Chapter 1

Introduction

1.0 Background and statement of the problem

Higher temperatures and declining rainfall patterns, as well as increasing frequency of extreme climate events (such as droughts and floods), are the expected future climate in the tropics (IPCC, 2007; Mitchell & Tanner, 2006; IPCC, 2001). In southern Africa, for example, rainfall patterns show a declining trend of summer rainfall (about 20%) from 1950-1999 and a high frequency of droughts, predicted to intensify in the 21st century (Mitchell & Tanner, 2006). Predictions for 2050 by the US National Center for Atmospheric Research show that the declining trend in rainfall is set to continue and the region is expected to be 10–20 percent drier than the previous 50 years (Mitchell & Tanner, 2006). These predicted changes in climate are expected to have differential impacts on agricultural productivity, food security and other sectors, across spatial and temporal scales. In the tropics and Africa in particular, changes in climate are expected to be detrimental to agricultural livelihood (IPCC, 2007; IAC, 2004; Dixon, Gulliver & Gibbon, 2001; IPCC, 2001). Recent studies suggest that agricultural crop productivity in Africa will be adversely affected by any warming above current levels (Kurukulasuriya et al., 2006; Kurukulasuriya & Mendelsohn, 2007a; Seo & Mendelsohn, 2007a).

Local ecosystems provide the main source of livelihood for many of the world's poor. Most of the rural poor in sub-Saharan Africa rely for their livelihood and food security on highly climate-sensitive rain-fed subsistence or small-scale farming, pastoral herding and direct harvesting of natural services of ecosystems such as forests and wetlands (Mitchell & Tanner, 2006; Leary et al., 2005; Roach, 2005; IPCC, 2001; Kandlinkar & Risbey, 2000). The productivity of this livelihood base is highly vulnerable to climate-related stresses, such as changes in temperature, precipitation (both amount and variability), and increased frequency of droughts and floods. The vulnerability of the majority of the poor in Africa to climate-related stresses is worsened by widespread poverty, HIV/AIDS, lack of access to resources (e.g. land and water) and management capabilities, wealth, technology, education, ineffective institutional arrangements, and lack of social safety nets (Leary et al., 2005; Nyong, 2005; APN, 2002; IPCC, 2001).

Studies based on the Global Environmental Facility (GEF) African Climate Project estimated the economic impacts of climate change on African agriculture (Dinar, Hassan, Mendelsohn & Benhin, 2008). These studies however, analysed impacts on dryland crops, irrigated crops and livestock separately. This is a significant limitation, since factors affecting the choice between crop and livestock production or their combination (mixed systems), cannot be separated. The selection must be an endogenous decision made by agricultural producers in response to varying climates and other circumstances. The decision of what to produce and how to produce it is accordingly an important adaptation mechanism in the face of changing climate and other ecological and economic circumstances. This is of special importance to Africa, where the majority of poor small-scale farmers practice mixed crop–livestock agriculture and few depend on crops or livestock alone.

One main objective of this study is therefore to measure the aggregate impact of climate change on income from all agricultural production systems (crop, livestock and mixed) in Africa, and to predict future impacts under various climate scenarios. In addition, the study also measures and compares impacts on specialised crop and livestock farms. The results are contrasted with findings of other regional studies using the same data but generating different climate response functions for crop and livestock farming separately (Kurukulasuriya et al., 2006; Kurukulasuriya & Mendelsohn, 2007a; Seo & Mendelsohn, 2007a).

Climate is changing and mitigation efforts to reduce the sources or enhance the sinks of greenhouse gases will take time and may also be very expensive (Stern, 2006). Empirical studies measuring the economic impacts of climate change on agriculture in Africa (Kurukulasuriya & Mendelsohn, 2007a; Seo & Mendelsohn, 2007a; Mano & Nhemachena, 2007; Benhin, 2006; Kabubo-Mariara & Karanja, 2007) showed that such impacts can be significantly reduced through adaptation. Adaptation is therefore critical and of major concern in developing countries which are most vulnerable, particularly Africa. While African farmers have low capacity to adapt to such risks, they have survived and have coped with climate change in various ways over time and under changing circumstances (Kurukulasuriya & Rosenthal, 2003). The second objective of this study is to analyse adaptation measures used by African farmers and determinants of their choices.

Better understanding of how farmers have coped with and adapted to climate change is essential for designing incentives to enhance private adaptation. This is also true for public adaptation as better understanding will help governments to design programmes to help farmers adapt. Supporting the coping strategies of local farmers through appropriate public policy, investment and collective actions has the potential to facilitate increased adoption of adaptation measures. Such adoption will reduce the negative consequences of predicted future climate changes, with great benefits to vulnerable rural communities in Africa. Our analysis is different from other adaptation studies in that we consider actual adaptation measures being taken by farmers, compared to the analysis conducted by Maddison (2007) on the same sample of African farmers, which is based on farmers' perceived adaptations. We also consider the choice between many adaptation measures simultaneously, compared to studies that analysed such joint endogenous decisions in separate analyses for crop selection (Kurukulasuriya & Mendelsohn, 2007b), irrigation modelling (Kurukulasuriya & Mendelsohn, 2007c) and livestock choice analysis (Seo & Mendelsohn, 2007b).

1.2 Objectives of the Study

The first main objective of this study is to measure the aggregate impact of climate change on income from all agricultural production systems (crop, livestock and mixed) in Africa, and to predict future impacts under various climate scenarios. The study analyses the impacts of global warming on African agriculture in terms of long-term changes in climate variables (temperature and precipitation). In addition to measuring economic impacts, the second main objective of the study is to analyse determinants of farmers' choices between alternative adaptation measures available to African farmers. Adaptation measures[1] refer to adjustments in management strategies to reduce risks or realise opportunities from actual or expected changes in climatic conditions.

Under these main objectives the following specific objectives were pursued:

1. Apply a cross-sectional model to measure the impacts of changes in seasonal climate attributes (rainfall and temperature levels) on net revenue from crop and livestock farming, while controlling for the effect of other factors.
2. Use estimated model parameters to predict impacts of future climate changes on net revenue from crop and livestock farming under various climate scenarios.
3. Estimate climatic response functions of different production systems under irrigation and dryland conditions.
4. Analyse the significance of seasonal climate, household and other socio-economic factors in influencing the use of adaptation measures at the farm level.
5. Suggest policy options that can reduce negative impacts of climate change and help improve regional food security in the face of anticipated changes in climate.

1.3 Hypotheses of the study

1. In regions in Africa that are already hot and dry, increases in warming and declining precipitation are expected to have negative effects on net revenue from crop and livestock farming, controlling for the effects of other factors.
2. In regions in Africa experiencing dry and average wet conditions, increases in seasonal rainfall are expected to increase net farm revenues, controlling for the effects of other factors.

[1] See Chapter 5 section for more details on adaptation.

3. The adverse impacts of increases in warming and declining precipitation in Africa are expected to be higher for dryland, single-cropping and pastoralist systems than for irrigated and mixed crop–livestock farms.
4. Improved access of African farmers to resources such as credit, extension, information etc., enhances farm-level use of adaptation measures.

1.4 Approach and Methods of the Study

This study employs two main analytical techniques to attain the above objectives. It firstly adopts the cross-section (Ricardian) approach to measure the impacts of climate change attributes (rainfall and temperature levels) on income from all agricultural production systems (crop, livestock and mixed) in Africa, controlling for other production factors. Based on empirical estimates from the Ricardian model, future impacts under various climate scenarios are predicted. In addition to estimating impacts on mixed crop–livestock farms, impacts on specialised crop and livestock farms are also measured and compared. Responses of different production systems are analysed under irrigation and dryland conditions. Secondly, the study employs the multinomial logit approach to analyse determinants of farm-level adaptation measures of African farmers.

The empirical estimations are based primarily on existing survey and other data collected by the Global Environmental Facility/ World Bank/ Centre for Environmental Economics and Policy in Africa (GEF/WB/CEEPA) study on climate change and agriculture (Dinar et al., 2008). This data covers eleven countries: Burkina Faso, Cameroon, Egypt, Ethiopia, Ghana, Kenya, Niger, Senegal, South Africa, Zambia and Zimbabwe.

1.5 Organisation of the Thesis

Chapter 2 provides background information on the climate, farming systems and agricultural production in Africa. Chapter 3 presents a review of approaches for measuring the economic impacts of climate change and empirical studies that have estimated climate change impacts on agriculture. Specification of the Ricardian analytical model and results of the empirical analyses of climate change impacts on agriculture are presented and discussed in Chapter 4. Chapter 5 briefly reviews selected theoretical and empirical studies relating to the economics of climate change adaptation in agriculture. The empirical specification and estimation of the multinomial discrete choice model of determinants of farm strategies is presented in Chapter 6. A summary, conclusions and implications for policy and research are presented in Chapter 7.

Chapter 2

African climate, farming systems and agricultural production

2.0 Introduction

Agricultural production remains the main source of livelihood for most rural communities in developing countries. In sub-Saharan Africa in particular, agriculture provides a source of employment for more than 60% of the population and contributes about 30% of the Gross Domestic Product (GDP) (Kandlinkar & Risbey, 2000). In addition, agriculture provides an important source of export earnings, accounting for 16% of the total exports in sub-Saharan Africa (47% of total exports in East Africa, 14% in southern Africa and 10% in West Africa) (IAC, 2004; Dixon et al., 2001).

Agricultural production in Africa is vulnerable to climatic conditions due to a number of reasons: (i) most parts of the continent are already experiencing very high temperatures; (ii) most farmers depend on the quality of rain and production is mainly subsistence; and (iii) most parts of the continent are already water stressed[2] (IPCC, 2001). African farmers and systems have adapted in many ways to climate change through, for example, growing multiple crops, mixing crops and livestock, and using irrigation (Kurukulasuriya & Rosenthal, 2003). With respect to the main goals of the study, this chapter presents an overview assessment of the African climate and how it influences agricultural production in major farming systems.

[2] Many parts of Africa are vulnerable to lack of access to safe water arising from multiple factors, with the situation exacerbated by climate change. For example, some assessments show severe increased water stress and possible increased drought risk for parts of northern and southern Africa, and increases in runoff in East Africa (IPCC, 2007). Further, Africa has the lowest conversion factor of precipitation to runoff, averaging 15%. Also, although the equatorial region and coastal areas of eastern and southern Africa are humid, the rest of the continent is dry sub-humid to arid (IPCC, 2001).

2.1 African climate and agricultural potential

According to the IPCC (2001), most parts of Africa are mainly tropical and experience hot and dry conditions. Temperate climatic conditions are found in the extreme south and north, and at high altitudes in between. Humid conditions are experienced in parts of West Africa, including the western part of Central Africa, throughout the year. The sub-humid region covers a large area north and south of the humid central region, and experiences substantial rainfall during the wet season and almost no rain during the dry season. Semi-arid climates are located from the sub-humid region further to the poles, and are characterised by extreme unreliability of rainfall. Most of the human population is located in the sub-humid and semi-arid zones (IPCC, 2001).

Scientific evidence on global warming shows that further increases in average temperatures of 1.4-5.8°C are expected in the 21st century (Wilson, 2001). These increases are expected to be more harmful in tropical areas such as Africa that are already experiencing very high temperatures. Most climate models predict more frequent and severe extreme weather events in the tropics generally, including both localised drought and flooding. Agricultural productivity in Africa is considered to be vulnerable to such extreme weather events.

An important example is the increased frequency of drought episodes over the last several decades particularly in southeast Africa that are associated with the El Niño-Southern Oscillation (ENSO[3]) phenomenon. In addition, arid and semi-arid sub-regions and the grassland areas of eastern and southern Africa, as well as areas currently under threat from land degradation and desertification, are particularly vulnerable to global

[3] "The El Niño-Southern Oscillation (ENSO) is the atmosphere-ocean phenomenon responsible for interannual climate variability" (IPCC, 2007; Nicholson & Entekhapi, 1986). "The ENSO events have great impact on the wind, sea surface temperature, and precipitation patterns" (IPCC, 2007). "The typical rainfall anomaly associated with ENSO is a dipole rainfall pattern: some regions will experience warm ENSO episodes, whereas others will be negatively correlated with these events" (Nicholson & Kim, 1997).

warming, indicating reduced potential for agricultural activities in these regions. A reduction in rainfall projected by some climate models for the Sahel and southern Africa, if accompanied by high inter-annual variability, could be detrimental to the hydrological balance of the continent and disrupt various water-dependent socio-economic activities that include agricultural production systems (IAC, 2004).

Figures 2.1(a), (b) and (c) below show trends in temperature, precipitation and food production in Africa respectively. Trends in precipitation and temperature for the African region indicate that the region is warming and getting drier. Trends in variability of temperature in Africa over the 20th century show a rising trend in observational records at a rate of about 0.05°C per decade. Much of the warming has been recorded in the June-November seasons compared to the December-May seasons (Hulme, Doherty, Ngara, New & Lister, 2001). According to the IPCC (2001), temperatures are expected to increase most in southern and northwest Africa at a rate of about 0.6°C to 1°C per decade and around 0.4°C in East Africa. Precipitation trends show that Africa is going to experience drier conditions, with precipitation decreasing at a rate of between 10 and 20% in southern Africa and 10 to 50% in eastern and northern parts of Africa (IPCC, 2001). These trends are expected to negatively affect agricultural productivity and food security in the region, unless precautionary adaptive measures are taken. These adaptive measures, both at the local farm level and national levels are necessary to help reduce the potential negative effects associated with these changes in temperature and precipitation.

It is difficult to establish causality between climate variability and rain-fed crop and livestock production. It is however, true that for some countries and certain years, food production has been declining in the face of increasing temperature and decreasing precipitation regimes. The impact of these changes, in addition to other factors, is that food production in most of sub-Saharan Africa (SSA) has not kept pace with population growth over the past three decades. For example, in Africa as a whole, food consumption exceeded domestic production by 50% in drought-prone areas in the mid-1980s and by more than 30% in the mid-1990s (WRI, 1998). This has left many countries in Africa being net food importers, with food aid constituting a major proportion of net food trade in the region. For instance, food aid constituted two-thirds of food imports during the 1990s in Kenya and Tanzania (IPCC, 2001).

In addition, per capita dietary needs supply (DES) remains relatively low (Hulme, 1996). About one-third of the countries in Africa had per capita DES of less than 2000 kcal per day in the 1990s, which is lower than the minimum recommended intake of 2100 (Todd, 2004; Naiken, 2002). The results from the three graphs suggest a direct correlation between increasing temperatures, decreasing precipitation and declining food production. The implication of predicted further warming in Africa is that food production is going to be adversely affected, unless farmers use adaptation strategies such as irrigation. It is therefore important to find ways and strategies of reducing the vulnerability and improving the adaptive capacity of African agriculture in the face of the adversities of predicted climate changes.

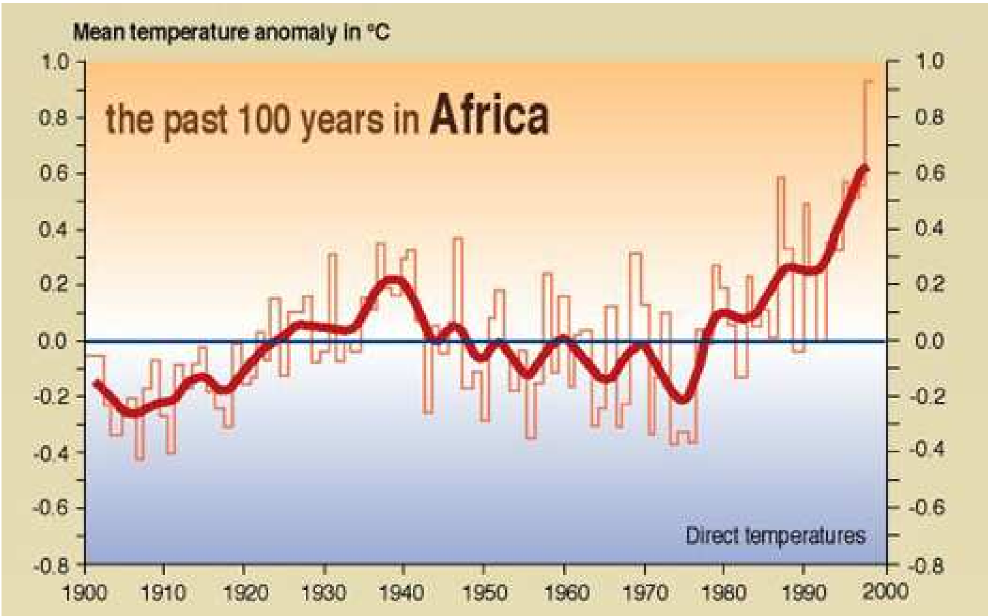

Figure 2.1 (a): Variations of the earth's surface temperature for the past 100 years in Africa

Source: UNEP Grid Arendal (2002).

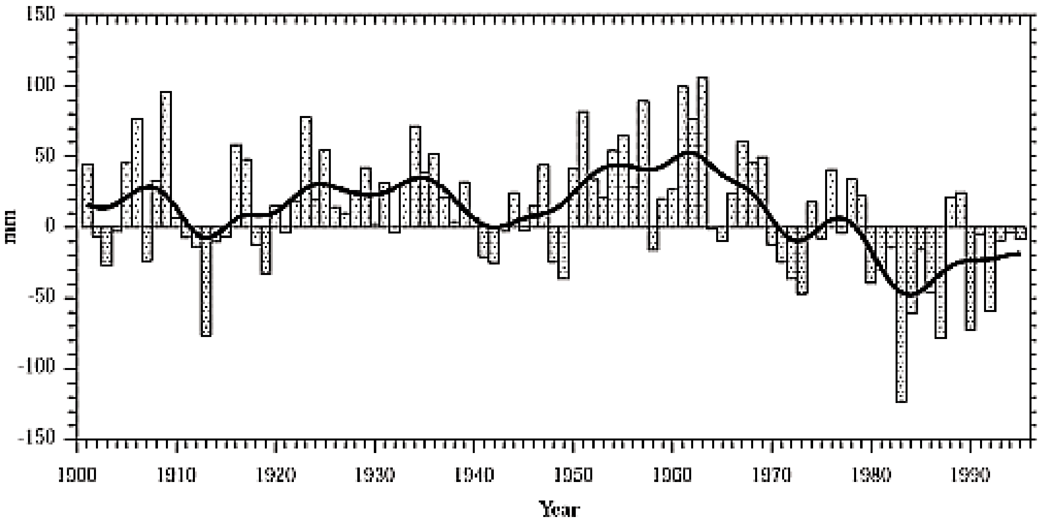

Figure 2.1 (b): Observed annual precipitation changes for the Africa region

Source: IPCC (2001)

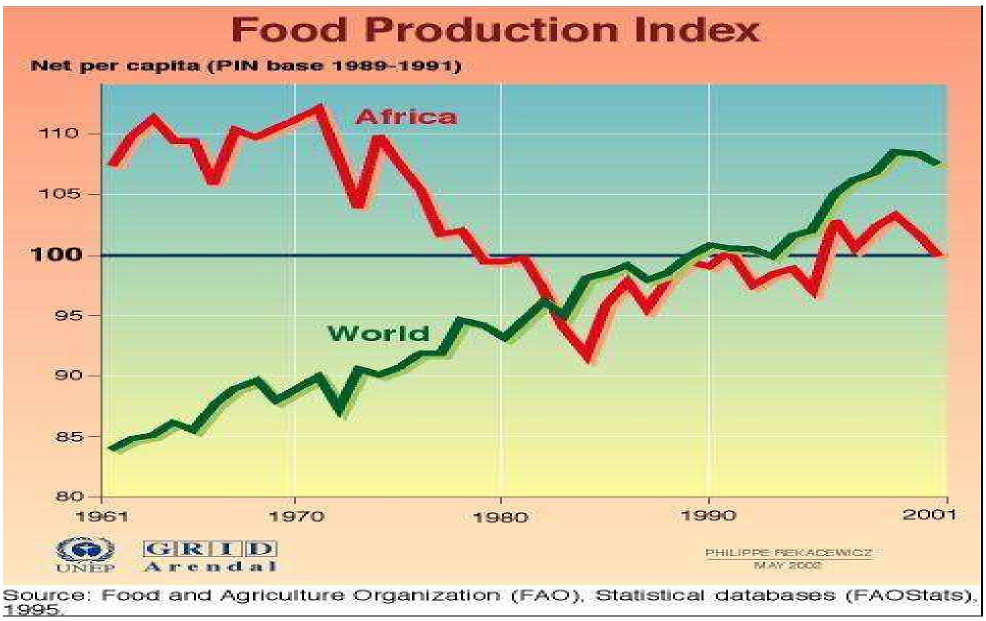

Figure 2.1 (c): Food production index in Africa

2.2 Agro-climates and farming systems in sub-Saharan Africa

A farming system is defined as "a population of individual farm systems that have broadly similar resource bases, enterprise patterns, household livelihood and constraints, and for which similar development strategies and interventions would be appropriate" (Dixon et al., 2001; FAO, 2001). Dixon et al. (2001) and FAO (2001) classified 15 major farming systems in SSA (see Figure 2.2 and Table 2.1). This classification of farming systems was based on: (a) natural resource base (e.g. water, land, grazing areas and forest); climatic conditions (e.g. altitude); landscape characteristics (e.g. slope); farm size, tenure and organisation) and (b) main farming activities and sources of livelihood (e.g. field crops, livestock, trees, aquaculture, hunting and gathering, processing and off-farm activities); intensity of production; and integration of crops, livestock and other activities based on technology use.

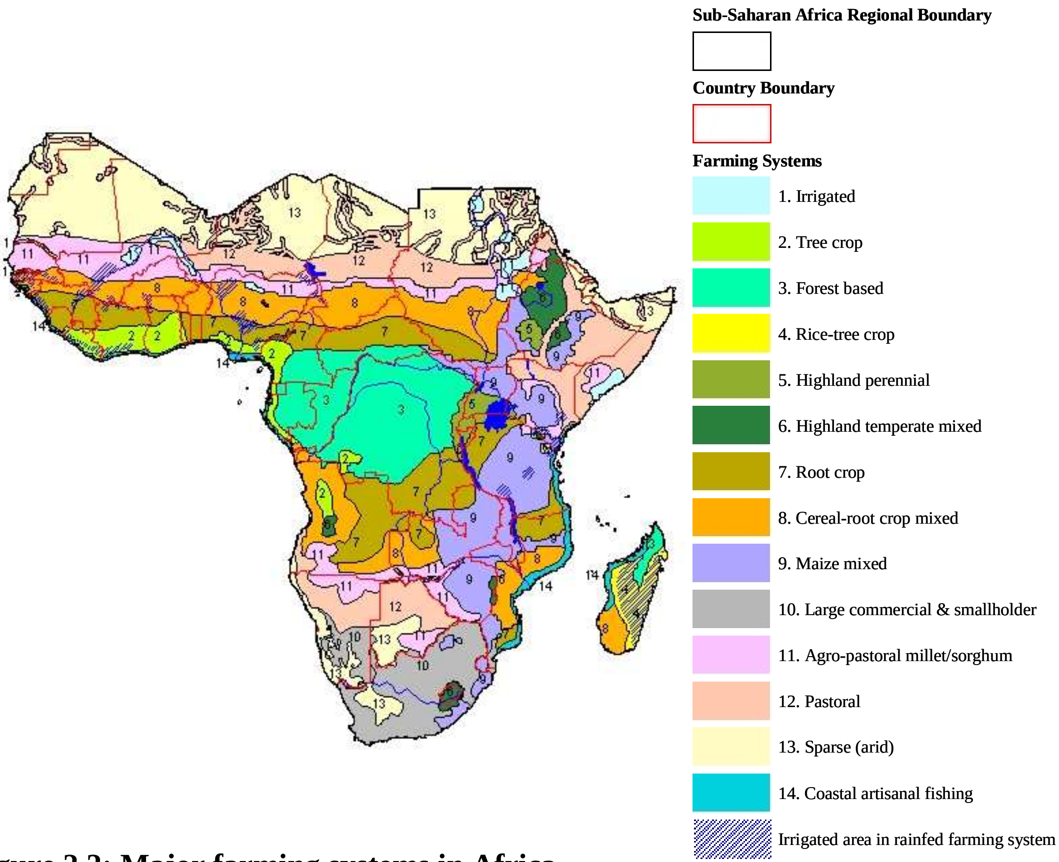

Figure 2.2: Major farming systems in Africa

Source: Dixon et al. (2001)

Table 2.1: Major farming systems in sub-Saharan Africa

Farming system	Land area (% of region)	Agric. population (% of region)	Principal livelihood	Agro-ecological zone	Sources of Vulnerability
Maize-mixed (9)	10	15	Maize, tobacco, cotton, cattle, goats, poultry, off-farm work	Semi-arid and dry sub-humid	Drought, market volatility
Cereal-root crop mixed (8)	13	15	Maize, sorghum, millet, cassava, yams, legumes, cattle	Dry sub-humid	Drought
Root crop (7)	11	11	Yams, cassava, legumes, off-farm work	Moist sub-humid and humid	Lack of appropriate technologies
Agro-pastoral millet/ sorghum (11)	8	9	Sorghum, pearl millet, pulses, sesame, cattle, sheep, goats, poultry, off-farm work	Semi-arid	Drought
Highland perennial (5)	1	8	Banana, plantain, enset, coffee, cassava, sweet potato, beans, cereals, livestock, poultry, off-farm work	Sub-humid and humid	Declining soil fertility, poor markets; infrastructure
Forest based (3)	11	7	Cassava, maize, beans, coco yams	Humid	Lack of physical infrastructure, markets
Highland temperate mixed (6)	2	7	Wheat, barley, teff, peas, lentils, broad beans, rape, potatoes, sheep, goats, cattle, poultry, off-farm work	Sub-humid and humid	Early and late frosts
Pastoral (12)	14	7	Cattle, camels, sheep, goats, remittances	Arid and semi-arid	Drought
Tree crop (2)	3	6	Cocoa, coffee, oil palm, rubber, yams, maize, off-farm work	Humid	Price fluctuations
Commercial large-scale and small-scale (10)	5	4	Maize, pulses, sunflower, cattle, sheep, goats, remittances	Semi-arid and dry sub-humid	Drought, poor soils
Coastal artisanal fishing (14)	2	3	Marine fish, coconuts, cashew, banana, yams, fruit, goats, poultry, off-farm work	Humid	
Irrigated (1)	1	2	Rice, cotton, vegetables, rain-fed crops, cattle, poultry	Various	Water shortages, scheme breakdowns, High costs
Rice/ tree crop (4)	1	2	Rice, banana, coffee, maize, cassava, legumes, livestock, off-farm work	Moist humid and humid	Shortage of appropriate technologies, small farm size, poor markets
Sparse agriculture (arid) (13)	18	1	Irrigated maize, vegetables, date palms, cattle, off-farm work	Arid	Drought
Urban based (15)	<1	3	Fruit, vegetables, dairy, cattle, goats, poultry, off-farm work	Various	

NB: Numbers in parenthesis represent the respective farming system numbers as indicated in Figure 2.2

Source: Dixon et al. (2001)

Despite the central role that agriculture plays in the region, most of the region has marginal conditions for productive agriculture. Forty-three percent of sub-Saharan Africa is located in the arid and semi-arid agro-ecological zones, thirteen percent is in the dry sub-humid zones and thirty-eight percent is covered jointly by the sub-humid and humid zones (IAC, 2004; Dixon et al., 2001; FAO, 2001). The arid, semi-arid and dry sub-humid areas are characterised by large marginal areas, which experience very high temperatures and very low and highly variable rainfall, all of which limit agricultural productivity. Farming systems in the arid, semi-arid and dry sub-humid zones are expected to suffer most from the adverse effects of climate change, such as increased frequency and severity of droughts, high temperatures and rainfall variability (IAC, 2004).

The major farming systems that support most of the agricultural population in Africa and in southern Africa in particular, are located in the dry sub-humid zone (cereal-root mixed, maize mixed, large commercial and smallholder systems), semi-arid zone (agro-pastoral, millet) and arid zone (pastoral). About half of the population in southern and eastern Africa lives in the sub-humid and humid zones, compared to about seventy percent living in the same areas in West Africa. The former areas are already experiencing very high temperatures with a significant proportion of the region receiving mean annual rainfall of less than 1000mm and having mean annual temperatures between 20 and 30 degrees Celsius and (Figure 2.3(a) and 2.3(b) below).

Changes in climate in terms of increasing frequency and severity of droughts are expected to have significant impacts on the arid, semi-arid and dry sub-humid agro-ecological zones. The impacts would translate into widespread crop failure, high and rising cereal prices, low and falling livestock prices, distress sales of animals, decapitalisation, impoverishment, hunger and eventually famine (Dixon et al., 2001; FAO, 2001). Mixed cropping systems are better able to cope with changes in climate and other stresses. They can reduce risk of crop failure, reduce incidence and losses from pests and diseases, and can make efficient use of labour (IAC, 2004).

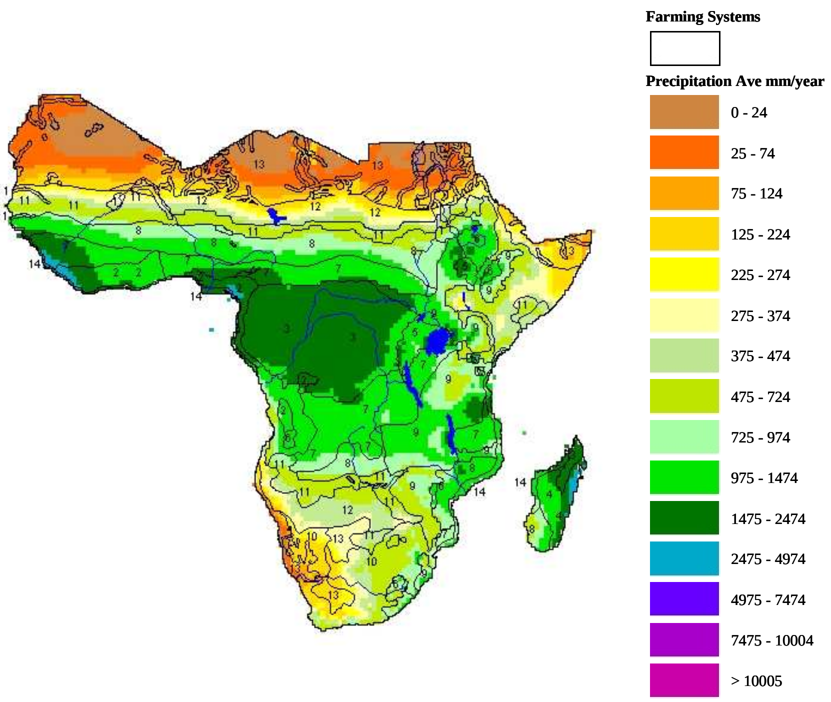

Figure 2.3(a): Average annual precipitation in major farming systems

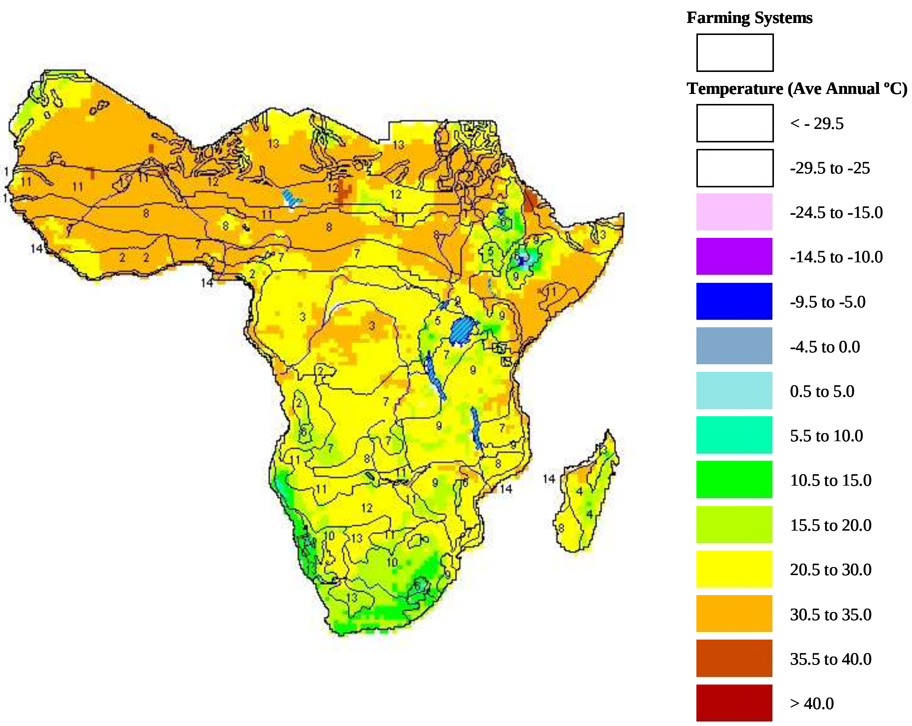

Figure 2.3(b): Average annual temperatures in major farming systems

Source: Dixon et al. (2001)

2.3 Characterisation of selected priority farming systems

Table 2.2 presents further information characterising the four priority farming systems: maize-mixed; cereal-root crop mixed; irrigated and root crops, which support about 41% of the agricultural population (IAC, 2004). Table 2.3 shows annual productivity growth for the major commodities over the last two decades (1980-2000) and the two preceding decades (1960-1980). Productivity trends for six of the major crops in the maize-mixed farming system have been declining since 1981. On the other hand, crops in the irrigated and tree crop systems that involve more commercial crops show increasing productivity trends from 1981. In the main systems examined, productivity was relatively higher for food crops (e.g. maize, wheat and cassava) than for other crops (e.g. coffee, palm oil and cocoa).

Table 2.2: Major characteristics of selected priority farming systems

	Maize-mixed	Irrigated	Cereal-root crop	Tree crop
A. Major characteristics*				
Total population (‘000 000 people)	95	14	85	50
Agricultural population (‘000 000 people)	60	7	59	25
Total area (‘000 000 ha)	246	35	312	73
Cultivated area (‘000 000 ha)	32	3	31	10
Irrigated area (‘000 000 ha)	0.4	2	0.4	0.1
Agro-climatic zone	Dry sub-humid to moist sub-humid	Various	Dry sub-humid	Humid
Vulnerability	Drought and market volatility	High costs	Drought	Price fluctuations
Prevalence of poverty	Moderate	Limited	High	Limited-moderate
Agriculture growth potential	Good	High	Limited	Moderately high
B. Indices				
Malnutrition index	81	28	100	50
Agricultural added value index	73	100	28	67
C. Dominant (++) and other important (+) commodities				
Maize	++	++	++	+
Rice	+	++		+
Sorghum	+	+	++	+
Millet	+		++	+
Wheat		++		
Cassava	++		++	++
Yam			++	++
Cocoyam				++
Pulses	+		+	
Vegetables/Melon		++		
Banana/Plantain	+			
Cotton	+		+	
Coffee	+			+
Oil Palm				+
Cocoa				+
Rubber				+
Tobacco	+			
Groundnuts	+			
Sunflower	+			
Cattle population (‘000 000 head)	36	3	42	2
Poultry	+	+		
Goats	+		+	+

Source: IAC, 2004

Table 2.3: Productivity trends for various commodities in the priority farming systems

Crop	Decades	Annual % yield increase over two periods of two decades			
		Maize-mixed	Irrigated	Cereal-root crop	Tree crop
Maize	1961-1980	2.63	1.97	-0.36	0.27
	1981-2002	-0.04	3.3	3.83	2.56
Rice	1961-1980	0.98	0.2	-0.94	1.28
	1981-2002	0.69	2.71	1.35	2.98
Sorghum	1961-1980	0.16	0.32	0.72	0.58
	1981-2002	0.64	2	1.68	2.28
Millet	1961-1980	1.22		0.04	-1.07
	1981-2002	0.54		1.92	0.11
Wheat	1961-1980	6.92	1.92		
	1981-2002	-0.08	3.19		
Cassava	1961-1980	2.8		1.37	-0.06
	1981-2002	0.03		2.09	1.75
Yam	1961-1980			1.29	
	1981-2002			0.92	
Pulses	1961-1980			0.9	
	1981-2002			4.48	
Vegetables/Melon	1961-1980		0.21		
	1981-2002		1.13		
Banana	1961-1980	-0.4			
	1981-2002	1.4			
Cotton	1961-1980	2.69			
	1981-2002	0.77			
Coffee	1961-1980				-0.34
	1981-2002				0.86
Oil Palm	1961-1980				0.44
	1981-2002				0.48
Cocoa	1961-1980				-0.15
	1981-2002				1.94

Source: IAC (2004). Indicator countries: Maize-mixed (Malawi and Zimbabwe: 70%; and Tanzania, Uganda and Zambia: 50%); Irrigated (Egypt); Cereal-root crop mixed (Gambia, Guinea-Bissau and Mozambique: 70%; and Benin and Burkina Faso: 50%) and tree crop based (Guinea and Liberia: 70%; and Ghana: 50%). The percentages refer to minimum proportions of the countries that are covered by the indicated systems.

Table 2.4 shows irrigated land in farming systems in Africa in 2000. Much of the agricultural output in Africa is produced from rain-fed agricultural systems and only a small area (about 1.2%) is under irrigation (IAC, 2004). These figures illustrate that the use of irrigation is very limited in Africa, despite its potential for increasing agricultural productivity in the face of frequent drought regimes in most parts of the region due to changes in climate. Irrigation offers an important adaptation strategy to water stresses and droughts that are being experienced in the region and it may be necessary to find ways of enhancing its expansion in Africa. In addition, there is great potential for raising productivity levels of agricultural systems currently under rain-fed agriculture, through the adoption of irrigation technologies.

Table 2.4: Irrigated land within the main farming systems in Africa in 2000

Farming system	Agricultural area (1 000 ha)		
	Land use	**Irrigation**	**Percent irrigated**
Cereal-root crop mixed	62,874	163	0.26
Highland perennial	3,890	79	2.03
Maize-mixed	108,629	360	0.33
Root crop	11,525	37	0.32
Forest based	38,594	27	0.07
Tree crop	49,289	182	0.37
Agro-pastoral	8,050	71	0.88
Sparse (arid)	111,395	1,145	1.03
Large commercial	99,640	1,498	1.5
Irrigated	3,291	3,291	100
Africa total	**1,101,166**	**12,680**	**1.15**

Source: IAC (2004)

Despite low productivity levels of rain-fed agriculture, baseline projections to 2021-25 (Table 2.5) indicate no significant changes in the proportion of land under irrigation for important food crops (Rosegrant, Cai & Cline, 2002). Table 2.5 shows that only soybean is expected to continue to derive most of its production from irrigated agriculture. Maize, which constitutes the main cereal in Africa, continues to derive most of its production from rain-fed agricultural systems.

Table 2.5: Proportions of rain-fed areas and production totals in 1995 and projected to 2021-25 in Africa for selected crops

Region/commodity	Percentage rain-fed			
	Area (%)		Production (%)	
	1995 actual	2021-25 baseline projection	1995 actual	2021-25 baseline projection
Sub-Saharan Africa				
Total cereals	96	95	89	89
Rice	81	77	68	64
Wheat	78	75	73	71
Maize	96	96	90	90
Soybean	25	27	49	52

Source: Rosegrant et al. (2002)

According to the IAC (2004), sustainable yield increases (e.g. through innovations in integrated water, soil and nutrient management) should be the driving force in future rain-fed agricultural strategies, rather than the former strategy of increasing production through area expansion. The limitations of this former strategy are that with population increases in the region and limited available agricultural land, further agricultural land expansion will extend into marginal areas, leading to further land degradation, erosion and loss of biodiversity.

The implication of expected dry and warm conditions in the future is that rain-fed agricultural systems need more water-efficient farm management systems, combined with drought-tolerant crops and varieties with higher water use efficiency. Recommended practices include water harvesting, supplementary irrigation, run-off management, conservation tillage and integration of more leguminous species into rotation systems. Improved soil surface management practices, small water harvesting systems and small irrigation systems have been shown to offer great potential for making maximum use of rainwater. In addition, such practices allow farmers to intensify their production activities and encourage increased diversity in production of high value crops (IAC, 2004).

2.4 Importance of livestock in African farming systems

Livestock provides an important source of livelihood for most of the rural poor. Livestock are important as a source of cash; a coping strategy against climate change and other stresses; and they provide a good source of social security capital and social networking instruments (IAC, 2004). Other important benefits of livestock include: draft power for land operations and post harvesting operations; soil fertility improvement from manure; source of transport to markets; source of diversifying income sources; and an important source of high quality proteins and energy (IAC, 2004).

Major animal production systems are presented in Table 2.6. Cattle are a major breed for most poor people in mixed crop–livestock systems in arid and semi-arid regions (MRA), humid/sub-humid regions (MRH) and the tropical highlands (MRT) of eastern, central and southern Africa. Other livestock in these farming systems are: sheep, goats, poultry, horses, donkeys, mules and pigs. In West Africa, sheep and goats are the most important, followed by poultry and cattle, horses, donkeys, mules and pigs. Sheep and goats are also of great importance for the poor in pastoral rangeland-based systems, as are cattle, camels, donkeys and mules (IAC, 2004).

Table 2.6: Major animal production systems in African agro-ecological zones

Abbreviation	Animal production system	Agro-ecological zone
LGA	Pastoral, livestock only, rangeland-based	arid/semi-arid
LGH	Pastoral, livestock only, rangeland-based	humid/sub-humid
LGT	Pastoral, livestock only, rangeland-based	temperate/tropical highland
MRA	Agro-pastoral, mixed rain-fed	arid/semi-arid
MRH	Agro-pastoral, mixed rain-fed	humid/sub-humid
MRT	Agro-pastoral, mixed rain-fed	temperate/tropical highland
MIA	Agro-pastoral, mixed irrigated	arid/semi-arid
MIH	Agro-pastoral, mixed irrigated	humid/sub-humid
LL	Peri-urban, landless	

Source: IAC (2004). Includes both sub-Saharan and North Africa.

More than 70% of the estimated 280 million poor people in sub-Saharan Africa base their livelihood on the three mixed rain-fed crop–livestock farming systems (MRA, MRH and MRT) and only 10% rely on the pastoral rangeland-based systems (IAC, 2004). Livestock production contributes most to the livelihood of many poor people in the pastoral rangeland-based systems of the arid and semi-arid regions (LGA). The contribution is relatively high in the mixed rain-fed crop–livestock systems in the humid/ sub-humid tropics (MRH), and relatively low in the mixed rain-fed crop–livestock systems in the arid and semi-arid tropics (MRA) (IAC, 2004).

2.5 Environmental constraints in major farming systems

Figure 2.4 presents environmental constraints in major farming systems in sub-Saharan Africa. Environmental factors such as soil moisture, temperature, soil quality and precipitation affect productivity of crop and livestock farming systems. For example, low to medium climatic production potential is the main environmental constraint affecting major farming systems such as maize-mixed, root crop, and cereal-root crop mixed farming systems that support about 41% of the agricultural population. Another key environmental constraint is erratic rainfall and cold stress risk, which is prevalent in the pastoral, agro-pastoral millet/sorghum, cereal-root crop mixed, large commercial and smallholder farming systems. The sparse arid farming system is located in dry and/or cold areas with low production potential.

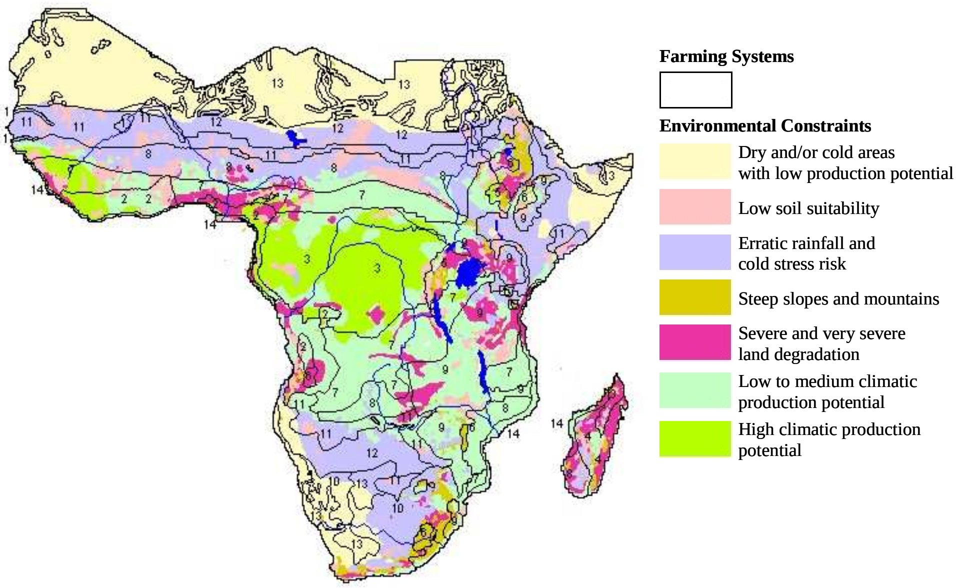

Figure 2.4: Environmental constraints in major farming systems

Source: Dixon et al. (2001)

Climate related factors (erratic rainfall and cold stress, climatic production potential and dry and/or cold areas) are the main limiting environmental factors for agricultural productivity in Africa. Farming systems, crop and livestock production and hydrological balances are expected to be greatly influenced by changes in climatic variables (temperature, precipitation) and the frequency and severity of extreme climate events (droughts and floods).

The relatively large extent of areas already experiencing climate related constraints implies that climatic factors have significant effects on performance of agricultural systems in Africa. Figures 2.3(a) and 2.3(b) showing rainfall and temperature maps indicate that these areas experience climate related constraints such as low to medium rainfall and very high temperatures. The combination of these factors and other economic factors such as low technology use, lack of inputs, and market access will negatively affect productivity of farming systems in major farming systems in Africa.

2.6 Summary

This chapter described the various agro-ecological regions and the location of major farming systems in Africa. Major farming systems in Africa are located in subtropical and tropical regions which have marginal conditions for productive agricultural production, with about 43% of the total land area being arid and semi-arid agro-ecological zones. These regions are characterised by large marginal areas, very high temperatures and very low and highly variable rainfall, all of which limit agricultural productivity. The implication is that changes in climate attributes will have significant impacts on agricultural production.

The maize-mixed, cereal-root crop mixed and root crop farming systems support about 41% of the agricultural population. Agro-pastoral millet/sorghum, highland perennial, pastoral, forest based and highland temperate mixed are also important systems. The mixed farming system is very important in Africa, which justifies the empirical analysis in this study for estimating the impacts of climate change on mixed crop–livestock systems.

It is difficult to establish causality between climate variability and rain-fed crop and livestock production. However, it is true that for some countries and years, food production has been declining in the face of increasing temperature and decreasing precipitation regimes. Generally, long term temperature and precipitation patterns show increasing and decreasing trends respectively, and food production trends show some direct correlation with trends in climate attributes (temperature and precipitation). Furthermore, maps of major farming systems and temperature and precipitation maps show that most of the region experiences warm and dry climatic conditions. The implication may be that climate change attributes have significant effects on agricultural productivity and food security in the region.

This chapter also presented the environmental constraints in major farming systems. Environmental factors such as soil moisture, temperature, soil quality and precipitation affect productivity of crop and livestock farming systems. Climate related factors (erratic rainfall and cold stress, climatic production potential, and dry and/or cold areas) affect most parts of the sub-Saharan region. This evidence further justifies the hypothesis that climate attributes (temperature and precipitation) have significant effects on agricultural performance in Africa.