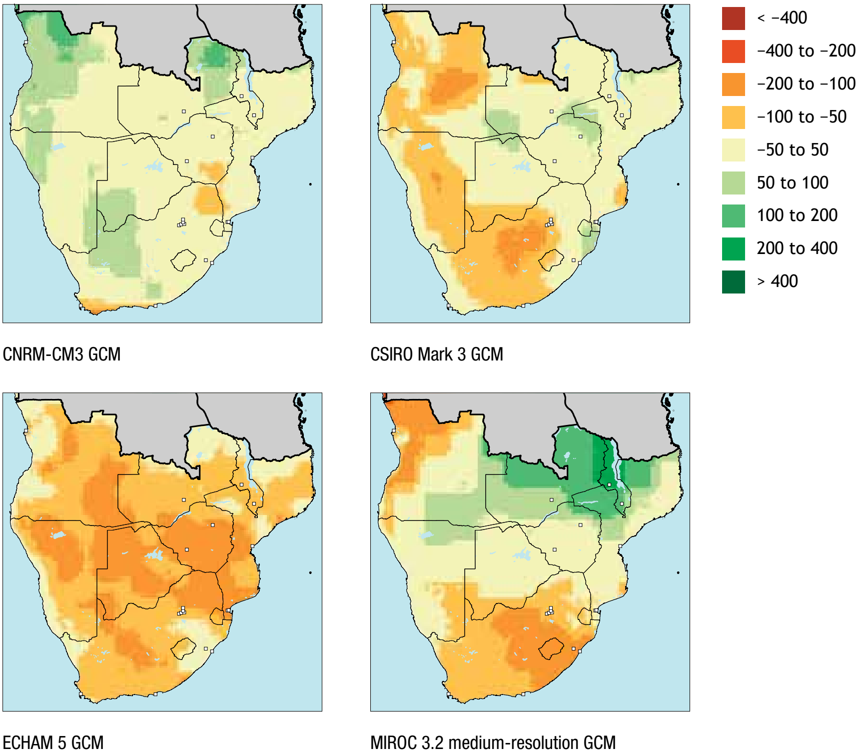
combines high GDP growth with low population growth. The baseline scenario combines medium GDP growth with medium population growth. Finally, the pessimistic scenario combines low GDP growth with high population growth. The GDP per capita projections show an increase in all three scenarios by 2050.

Climate Change Scenarios

Although the general consequences of climate change are becoming increasingly well known, great uncertainty remains about how the effects of climate change will play out in specific locations. Plants and animals that can neither quickly adapt to new conditions nor relocate to new areas will become extinct as a result of climate change (CGIAR 2009). This will destabilize vital ecosystems and erode the genetic base for future crops and livestock. Figure 1.5 shows changes in average precipitation over southern Africa between 2000 and 2050 as modeled by four GCMs, each using the A1B scenario.[2] Figure 1.6 shows the changes in average maximum temperatures. In

2 The A1B scenario describes a world of very rapid economic growth, low population growth, and rapid introduction of new and more efficient technologies, with moderate resource use and a balanced use of technologies. It represents the "best-case" scenario.

FIGURE 1.5 Changes in mean annual precipitation in southern Africa, 2000–2050, A1B scenario (millimeters)



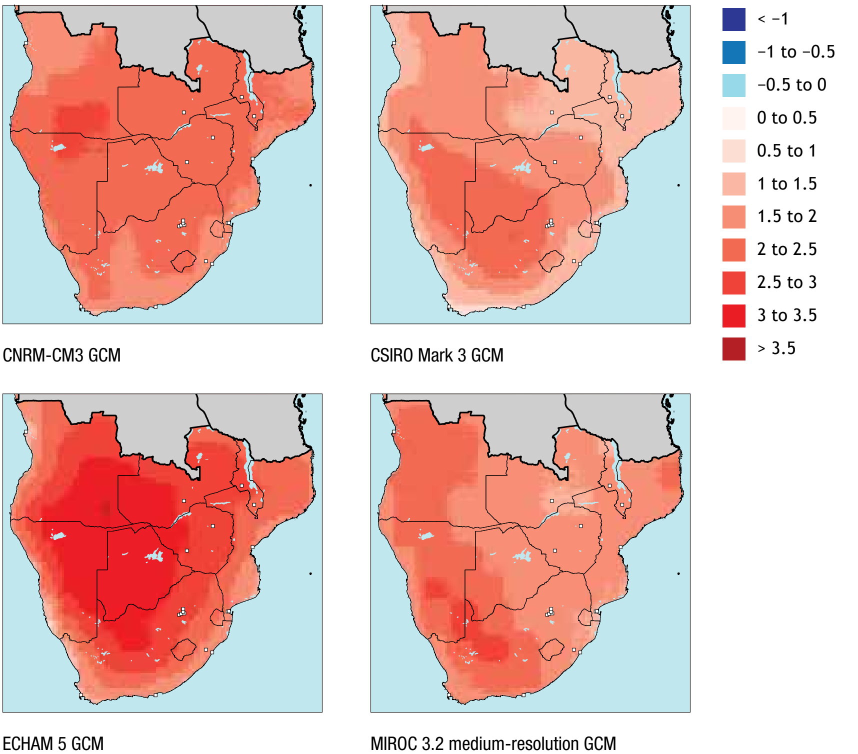
Source: Authors' calculations based on Jones, Thornton, and Heinke (2009).

Notes: A1B = greenhouse gas emissions scenario that assumes fast economic growth, a population that peaks midcentury, and the development of new and efficient technologies, along with a balanced use of energy sources; CNRM-CM3 = National Meteorological Research Center–Climate Model 3; CSIRO Mark 3 = 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 in Hamburg; GCM = general circulation model; MIROC 3.2 = Model for Interdisciplinary Research on Climate, developed by the University of Tokyo Center for Climate System Research.

each set of figures, the legend colors are identical; a specific color represents the same change in temperature or precipitation across the models.

A quick glance at these figures shows that differences exist. For example, Figure 1.5 shows that the ECHAM 5 model projects that all of southern Africa will become drier, while the other models show a mixture, with areas that are wetter, other areas that are drier, and still other areas that will remain unchanged. The CNRM-CM3 model results show the central part of South Africa getting marginally wetter, while the other model results show the same area getting drier. Other studies, such as one conducted at the University of

FIGURE 1.6 Change in monthly mean maximum temperature in southern Africa for the warmest month, 2000–2050, A1B scenario



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

Notes: A1B = greenhouse gas emissions scenario that assumes fast economic growth, a population that peaks midcentury, and the development of new and efficient technologies, along with a balanced use of energy sources; CNRM-CM3 = National Meteorological Research Center–Climate Model 3; CSIRO Mark 3 = 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 in Hamburg; GCM = general circulation model; MIROC 3.2 = Model for Interdisciplinary Research on Climate, developed by the University of Tokyo Center for Climate System Research.

Cape Town using downscaled climate models, show the eastern parts of South Africa becoming wetter by 2050. In Figure 1.6, although all the models show temperature increases for most of southern Africa, they differ on the amount of increase, with the ECHAM 5 model showing a much hotter future.

The precipitation figures shown here illustrate the range of potential climate outcomes using current modeling capabilities and indicate the uncertainty inherent in estimating the impacts of climate change. Policymakers therefore need to develop plans that will allow for flexibility in responsiveness to climate change.

Scenarios Showing Changes in Crops

Tables 1.7–1.9 show simulations from the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) associated with maize, millet, and sorghum, respectively, for 2010 and 2050, based on the GDP per capita and population growth scenarios and climate change scenarios discussed earlier. Each featured crop has three categories, representing yield, area, and production. The production of maize over the region increases in all scenarios by 2050. However, in some countries the increased production will not meet local demand, resulting in an increase in net maize imports.

IMPACT shows the world price of maize increasing from $120 per ton to over $200 per ton by 2050, which would have a serious implication for affordability for the majority of the population living below the poverty line.[3] The average yield of maize is shown to increase by 2050, but the harvested area for maize is shown to remain about the same except in South Africa, where it is projected to decline by a large amount. Similar outcomes are shown for the yield and production of sorghum and millet; the area under these crops are projected to increase, however, and this would partially compensate for the reduction in area harvested for maize.

Conclusions and Recommendations

Smallholder farmers account for the majority of agriculture production in the region. This makes the agricultural sector in the region very vulnerable to the impacts of climate change, especially given the poor travel times and already low yields there. Rapidly growing populations and higher rates of evapotranspiration (resulting from increased temperatures) can be expected to put pressure on the region's water resources, increasing the rate of rural–urban migration.

Most governments in southern Africa are making efforts to highlight the impacts of climate on agriculture. For instance, in Botswana, National Vision 2016 strives to promote irrigation, drought-resistant crops, and selective breeding of drought-tolerant livestock while diversifying the agricultural base and conserving scarce agricultural land resources. This is especially encouraging because Botswana is likely to remain a net importer of grains such as maize and sorghum. In addition, deployment of better farming technologies is envisaged to increase yields for both crops—depending on the successful uptake of these technologies by farmers through effective subsidies.

3 All dollar figures in this monograph are constant 2000 US dollars, and all tons are metric tons.

TABLE 1.7 Maize projections for southern Africa showing yield, area, and production, 2010–2050

	2010			2050					
				Yield (MT/ha)		Area (thousands of ha)		Production (thousands of MT)	
Country	Yield (MT/ha)	Area (thousands of ha)	Production (thousands of MT)	Min	Max	Min	Max	Min	Max
Angola	0.55	1,140	631	1.25	1.39	1,133	1,191	1,417	1,660
Botswana	0.20	56	11	0.29	0.41	43	55	12	22
Lesotho	0.67	139	94	1.80	2.34	142	155	273	333
Malawi	0.88	1,399	1,232	0.98	1.06	1,320	1,437	1,298	1,522
Mozambique	1.02	1,290	1,314	1.93	2.06	1,250	1,360	2,409	2,796
Namibia	1.32	25	33	1.36	1.73	22	23	30	40
South Africa	3.86	2,845	10,979	5.72	6.56	1,981	2,175	11,332	13,777
Swaziland	0.81	42	34	1.35	1.69	25	28	34	45
Zambia	2.00	546	1,090	3.06	3.19	541	589	1,657	1,877
Zimbabwe	0.57	1,353	770	1.14	1.31	1,265	1,377	1,445	1,807

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

Notes: Min (minimum) represents the smallest projected number from the simulations based on the CSIRO A1B, CSIRO B1, MIROC A1B, and MIROC B1 climate model/scenarios combined with the pessimistic, baseline, and optimistic scenarios. Max (maximum) represents the largest of the twelve simulated values. 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; B1 = greenhouse gas emissions scenario that assumes a population that peaks midcentury (like the A1B), but with rapid changes toward a service and information economy and the introduction of clean and resource efficient technologies; CSIRO = climate model developed at the Australia Commonwealth Scientific and Industrial Research Organisation; MIROC = Model for Interdisciplinary Research on Climate, developed at the University of Tokyo Center for Climate System Research; ha = hectares; MT = metric tons.

TABLE 1.8 Millet projections for southern Africa showing yield, area, and production, 2010–2050

	2010			2050					
				Yield (MT/ha)		Area (thousands of ha)		Production (thousands of MT)	
Country	Yield (MT/ha)	Area (thousands of ha)	Production (thousands of MT)	Min	Max	Min	Max	Min	Max
Angola	0.27	366	97	1.00	1.06	495	534	507	566
Botswana	0.36	4	2	1.23	1.54	5	6	7	9
Lesotho	0	0	0	0	0	0	0	0	0
Malawi	0.40	40	16	1.37	1.44	45	48	62	69
Mozambique	0.25	110	27	0.38	0.40	148	158	57	63
Namibia	0.21	266	56	0.64	0.83	335	355	222	290
South Africa	0.53	21	11	1.35	1.45	19	20	26	28
Swaziland	0	0	0	0	0	0	0	0	0
Zambia	0.42	63	26	1.43	1.50	87	92	124	137
Zimbabwe	0.33	128	42	1.31	1.44	168	179	225	256

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

Notes: Millet is not grown in Lesotho or Swaziland. Min (minimum) represents the smallest projected number from the simulations based on the CSIRO A1B, CSIRO B1, MIROC A1B, and MIROC B1 climate model/scenarios combined with the pessimistic, baseline, and optimistic scenarios. Max (maximum) represents the largest of the twelve simulated values. 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; B1 = greenhouse gas emissions scenario that assumes a population that peaks midcentury (like the A1B), but with rapid changes toward a service and information economy and the introduction of clean and resource efficient technologies; CSIRO = climate model developed at the Australia Commonwealth Scientific and Industrial Research Organisation; MIROC = Model for Interdisciplinary Research on Climate, developed at the University of Tokyo Center for Climate System Research; ha = hectares; MT = metric tons.

TABLE 1.9 Sorghum projections for southern Africa showing yield, area, and production, 2010–2050

	2010			2050					
				Yield (MT/ha)		Area (thousands of ha)		Production (thousands of MT)	
Country	Yield (MT/ha)	Area (thousands of ha)	Production (thousands of MT)	Min	Max	Min	Max	Min	Max
Angola	0	0	0	0	0	0	0	0	0
Botswana	0.34	58	19	0.81	1.08	69	83	57	87
Lesotho	0.60	35	21	2.48	2.80	51	53	129	147
Malawi	0.64	73	46	1.44	1.49	106	108	152	160
Mozambique	0.48	582	282	1.12	1.15	841	862	945	992
Namibia	0.35	21	7	1.29	1.52	27	28	36	42
South Africa	2.79	94	263	4.49	4.91	92	95	414	461
Swaziland	0.61	1	1	1.92	1.95	2	3	5	5
Zambia	0.74	32	23	1.61	1.64	35	36	57	59
Zimbabwe	0.61	140	85	1.55	1.66	171	175	265	288

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

Notes: Sorghum is not grown in Angola. Min (minimum) represents the smallest projected number from the simulations based on the CSIRO A1B, CSIRO B1, MIROC A1B, and MIROC B1 climate model/scenarios combined with the pessimistic, baseline, and optimistic scenarios. Max (maximum) represents the largest of the twelve simulated values. 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; B1 = greenhouse gas emissions scenario that assumes a population that peaks midcentury (like the A1B), but with rapid changes toward a service and information economy and the introduction of clean and resource efficient technologies; CSIRO = climate model developed at the Australia Commonwealth Scientific and Industrial Research Organisation; MIROC = Model for Interdisciplinary Research on Climate, developed at the University of Tokyo Center for Climate System Research; ha = hectares; MT = metric tons.

Because agriculture employs 60–70 percent of the labor force in Lesotho, climate scenarios showing adverse effects on food production and water supply pose a particular threat to a great proportion of the labor force and their extended families. However, despite the existing gaps in mainstreaming climate change issues, Lesotho is taking important steps toward increasing awareness through outreach programs, the creation of institutional frameworks for action, and the adaption of drought-resistant crop varieties. In addition to the recommendations presented below, the Lesotho government could also pay attention to capacity building in terms of climate change knowledge and promoting needed skills development across all the sectors of development as well as in learning institutions across different disciplines. Effective communications technologies need to be made available to poor and inaccessible communities to allow broad access to seasonal weather forecasts and early warning systems.

Scenarios for Swaziland paint a rather uncomfortable picture, with temperatures shown increasing by as much as 2.5°C by 2050 and precipitation decreasing by as much as 100 millimeters in the highveld and the lowveld—the ecological zones where most of the crops are produced. In developing Swaziland's climate change policy, the National Committee (which is made up of government officers, to the exclusion of public or private organizations and representatives of nongovernmental organizations [NGOs]) needs to engage all relevant stakeholders to represent a broad range of interests on this topic. There is a need to improve the understanding of local communities regarding climate change. At the same time, continued dialogue between researchers and policymakers would provide mutual learning opportunities and ensure that the knowledge produced by researchers is both useful and used.

There will be no one-size-fits-all solution, because each country in the region faces different challenges. For instance, as in most countries in the region, agriculture in Zambia is mainly dependent on rainfall and thus vulnerable to climate variability and change. The development of an integrated approach, tailored to address local challenges, will be essential to develop effective climate change adaptation and mitigation strategies. There is a strong drive by organizations in civil society and the private sector to implement climate change adaptation strategies for agriculture, especially in rural areas.

In Zimbabwe, models show a shift in agroecological zones as a result of climate change. Some of the maize-producing areas would need to adopt drought-tolerant varieties or crops like sorghum and millet. With improved availability of agriculture inputs, yields and production are projected to increase for maize, while the harvest area will increase for sorghum and millet. About 70 percent of the population is resident in semiarid areas where the area under crop production would decrease as a result of climate variability and change.

Scenarios for Mozambique show that the country faces risks from a changing climate, with loss of cultivated and managed lands projected for most of southern Mozambique. The modeled results show the production and yield of cassava increasing slowly until 2025 and then declining from 2025 to 2050. This potential outcome reinforces the need to implement the Mozambican National Adaptation Programme of Action for agriculture. It would help if the government enhanced the road network in the north of Mozambique so that the expected increase in cassava and maize production can be efficiently distributed throughout the country when the need arises in the near future.

Agricultural production in South Africa is mainly commercial, and though adapting to climate change is not less expensive for commercial farmers, in most cases it repays the extra investment. Commercial agriculture provides food for the majority of South Africans (and significant amounts for export to neighboring countries); shifts in climate patterns, the suitability of ecological regions, and market prices have a major influence on plantings and yields and therefore on production and returns. Our main recommendation for the country in this chapter is to educate decisionmakers, policymakers, and water users regarding the implications of climate change on agriculture, identifying the various vulnerabilities. Adaptation frameworks and actions will be needed to build resilience and to guarantee food security for the country and the region. Because vulnerability to climate change is highly variable throughout South Africa, policymakers should tailor policies to local conditions (Gbetibouo and Ringler 2009).

Some adaptation recommendations identified in the country chapters include the following:

- Incorporation of climate change adaptation in long-term planning and developmental programs, including budgetary allocations for climate change adaptation strategies.
- Smallholder irrigation development targeting vulnerable communities.
- Capacity building in skills and tools for technical assessments, planning, and policy development in the context of climate change.
- Awareness raising regarding climate change issues to gather support for action on the part of governments, NGOs, the private sector, and the public.

- Development and promotion of drought-tolerant and heat-tolerant crop varieties and hardy livestock and development of linkages between research institutions and extension institutions for more rapid transmission of information to farmers.
- Increased availability of weather and climate information.

Despite government efforts, gaps and disconnects still exist between climate change science and adaptation action. Important components are still needed: plans and policies that incorporate climate change issues, education on climate change among communities, and information on outreach programs as they are developed. Critical interventions must be based on developing institutional frameworks for action, drought-resistant crop varieties, smallholder water harvesting and supply strategies, and strategies for alleviating poverty aimed at making people more resilient to climate variability.

The next chapter, on methodology, presents some of the technical information needed for the reader to understand at a deeper level many of the results in this chapter and each of the country chapters. The rest of the chapters focus on impacts of climate on agriculture in individual countries.

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