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Climate Change:
Key Issues for Farmers in Southern Africa,
Opportunities and Possible Responses

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Southern African Confederation of Agricultural Unions
Post Office Box 10480
Centurion
0046
South Africa

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Commissioned authors: CSIR-NRE (Centre for Scientific and Industrial Research – Natural Resources and Environment), Post Office Box 395, Pretoria 0001, RSA. Lead researcher: Constansia Musvoto.

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List of Acronyms

AAU:	Assigned Amount Units
ACCID:	Africa-wide Civil Society Climate Change Initiative for Policy Dialogues
AfDB:	African Development Bank
AFOLU:	Agriculture, Forestry and Other sustainable Land Uses
ASARECA:	Association for Strengthening Agricultural Research in Eastern and Central Africa
BFAP:	Bureau for Food and Agricultural Policy
CAADP:	Comprehensive Africa Agriculture Development Programme
CC:	Climate Change
CCAA:	Climate Change for Adaptation in Africa
CDM:	Clean Development Mechanism
CEEPA:	Centre for Environmental Economics in Africa
CER:	Certified Emission Reduction
CGIAR:	Cooperation Group for International Agricultural Research
CH₄:	Methane
COMESA:	Common Market for Eastern and Southern Africa
CO₂:	Carbon Dioxide
COP:	Conference of the Parties
CSIR:	Centre for Scientific and Industrial Research
CSO	Civil Society Organisation
DFID:	Department For International Development
DWAF:	Department of Water Affairs (South Africa)
EBRD:	European Bank for Reconstruction and Development
EGS:	Environmental Goods and Services
EIB:	European Investment Bank
ERU:	Emission Reduction Unit
EU ETS:	European Union Emission Trading Scheme
FANRPAN:	Food, Agriculture and Natural Resources Policy Analysis Network
FAO:	Food and Agriculture Organisation
GEF:	Global Environment Fund
GHG:	Greenhouse Gas
GNI:	Gross National Income
ICRAF:	International Centre for Research in Agro-Forestry
IDRC:	International Development Research Centre
IFAD:	International Fund for Agricultural Development
IFC:	International Finance Corporation
IFPRI:	International Food Policy Research Institute
IPCC:	Intergovernmental Panel on Climate Change

IPR:	Intellectual Property Rights
JI:	Joint Implementation
LDCF:	Least Developed Countries Fund
LULUCF:	Land Use, Land-Use Change, and Forestry
MDG:	Millennium Development Goals
MET:	Ministry of Environment and Tourism (Namibia)
MTSP:	Medium-Term Strategic Plan
N:	Nitrogen
NAPA:	National Adaptation Plans of Action
NEPAD:	New Partnership for Africa's Development
NDFU:	North Dakota Farmers Union
NMS:	National Meteorological Services
N₂O:	Nitrous oxide
O₃:	Ozone
ODA:	Overseas Donor Assistance
pH:	Power of Hydrogen (pH is a measure of the acidity or basicity of a solution)
PPCR:	Pilot Programme for Climate Resistance
PRSP:	Poverty Reduction Strategy Papers
REDD:	Reducing Emissions from Deforestation and Degradation
RISDP:	Regional Indicative Strategic Development Plan
SACAU:	Southern Africa Confederation of Agricultural Unions
SADC:	Southern African Development Community
SPA:	Strategic Plan on Adaptation
SRES:	Special Report on Scenarios
UN DESA:	United Nations Department of Economic and Social Affairs
UNECA:	United Nations Environmental Commission for Africa
UNEP:	United Nations Environment Programme
UNFCCC:	United Nations Framework Convention on Climate Change
UNISDR:	United Nations International Strategy for Disaster Reduction
USD:	United States Dollars
US EPA:	United States Environmental Protection Agency
WFP:	World Food Programme
WMO:	World Meteorological Organisation
WTO:	World Trade Organisation

Executive Summary

Climate change is affecting agriculture in Southern Africa and farmers need to be equipped to deal with it. This discussion paper aims to provide the Southern African Confederation of Agricultural Unions with information on climate change to enable the organisation and its members to address the most pressing climate change issues for agriculture.

Human activities such as the burning of fossil fuels, changes in land use and deforestation release greenhouse gases into the atmosphere. The main anthropogenic greenhouse gases are carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (N₂O). The increasing concentration of greenhouse gases in the atmosphere disturbs the Earth's natural temperature control mechanism resulting in the warming of the Earth's atmosphere – a phenomenon commonly referred to as 'global warming'. This warming in turn disrupts the Earth's climate system resulting in climate change. The effects of climate change include changes in wind and precipitation patterns, increase in the frequency of climatic extremes including heat waves and heavy precipitation. The changes set in motion by past human activities are so significant that climate change is already a reality and it will continue to cause impacts in the future.

Agriculture, due to its dependence on environmental conditions, is one of the human activities that will be most affected by climate change. However, it is also one of the human activities that contribute to climate change because of the greenhouse gases it produces. Agriculture accounts for between 10% and 20% of the total anthropogenic greenhouse gases, including agricultural methane emissions, which emanate primarily from ruminant livestock; manure decomposition under anaerobic conditions and wetland rice cultivation; and nitrous oxide and carbon dioxide emitted by agricultural soils. The conversion of natural ecosystems such as forests or grasslands to cultivated systems is also responsible for significant carbon dioxide emissions. The increasing demand for food to feed a growing population in many parts of the world means that greenhouse gas emissions from agriculture will continue to increase. Agricultural emissions can, however, be controlled through the application of appropriate management practices, such as a reduction in deforestation and wildfires, use of more efficient crop varieties, better soil management, improved nutrition of ruminant livestock and efficient management of livestock waste. The sector can also contribute to the reduction of atmospheric greenhouse gases through carbon sequestration.

It is projected that agricultural production, which gives access to food in many African countries, will be severely compromised by climate change. Climate change may result in reduced crop yields and agricultural productivity because of increases in intense storms that wash away topsoil, higher incidences of pests, limited availability of water, exacerbation of drought periods and reduction in soil fertility. The negative impacts of climate change are expected to be especially severe for small-scale farmers due to the many structural difficulties they face. Climate change is already affecting agriculture in southern Africa, with farmers in different countries reporting climate-induced disruptions to farming and declining crop yields.

Climate change can be addressed through mitigation and adaptation. Mitigation aims to lower the concentration of greenhouse gases in the atmosphere, either by reducing the sources of greenhouse gasses or by removing them from the atmosphere. Adaptation, on the other hand, comprises actions

to reduce vulnerability or enhance resilience to climate change. Both mitigation and adaptation apply to the agricultural sector. As previously mentioned, agriculture can be used to abate greenhouse gas emissions through actions such as improving livestock and manure management and improving agronomic practices such as nutrient use efficiency, tillage, efficient crop and pasture management and residue management to both reduce emissions and increase carbon dioxide removal through photosynthesis. Adaptation options in agriculture include using crop varieties that can withstand heat and moisture stress, improved water management practices, altering the location or timing of cropping activities and diversifying livelihoods. Farmers in southern Africa are already adapting to climate change by modifying their agricultural practices to suit the changing climatic conditions. For adaptation to be sustainable, it should not only focus on reacting to climate change, but should aim to build farmers' adaptive capacity in addition to agriculture's climate resilience. Adaptation would therefore need to also address other factors, including lack of inputs, limited access to information, security of tenure, etc., which affect the agricultural sector in the region.

There are a number of initiatives currently addressing climate change, ranging from the local to the global planning levels. At the global level, the United Nations Framework Convention on Climate Change (UNFCCC) and the Intergovernmental Panel on Climate Change (IPCC) are key players. The IPCC is an authoritative source of climate change information used to inform climate change decisions. The UNFCCC is an international environment treaty of which most countries are signatories. The Kyoto Protocol, an international agreement linked to the UNFCCC, sets binding greenhouse gas emission targets for developed countries and provides market based mechanisms (e.g. carbon trading) to allow countries to meet their targets through its Emissions Trading mechanisms: the Clean Development Mechanism (CDM) and Joint Implementation (JI). These mechanisms allow for compensation for investing in greenhouse gas emission reduction projects – either in developed or developing countries. There are provisions in the Kyoto Protocol for trading in emission reductions generated through agriculture, forestry and other land use activities. The Kyoto Protocol will expire in 2012 and negotiations for a new global treaty to take effect upon its expiry are under way. They will culminate in talks in Copenhagen in December 2009.

African countries have generally not been active in the global carbon market, with Africa accounting for only 1.4% of carbon trading activities through the CDM. Agricultural projects also represent a very small proportion of the CDM funded projects. Yet Africa, due to its agricultural and land use potential, could contribute significantly to the abatement of greenhouse gas emissions. Through this mechanism, Africa could – while gaining in the process much-needed funds for development – develop an African response to climate change, which is projected to impact the continent severely. Factors such as inability to meet some of the requirements of the CDM, lack of technical capacity, and high transaction costs of participating in the CDM have been barriers to Africa's participation in the carbon trade.

In Africa, the New Partnership for Africa's Development (NEPAD) and the Common Market for Eastern and Southern Africa (COMESA), in partnership with different organisations, are engaged in various activities to address climate change. COMESA is spearheading initiatives to address the challenges that constrain African agricultural and forestry projects from participating in the CDM and to promote the acceptance of agricultural and land use projects into the world's carbon markets. There are also several NGOs, aid agencies, UN agencies, development agencies, academic and research institutions addressing climate change as it relates to agriculture and forestry at different levels in southern Africa. Farmers should also actively engage in these initiatives.

There are climate change-related opportunities for agriculture in southern Africa, especially in the conversion of degraded lands into well-managed agro-forestry systems. Although there are opportunities to earn credits for afforestation, reforestation, agro-forestry, reduced tillage, and other agricultural activities that increase carbon sequestration, this market has not been fully captured in Africa. This is due to constraints such as the absence of cost-effective measurement and monitoring systems for agricultural projects, weak institutional capabilities and the slow adoption of agro-forestry and other strategies for sustainable land management.

The agriculture sector in southern Africa needs a comprehensive approach to address climate change, which would need to include long-term adaptation strategies, building climate change resilience and ensuring that initiatives to address climate change reach all farmers – including the most vulnerable. Dissemination of high-quality information on climate change to all agricultural stakeholders, particularly information that is relevant and understandable to all farmers, is key to addressing the challenges posed by climate change to agriculture in the region. It is also important to address capacity and resource constraints so as to adequately respond to climate change in Africa, including the issues relating to the carbon trading in the agriculture sector. Due to the pervasive impacts of climate change, the mainstreaming of climate change into all aspects of agricultural planning, as well into planning for its related sectors, is necessary.

1. Introduction

The Southern African Confederation of Agricultural Unions (SACAU) is an organisation that represents farmers unions in southern Africa. The organisation is recognised as a main dialogue partner on agricultural matters for the two principal regional economic communities in southern Africa, namely the Southern African Development Community (SADC) and the Common Market for Eastern and Southern Africa (COMESA), as well as for other international institutions and agencies. To participate effectively in the dialogue processes and to influence policy and programme discussions pertaining to agriculture, SACAU has undertaken a programme of formulating policy positions on various fundamental issues affecting agriculture in the region. Climate change is one of these issues, and the present discussion paper aims at providing relevant information on climate change to enable farmers' representatives in the region to better understand the phenomenon as it relates to agriculture and eventually establish positions to address the most pressing issues for the agricultural sector in the region.

Climate change requires urgent attention as it is already seriously affecting agriculture in the region (Boko *et al.* 2007), and will continue to do so into the future. On the international climate change landscape, negotiations are underway to define rules for a climate change treaty to replace the Kyoto Protocol on its expiry in 2012. In Africa, COMESA and other regional initiatives are involved in climate change dialogue at the regional level and in global negotiations to secure African farmers' participation in the carbon trade. It is imperative that key stakeholders, such as SACAU and its members, contribute to the regional dialogue that in turn contributes to the global negotiations.

The majority of farmers in southern Africa are, however, ill prepared to address the complex issues pertaining to climate change. A lack of awareness and understanding prevents them from effectively participating in the on-going discourses on climate change, adopting positions that ensure maximum benefits from the global reforms and from taking action to secure their future from the serious threats that climate change poses to the sector. It is therefore crucial that farmers in southern Africa are well informed with regards to climate change issues and are empowered to develop positions and concrete proposals, particularly with respect to adaptive farming practices and risk management.

This discussion paper was developed from a study commissioned by SACAU and executed by the South African Centre for Scientific and Industrial Research (CSIR). This study was based on a desktop review and interview data collection about climate change and its implications for farmers in southern Africa, and was further enriched by a conference involving SACAU members, held in April 2009.

This paper is structured as follows: Section 2 defines climate change and its causes; Section 3 outlines the contribution of agriculture to climate change; Section 4 describes the implications of climate change for agriculture in southern Africa; Section 5 presents possible responses to climate change through mitigation or adaptation interventions; Section 6 provides an overview of institutions and initiatives addressing climate change, emphasising on the opportunities for agriculture in southern Africa; and Section 7 highlights southern Africa's agricultural opportunities arising from climate change; and Section 8 concludes by highlighting lessons learned for southern African agriculture to prepare for a future affected by climate change. A glossary of terms is

provided at the end to assist in getting familiar with all the technical, scientific, legal and economic jargon that is used in the vast and complex area of climate change.

2. Defining Climate Change and its Causes

2.1 What is climate change?

Climate change is one of the most topical environmental issues of this century. The term 'climate change' could mean different things to different people in different contexts. The Intergovernmental Panel for Climate Change (IPCC), a scientific intergovernmental body set up by the World Meteorological Organisation (WMO) and the United Nations Environment Programme (UNEP) to provide decision-makers and others interested in climate change with an objective source of information about climate change, defines climate change as:

'...any change in climate over time, whether due to natural variability or as a result of human activity' (IPCC 2007a, p.21).

The United Nations Framework Convention for Climate Change (UNFCCC), an international environmental treaty defines climate change as:

'...change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable periods' (UNFCCC 1994, Article 1).

Other common use definitions of climate change include:

'...changes in the Earth's climate, especially those produced by global warming' (en.wiktionary.org/wiki/climate_change 2009);

'...any significant change in measures of climate (such as temperature, precipitation or wind) lasting for an extended period (decades or longer)' (http://www.gogreenva.org/?/green_glossary 2009).

This document uses the UNFCCC definition of climate change.

Variations in climate are a natural phenomenon. The Earth's climate is not static and has changed many times during the planet's history, with events ranging from ice ages to long periods of warmth, that are influenced by factors such as volcanic eruptions, changes in the Earth's orbit, and the amount of energy released from the sun (US EPA 2009). Human activities that change the composition of the atmosphere, such as burning of fossil fuels, deforestation and other activities, also cause climate change. Of particular concern today is the fact that changes in the Earth's climate are occurring more rapidly than in the Earth's previous experiences. Moreover, unlike previous climate changes, the current climate change has a clear man-made influence.

The term 'climate change' has sometimes been used interchangeably with the term 'global warming'. There is, however, a clear distinction between 'climate change' and 'global warming'. While 'global warming' refers to an increase in the temperature of the Earth's atmosphere, 'climate change' refers to changes in measures of climate in addition to temperature (US EPA 2009). Commonly, 'global warming' refers to the warming that can occur as a result of increased

emissions of green house gases from human activities (see section 2.2), which can contribute to changes in climate patterns.

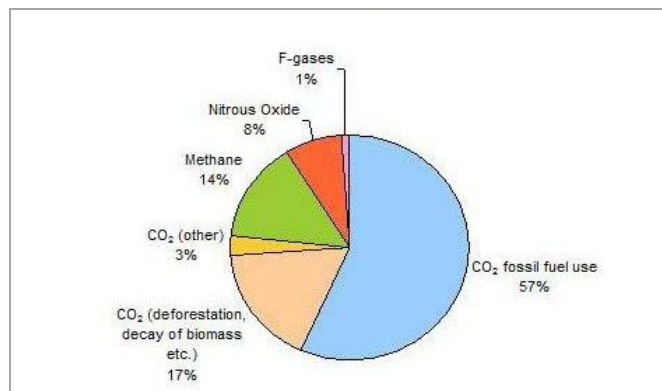
2.2 How and why is climate change happening?

The Earth's atmosphere is central to the phenomenon of climate change. The atmosphere is mainly composed of two gases nitrogen (N₂) and oxygen (O₂) (together comprising 98% of the atmosphere). Argon, neon, helium, krypton, water vapour, carbon dioxide (CO₂), ozone (O₃), methane (CH₄) and nitrous oxide (N₂O) are other components. Water vapour, carbon dioxide, ozone, methane and nitrous oxide are referred to as greenhouse gases (GHGs), and are central to the Earth's natural temperature control system. When solar radiation hits the Earth, approximately one third is immediately reflected back into space. The atmosphere, land and the oceans absorb the remainder of the radiation, with land and the oceans absorbing the majority of the radiation. This absorbed solar radiation warms the Earth's surface, which then emits infrared radiation. The atmosphere's greenhouse gases trap some of this infrared radiation – the remainder passing through the atmosphere to the space – thus warming the atmosphere by creating a natural greenhouse effect (UNEP/GRID-Arendal 2002a). Greenhouse gases are necessary for life on Earth, as they keep the Earth's surface warmer than it otherwise would be: without this natural greenhouse effect, the average temperature of the Earth would be -18°C instead of + 15°C, and the Earth would not be able to support life as we know it.

Human activities, such as the burning of fossil fuels in automobiles and industrial processes, or changes in land use, such as deforestation, also release greenhouse gases (referred to in this case as anthropogenic emissions) into the atmosphere. The concentration of greenhouse gases has drastically increased since 1750, with the onset of the industrial revolution in Europe; it has also increased in relation to global population growth. At the same time, the average temperature of the Earth has increased. There is now a large scientific consensus that the continued anthropogenic emissions of greenhouse gases into the atmosphere has been increasing the concentration of these gases in the atmosphere to the extent that it is the cause of the current global warming (IPCC 2007b).

The main anthropogenic emission is carbon dioxide, which accounts for about 80% of total greenhouse gas emissions, the other major gases being methane (14%) and nitrous oxide (8%) (see Figure 1).

Figure 1: Global anthropogenic greenhouse gas emissions

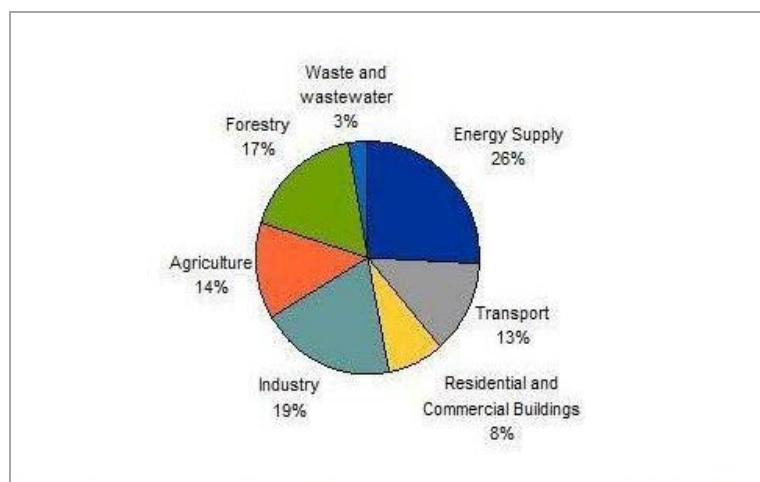


Source: IPCC (2007b)

The increases in carbon dioxide concentrations in the Earth's atmosphere are primarily due to fossil fuel use and land uses change, such as deforestation and conversion of land to agriculture, while the increased concentrations of methane and nitrous oxide are primarily due to agricultural activities (IPCC 2007b). During the past 20 years, about three-quarters of anthropogenic emissions came from the burning of fossil fuels (*ibid*).

Globally, the primary sources of greenhouse gas emissions are the energy supply sector (26%), industry (19%) and forestry (17%). Agriculture and transportation account for 14% and 13% of total emissions respectively (see Figure 2).

Figure 2: Global anthropogenic emissions of greenhouse gases by sector



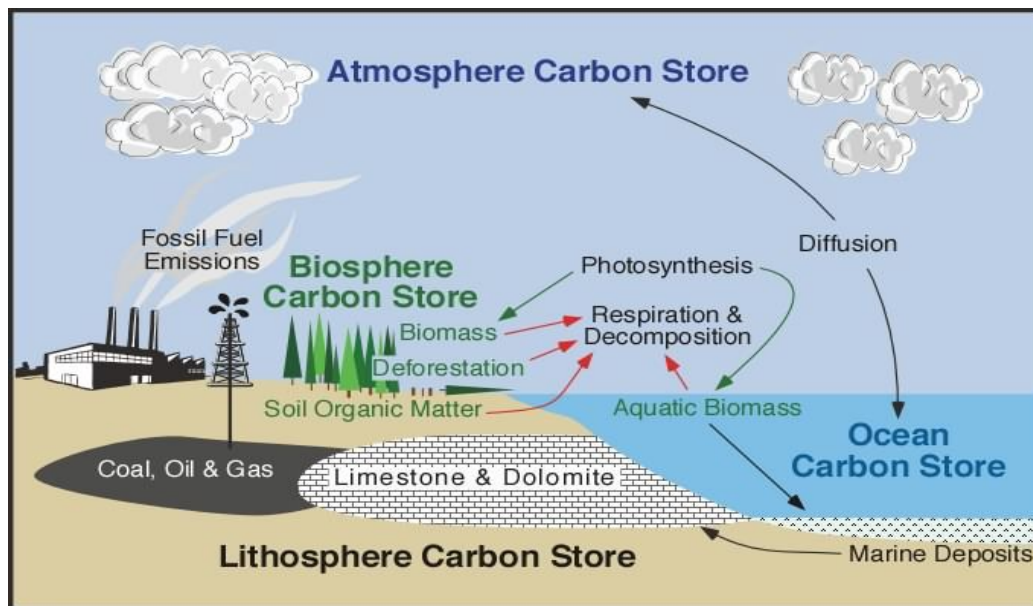
* Forestry includes deforestation

Source: IPCC (2007b)

The amount of carbon dioxide in the atmosphere is naturally regulated through numerous processes, known on the whole as the 'carbon cycle' (Figure 3). The carbon cycle is the process by which carbon moves between the Earth's atmosphere, the oceans, the vegetation and soils, and fossil fuels. In the cycle, there are four main sinks or stores of carbon: plants, oceans, the terrestrial biosphere (which is the soil including its living and non-living organic material, such as soil carbon

and freshwater bodies) and sediments (sediments include fossil fuels, such as coal and oil, and rocks, such as limestone that are used in cement manufacture), which comprise the lithosphere. There are various processes through which carbon is exchanged between these sinks.

Figure 3: The Carbon Cycle



Source: Pidwirny (2006)

Carbon exists in the atmosphere as the gas carbon dioxide (CO₂). Carbon is removed from the atmosphere through photosynthesis and absorption by oceans, where the CO₂ dissolves and is converted into biomass by marine plants. Atmospheric carbon dioxide is also absorbed through plant leaves and is incorporated as carbon into the biomass (the living parts) of plants, trees and agricultural crops through a process known as carbon sequestration. Roughly half of this biomass is carbon. Some of this carbon goes into soils when plants and roots decay. Carbon is then returned to the atmosphere as CO₂ through various processes including:

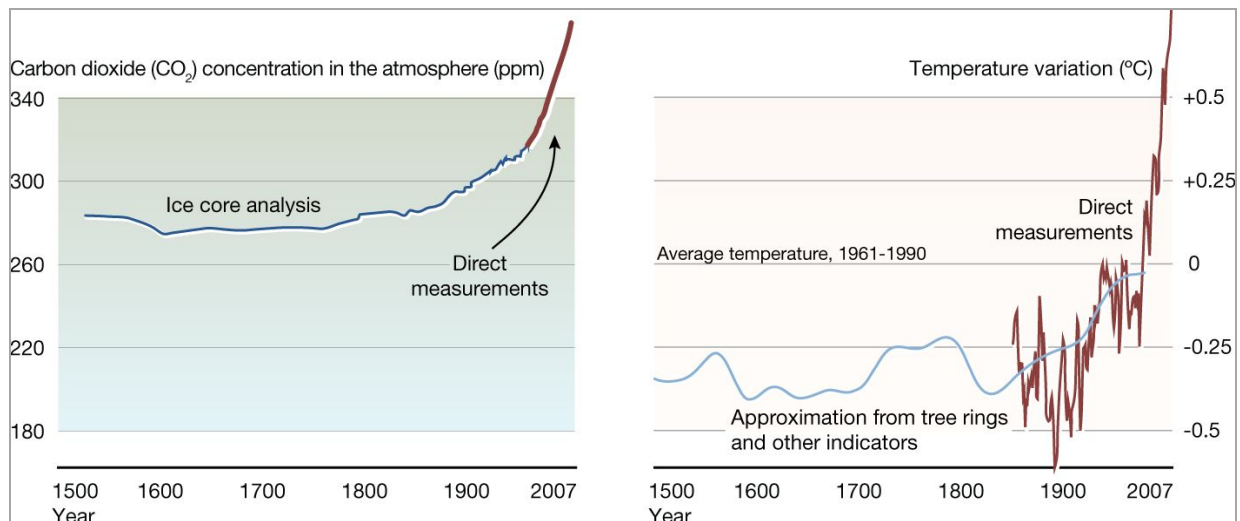
- Plant and animal respiration;
- Decay of plant and animal matter;
- Burning of organic materials, such as plants;
- Burning of fossil fuels, such as coal and oil; and
- Industrial process, such as the manufacturing of cement (burning of limestone releases carbon dioxide).

The main ways in which carbon stored in forests and soils can return to the atmosphere is through biomass decay and burning, or when agricultural tillage practices stir up soils. This often happens when land under natural vegetation is cleared for agriculture.

As previously mentioned, scientists have shown that global atmospheric concentrations of carbon dioxide, methane and nitrous oxide have increased markedly as a result of human activities since 1750 and now far exceed the pre-industrial values (IPCC 2007b). Carbon dioxide from human activities, such as fossil fuel burning, is being released faster than the absorption capacities of the oceans, vegetation and soils, thus allowing an accumulation of carbon dioxide in the atmosphere.

As the carbon dioxide concentration grows, it increases the degree to which the atmosphere traps incoming solar radiation. Thus, the increase of CO₂ brought into the atmospheric component of the carbon cycle through human activities upsets the natural regulatory processes and amplifies the Earth's natural greenhouse effect. This induces the phenomenon of 'global warming', wherein global surface temperatures increase as atmospheric CO₂ accumulates (Figure 4).

Figure 4: Historical trends in carbon dioxide concentrations and temperature



Source: UNEP/GRID-Arendal - Hugo Ahlenius (2007)

Rising temperatures may, in turn, produce climatic changes, including changes in precipitation patterns, and changes in sea levels. The type, frequency and intensity of extreme events such as tropical cyclones, floods, droughts and heavy precipitation events are expected to rise even with relatively small temperature increases (UNFCCC 2007). However, scientists are not certain the extent to which the Earth's climate will change, the rate of change, or what the exact effects of these changes will include (US EPA 2009).

2.3 What are the threats/risks associated with climate change?

The phenomenon of climate change is set to become part of life on Earth, as current trends are unlikely to significantly change in the near future. According to the IPCC (2007b, p. 7), 'greenhouse gases at emissions at or above current rates would cause further warming and induce many changes in the global climatic system during the 21st century, that would be very likely larger than those observed during the 20th century'. Climate change is projected to have numerous and varied impacts on the environment and human lives. According to the IPCC (2007b, p.18), some of the changes that climate change will bring include:

- Changes in wind patterns and precipitation;
- Contraction of snow cover and sea ice;
- Very likely increase in frequency of hot extremes, heat waves and heavy precipitation;
- Likely increase in tropical cyclone intensity; and
- Precipitation increases in high latitudes and likely decreases in most subtropical land regions.

Climate change is projected to affect water availability, ecosystems, food production, coastal areas, and human health, thus affecting all natural and man-made systems to some extent. Large-scale migration and relocation are likely to increase and competition over scarce resources such as food and water will become fiercer, which poses a serious threat to global security. The IPCC report specifies that the effects of climate change will be mixed across regions and will vary depending on the extent of adaptation, rate of temperature change and socio-economic conditions (IPCC 2007b). Some systems, sectors and regions are likely to be more affected than others, but the impacts will vary depending on system sensitivity and adaptive capacity.

Water resources in dry regions in the tropics will be affected by changes in rainfall and evapotranspiration, which means that agriculture will be largely affected by reduced water availability in low latitude areas. The IPCC (2007b) projects that by 2020, between 75 and 250 million people will be exposed to increased water stress as a consequence of climate change, which implies negative local impacts on food production by small-scale farmers in particular. Agricultural production, and particularly food crop production, is projected to be severely compromised in many African countries, with yields from rain-fed agriculture falling by as much as 50% in some countries. As scarcity of fresh water threatens livelihoods linked to agriculture and forestry in an estimated 40% of rural areas worldwide, the heightened threat from climate change is increasing the likelihood of large-scale migration and relocation. Low lying coastal areas and small islands will be affected by the threat of sea level rise and increased risk from extreme weather events, which exposes both large populations and infrastructure to projected climate change impacts (IPCC 2007b).

The least developed countries are increasingly expected to face climate-related threats such as droughts, floods and hurricanes. Their economic and trade specialisation in sectors like agriculture, fisheries and tourism, which are major impact-takers under climate change, renders them even more vulnerable to such natural disasters.

3. Agriculture's Contributions to Climate Change

3.1 Agriculture's negative contribution to climate change

Since 1961 global agricultural production has steadily increased at an average annual growth rate of 2.3%, driven by an increasing population, technological change, public policies and economic growth (UNFCCC 2008). This expansion of agriculture comes at an environmental cost, particularly in terms of its contributions to GHGs (GEF 2007a). Agricultural activities are indeed responsible for the release of significant amounts of carbon dioxide (CO₂) methane (CH₄) and nitrous oxide (N₂O) into the atmosphere. Although estimates of agriculture's contribution to GHG vary, the contribution is known to be significant. Lokupitiya and Paustian (2006) estimate that agriculture contributes 20% of the total anthropogenic GHG emissions, while UNFCCC (2008) and IPCC (2007b) place estimates between 10 and 12% and 14% respectively. Moreover, these estimations are from land uses only. When the other parts of the supply chain (e.g. transportation, storage, etc.) are included, the figure increases to one-third of total emissions (ICTSD 2008). In addition, as the global population growth continues, accompanied by an increasing demand for food, changing diets and trade expansion, emissions from the agricultural sector are expected to continue to increase in the future.

Some of the origins and main contributors of GHGs from key agricultural activities are (UNFCCC 2008):

Enteric fermentation

Ruminant animals (cattle, buffalo, sheep, goats, and camels) produce significant amounts of methane as part of their normal digestive processes and are the largest source of methane from human-related activities (US EPA, 2006). In the rumen (i.e. large fore-stomach), microbial fermentation, referred to as enteric fermentation, converts feed into products that can be digested and utilised by the animal. This microbial fermentation process produces methane as a by-product, which can be exhaled by the animal. Enteric emissions can, to some degree, be managed, as they depend on the average daily feed intake, the percentage of food converted to methane, genetic characteristics, and environmental conditions – all factors that can be managed. Enteric emissions are, however, likely to increase in the coming decades, as global demand for meat and milk are expected to increase from 229 to 465 million tonnes and 580 to 1043 million tonnes respectively by 2050, which will almost double the amount of methane produced by livestock (Trivedi 2008).

Manure management

The decomposition of manure under anaerobic conditions (i.e. in the absence of oxygen) during storage and treatment produces significant quantities of methane. These conditions occur most readily when large numbers of animals are managed in a confined area (e.g. dairy farms, beef feedlots, and pig and poultry farms), and where manure is disposed of using liquid-based systems (IPCC 2006). Methane emissions from manure can, however, be minimised through management. When manure is handled as a solid (e.g. stored in stacks or piles) or when it is deposited on pastures and rangelands, it tends to decompose under more aerobic conditions (i.e. in the presence of oxygen) and produces less methane (Eggleston *et al.* 2006). Under anaerobic conditions, controlling the temperature and the retention time of manure in storage units also greatly affects the amount of methane produced.

Soils

Agricultural soils emit carbon dioxide and nitrous oxide as a result of management practices. Nitrous oxide is produced in soils naturally through the microbially driven soil processes of nitrification and denitrification. Increasing nitrogen inputs, such as manure and nitrogen fertilisers, into the soil stimulates nitrification and denitrification (Lokupitiya and Paustian 2006). Nitrogen additions by grazing animals (in the form of dung and urine) can also stimulate nitrous oxide emissions. Similarly, land-use change enhances nitrous oxide emissions if associated with heightened decomposition in soil organic matter and subsequent nitrogen mineralisation (UNFCCC 2008). If more fertiliser or manure is applied to the soil than can be taken up by plants, the unused portion can be lost as nitrous oxide. According to Lokupitiya and Paustian (2006), the anthropogenic increases in nitrous oxide emissions from agriculture are mainly the result of fertiliser and manure use. Increasing nitrogen use efficiency through management can reduce nitrous oxide emissions.

Carbon dioxide emissions occur naturally from the soil as a result of the decomposition of soil organic matter and plant root respiration. Soil micro-organisms break down the soil's organic matter, partially converting it into carbon dioxide, which is released into soil pore spaces and

eventually into the atmosphere. Plant root respiration also produces carbon dioxide that contributes to soil carbon dioxide emissions. Factors such as soil texture, temperature, moisture, pH and nitrogen content of the soil influence the rate of decomposition and root respiration and therefore the rate of carbon dioxide emission (Rastogi *et al.* 2002). Agricultural practices, such as tillage and the application of nitrogenous fertilisers, also increase the rate of soil organic matter decomposition and hence the carbon dioxide released from soils. Tillage breaks down soil aggregates, helps to mix soil and organic particles and improves water infiltration in soils thus creating an environment favourable for micro-organism activity and accelerated decomposition (*ibid*). The application of nitrogenous fertiliser also affects carbon dioxide emissions from soils by providing nitrogen to crops and microbes, thus increasing their growth and respiration. Nitrogenous fertilisers also influence soil pH which influences microbial activity.

Rice cultivation

Wetland rice fields are a major source of methane emissions. In flooded conditions, such as wetland environments and paddy rice productions, a significant portion of the decomposing organic matter and soil organic matter is returned to the atmosphere as methane. Flooding cuts off the oxygen supply from the atmosphere resulting in anaerobic decomposition of organic soil matter, with methane as a major end product of the process. Estimates of global methane emissions indicate that rice cultivation presently accounts for 6 to 29% of total anthropogenic methane emissions (Neue 1993), and that these figures will continue to increase, as by 2020 the world will need to produce 350 million tons more rice per year to feed an anticipated three billion more people than in 1992 (*ibid*). Levels of methane emissions vary with soil conditions, production practices and climate (Adhya *et al.* 2000; Chareonsilp *et al.* 2000; Corton *et al.* 2000; Wang *et al.* 2000; Wassmann *et al.* 2000). Most of the methane from rice cultivation emanates from Asia, where about 90% of the world's harvested area of rice paddies is located (UNFCCC 2008). In southern Africa, small-scale paddy rice cultivation takes place in Malawi, Mozambique, Tanzania, Zambia and Zimbabwe; Madagascar, where rice production is done on a large-scale, is southern Africa's most significant rice paddy cultivator. Because of the limited scale of production, methane emissions from rice cultivation in southern Africa can be considered to be insignificant.

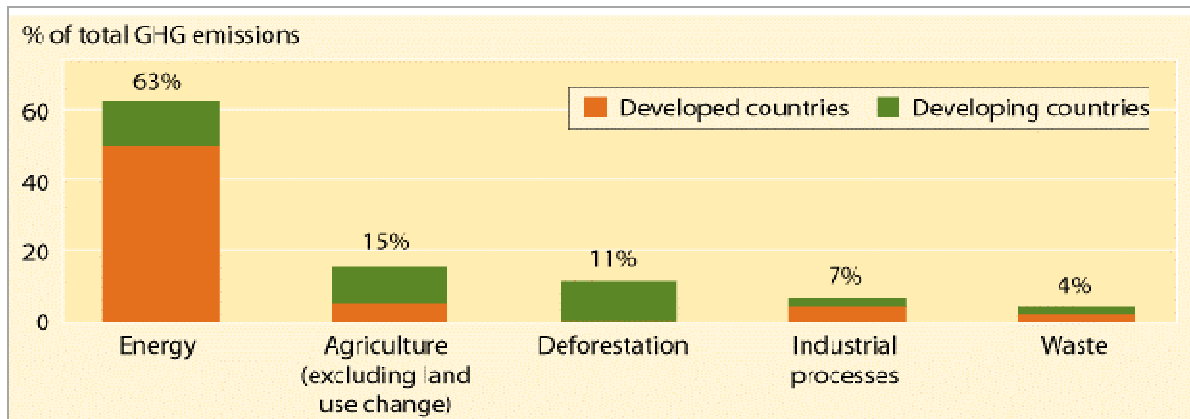
Land-use change

The conversion of natural or semi-natural ecosystems, especially forests to agriculture (cropland or pasture land), is responsible for greater emissions of carbon than any other land-use change (Lambin and Geist 2006). Emissions from the conversion of natural ecosystems to agriculture primarily result from carbon stock losses through the decomposition or burning of biomass from the converted land. In addition, agricultural land uses emit carbon dioxide through the decomposition of organic soil matter and crop residues. There are some additional emissions from fossil fuels associated with mechanised land clearing, but these emissions are generally a very small portion of the total carbon dioxide emitted by agriculture (UNFCCC 2008). Fire is often used as a land-clearing tool; in addition to carbon dioxide, this can lead to both nitrous oxide and methane emissions, depending on the oxygenation (i.e. availability of oxygen) of the burn and the nitrogen content of the vegetation (Scholes 1995). Finally, there are emissions associated with management after land-use change (e.g. nitrous oxide emissions associated with fertiliser use). These emissions represent a small fraction of emissions and most emissions from land-use change are from carbon stock losses.

3.2 Comparative emission levels and trends

The agricultural sector is thus a major emitter of GHGs. In 2005, agriculture accounted for 10 to 12% of the total global anthropogenic emissions of GHGs, with 47% of total anthropogenic methane emissions and 58% of anthropogenic nitrous oxide emissions coming from the sector (IPCC 2007b). About 80% of the emissions from agriculture come from developing countries (Helmuth *et al.* 2007); their global contribution is even higher if the estimated emissions include deforestation and the burning of vegetation in developing countries (see Figure 5).

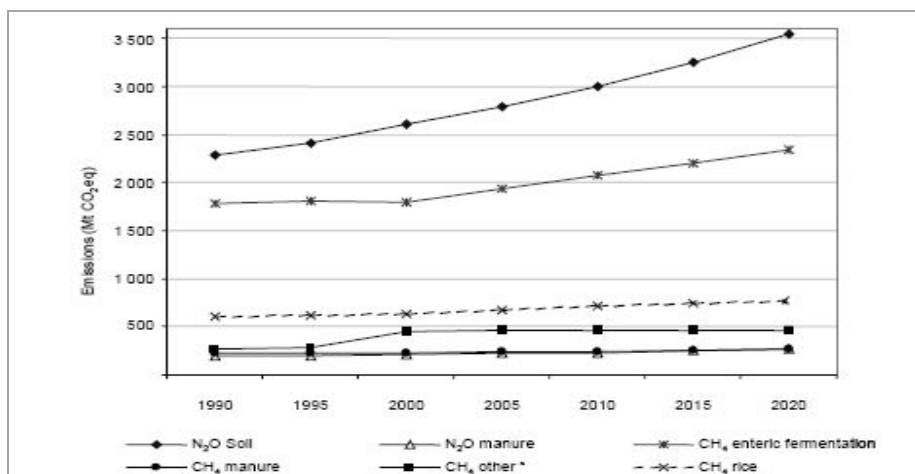
Figure 5: GHG emissions by sector in developed and developing countries



Source: World Bank 2008a, p. 201.

Between 1990 and 2005, global emissions of non-carbon dioxide GHGs from agriculture increased by 18% (see Figure 6). Apart from methane from biomass burning, the highest increase in emissions in 2005 was nitrous oxide from soil (up 22% from 1990 levels). Nitrous oxide emissions from manure management and methane emissions from rice cultivation both increased by 12%. IPCC projections indicate that nitrous oxide emissions will increase by about 50% relative to 1990, and, if demands for food increase and diets shift as projected, further escalation of annual emissions of GHG from agriculture will take place (IPCC 2007b).

Figure 6: Trends for global agricultural non-CO2 greenhouse gas emissions by source, 1900-2020

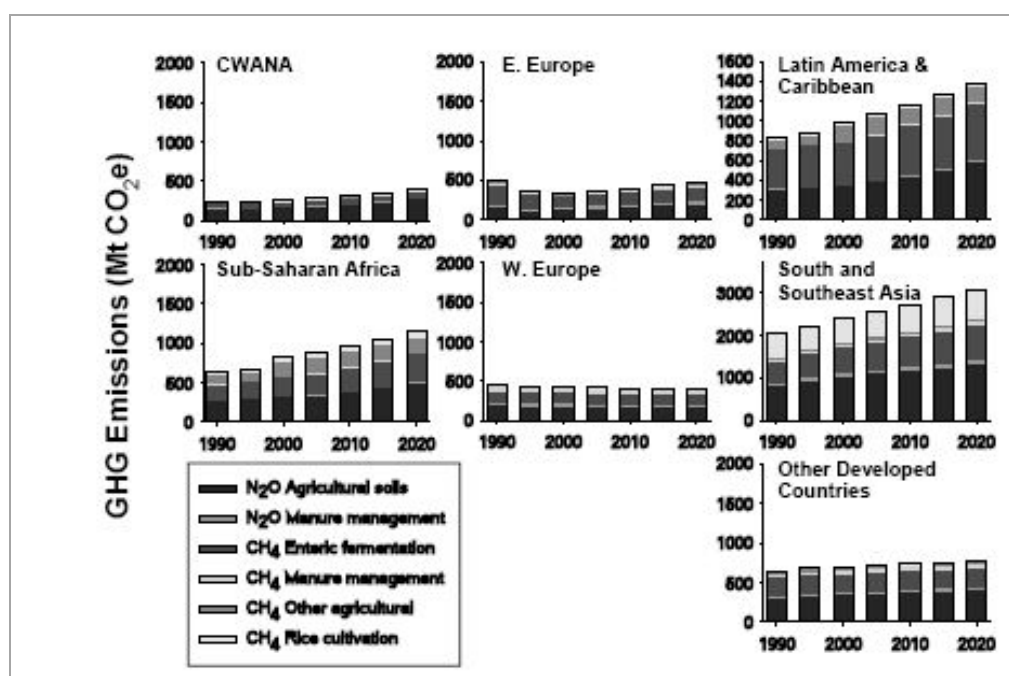


* 'CH₄ other' refers to biomass burning.

Source: United States Environmental Protection Agency, in UNFCCC 2008.

At a regional level, emissions of non-carbon dioxide GHGs are highest in South and Southeast Asia and the Latin American and Caribbean regions (see Figure 7). Middle East, North Africa and sub-Saharan Africa have the highest projected growth in emissions, with a combined 95% increase in the period 1990 to 2006 (US EPA in IPCC 2007b). Between 1990 and 2005, agricultural emissions in developing countries increased by 32%, resulting in these countries being responsible for about 75% of total agricultural emissions in 2005. During the same period, agricultural emissions in developed countries decreased by about 12% (IPCC 2007b). In the absence of mitigation measures, emissions from agriculture are projected to continue to grow in developing countries. According to the IPCC (IPCC 2007b), agricultural N₂O emissions are projected to increase by 35–60% by 2030 due to increased nitrogen fertiliser use and increased animal and manure production (FAO 2003), while methane emissions are expected to increase by 60%. Future trends for all main sources of global non-carbon dioxide GHG emissions are shown in Figure 7.

Figure 7: Regional non-CO₂ greenhouse gas emissions from agriculture, actual and projected, 1990-2020



Abbreviations: CWANA=Central West Asia and North Africa, E. Europe=Eastern Europe, W=Western Europe

Source: United States Environmental Protection Agency in UNFCCC 2008

Southern Africa is one of the regions where emissions are expected to grow rapidly. According to the IPCC (2007b), the rising wealth of urban dwellers in southern Africa is likely to increase demand for livestock products, which will result in both the intensification and the expansion of agriculture into areas that are largely unexploited. The expansion and intensification of agriculture is likely to take place in countries such as South Africa, Angola, Zambia, Democratic Republic of Congo, Mozambique and Tanzania, with a consequent increase in greenhouse gas emissions. As per Figure 7, emissions from Central West Asia and North Africa (CWANA), 'other developed countries' and Eastern Europe are relatively low and are expected to grow at a moderate pace. Emissions are expected to decline in Western Europe (UNFCCC 2008).

Although the dominant sources of non-carbon dioxide GHG emissions are nitrous oxide emissions from soils and methane emissions from enteric fermentation in all regions, each region has other large sources of emissions, particularly methane emissions from rice cultivation in South and Southeast Asia; methane emissions (mainly due to savannah burning in tropical areas) in sub-Saharan Africa and Latin America and the Caribbean; and methane emissions from manure management in Western Europe. Other sources generally represent less than 10% of regional emissions.

3.3 Positive contribution of agriculture to climate change

Although agricultural activities emit greenhouse gases into the atmosphere, agriculture can also contribute to reducing atmospheric carbon dioxide through carbon sequestration. According to the FAO (2007a), the agricultural sector has significant potential for mitigating climate change and a reduction of greenhouse gases through managing ecosystem services, reduction of land use change and related deforestation, more efficient crop varieties, better control of wildfires, improved nutrition for ruminant livestock, more efficient management of livestock waste, organic soil management, conservation agriculture and agro-forestry systems (UNFCCC 2008). The mitigation potential of agriculture is discussed in more detail in section 5.1.

4. Implications of Climate Change for Agriculture in Southern Africa

Most people in southern Africa are dependent on agriculturally based livelihoods; because changes in climate imply changes in agricultural production, this translates into significant impacts on large numbers of people and their livelihoods. About 95% of agriculture in Africa directly depends on rainfall (i.e. it is non-irrigated) (IFAD 2008), which makes African agriculture particularly vulnerable to climate change induced rainfall alterations. The agricultural sector in most developing countries is the sector most at risk from the impacts of climate change, which in turn has serious implications for food security (Commonwealth Secretariat 2006). According to the FAO (2005), in some 54 poor developing countries with a combined population of two billion, of which 450 million are undernourished, production losses due to climate change may drastically increase the number of undernourished people, severely hindering progress in combating poverty and food insecurity. IFAD (2008) estimates that climate change is expected to put 49 million people at risk of hunger by 2020 and 132 million by 2050. The IFAD estimates place the numbers of people exposed to increased water stress caused by climate change at between 75 and 200 million by the year 2020.

4.1 What conditions are likely to result from climate change?

Although it is not possible to precisely predict future climatic conditions, the scientific case for climate change is becoming increasingly well established. Observations already confirm changes in the Earth's climate and show increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising average global sea level (IPCC 2007b). The IPCC (2007b) also notes that 11 of the 12 years between 1995-2006 rank among the warmest years in the

instrumental records of global surface temperature. There is scientific consensus that global land and sea temperatures are warming and will continue to warm whether emissions increase or decrease in the next two decades (IPCC 2007b).

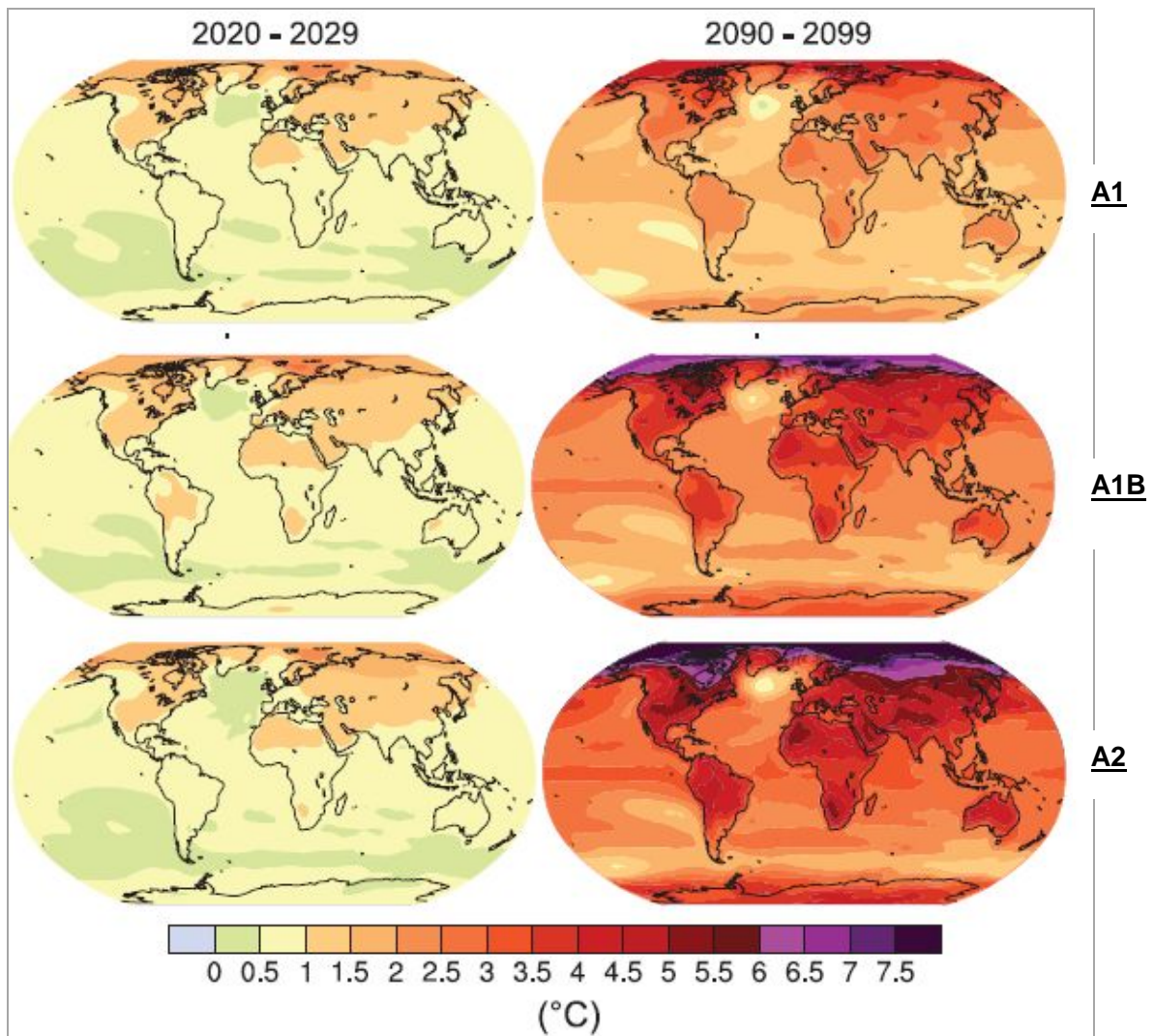
According to Christensen *et al.* (2007), all of Africa is likely to experience temperature increases during this century, with the drier subtropical regions warming more than the moister tropics. While the global average temperature is projected to increase by 0.2°C per decade, temperatures over southern Africa are projected to increase by between 1 and 6°C under different emission scenarios (see Figure 8).

The IPCC climate change projections, based on emission scenarios described in the IPCC Special Report on Scenarios (SRES) (IPCC 2000a), use alternative images of how the future might unfold. The driving forces of future GHG emissions, such as demographic change, economic growth and technological change, underpin these projections. The scenarios were developed using different modelling approaches and exclude any future policies that explicitly address climate change, although other types of policies are encompassed in the scenarios as well. The scenarios depicted in figures 8 and 9 are explained below:

A1: *The A1 storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario family develops into three groups that describe alternative directions of technological change in the energy system. The three A1 groups are distinguished by their technological emphasis: fossil intensive (A1FI), non-fossil energy sources (A1T), or a balance across all sources (A1B) (where balanced is defined as not relying too heavily on one particular energy source, on the assumption that similar improvement rates apply to all energy supply and end use technologies) (IPCC 2000a, p. 9).*

A2: *The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing population. Economic development is primarily regionally oriented and per capita economic growth and technological change more fragmented and slower than other storylines (IPCC 2000a, p. 10).*

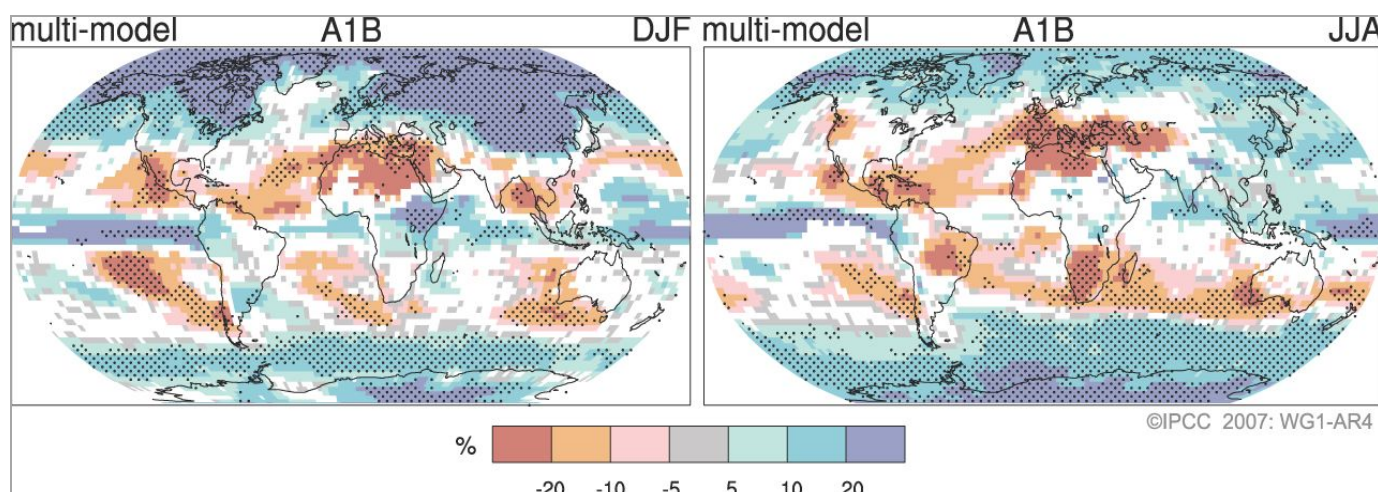
Figure 8: Projected surface temperature changes according to three emission scenarios (B1, A1B and A2) for the early to late 21st century relative to the period 1980 to 1999



Source: IPCC 2007b, p.15

In terms of precipitation, climate model simulations reported by the IPCC indicate large scale drying in much of the subtropics, and an increase (or little change in precipitation) in the tropics, resulting in increased rainfall gradients (Christensen *et al.* 2007). Declines in rainfall are forecasted for much of southern Africa with the extreme west of the region likely to experience reductions of as much as 40% between June and August (see Figure 9). Tropical and eastern Africa may experience a 7% increase in rainfall with east Africa experiencing an overall increase in annual mean rainfall. There is also an expected general increase in weather extremes, such as an increase in the intensity of high rainfall events. The IPCC (2007b) notes that the frequency of heavy precipitation events has increased over most of the land areas. In regions of mean drying, a larger decrease in number of rainy days is expected.

Figure 9: Relative changes in precipitation (%) for the period 2090-2099, relative to 1980-1999¹



Source: IPCC 2007b, p. 6

Widespread changes in extreme temperatures have been observed over the last 50 years. Cold days, cold nights and frost have become less frequent, while hot days, hot nights and heat waves have become more frequent (IPCC 2007b). It is also likely that future tropical cyclones (including typhoons and hurricanes) will become more intense with higher peak wind speeds and heavier precipitation (*ibid*). Observations since 1961 show that the average temperature of the world's oceans has increased, causing sea levels to rise (*ibid*). The global average sea level rose at an average rate of 1.8mm per year from 1961 to 2003, while the total 20th century sea level rise is estimated to be 0.17 m (*ibid*). Both past and future anthropogenic carbon dioxide emissions will continue to contribute to warming and sea level rise for more than a millennium due to the time scales required for the removal of this gas from the atmosphere (*ibid*).

4.2 What are the climate change-related threats for southern African agriculture?

The effects of climate change are already felt in Africa, with an increase in climate change induced-natural disasters observed on the continent (Oxfam 2007). Since the turn of the 21st Century, southern Africa, like many other parts of the world has experienced an increase in climate change related disasters and extreme weather events, such as spells of very high temperatures, torrential rain, flooding and droughts (AfrolNews, 2009).

The agricultural sector is highly vulnerable to climate change (Brown *et al.* 2007). Five main variables related to climate change, i.e. temperature, precipitation, sea level rise, atmospheric carbon dioxide content and incidence of extreme events affect the agriculture insofar as the performance of crops and livestock.

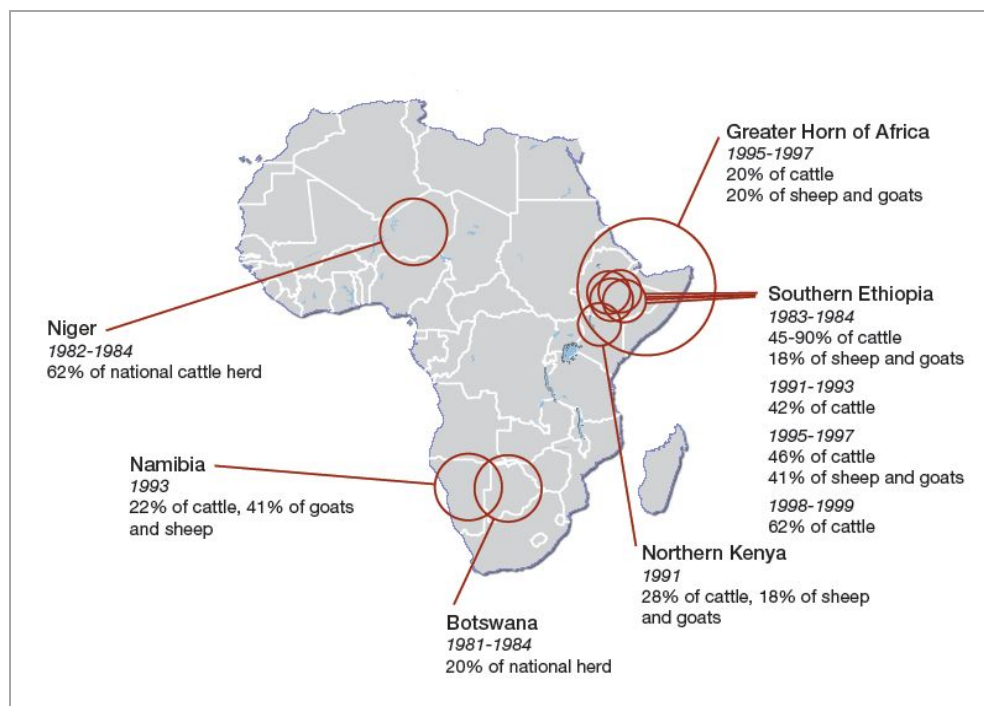
¹ Values are multi-model averages based on the SRES A1B scenario for December to February (left) and June to August (right). White areas are where less than 66% of the models agree with the sign of the change and stippled areas are where more than 90% of the models agree with the sign of the change (IPCC 2007b).

Crop development is related to meteorological factors (Hodges 1991; Challinor and Wheeler 2007): temperature, precipitation, solar radiation and mean annual carbon dioxide concentration in the atmosphere, and the duration of excessive toxic levels of ozone and sulphur dioxide are main variables which affect crop yields in most agricultural regions (Parry *et al.* 1998). These variables are all sensitive to climate change.

In southern Africa, there will be a notable increase of pressure on water resources. Competition will increase for water access, while demand for water – especially in urban areas and the manufacturing sector – is rising and water supply is becoming more and more erratic. The use of surface and ground water through irrigation, which represents an effective buffer against the effect of dryer climatic conditions and upon which commercial farming relies, might become capital intensive, and inaccessible to the majority of farmers (Blignaut 2009).

The expected increase in the frequency of droughts associated with climate change will also have devastating effects on livestock. In the last two decades for example, droughts have decimated large numbers of livestock in Africa (see Figure 10).

Figure 10: Impact of droughts on livestock in Africa



Source: UNEP/GRID-Arendal, 2009.

Climate affects not only the development of agricultural crops and livestock, but also their associated pests, as the proliferation and distribution of weeds, insects, bacteria, fungi and nematodes is responsive to climatic conditions. Higher temperatures, for instance, can reduce insect winterkill and lead to increased rates of infestation, while wet conditions promote the proliferation of bacteria, fungi and nematodes (Rosenzweig *et al.* 2000; Lal *et al.* 2005). Invasive exotic plants could also spread and completely new, or currently latent organisms and species that could be harmful to human health and crop yields could become prevalent (Blignaut 2009).

Based on these threats posed to agriculture as a primary sector, the impacts of climate change in warmer regions such as Africa are generally negative (see Table 1).

Table 1: Possible generalised impacts of climate change on agriculture due to changes in extreme weather and climate events based on projections to the mid to late 21st century

Phenomenon and direction of trend	Likelihood of future trends based on projections for 21 st century using SRES* scenarios	Major projected impacts on agriculture
Over most land areas, warmer and fewer cold days and nights, warmer and more frequent hot days and nights	Virtually certain	Increased yields in colder environments; decreased yields warmer environments; increased insect outbreaks
Warm spells/heat waves. Frequency increases over most land areas	Very likely	Reduced yields in warmer regions due to heat stress; increased danger of wildfire
Heavy precipitation events. Frequency increases over most areas	Very likely	Damage to crops, soil erosion, inability to cultivate land due to waterlogging of soils
Area affected by drought increases	Likely	Land degradation, lower yields/crop damage and failure; increased livestock deaths; increased risk of wildfire
Intense tropical cyclone activity increases	Likely	Damage to crops, windthrow (uprooting) of trees, damage to coral reefs
Increased incidence of extreme high sea level (excludes tsunamis)	Likely	Salinisation of irrigation water, estuaries and freshwater systems

Source: IPCC (2007a, p.18)

*SRES scenarios are the Emissions Scenarios of the IPCC Special Report on Emissions Scenarios (see IPCC 2007a, p. 22 for a full description). In the evaluation of the likelihood of certain outcomes, the associated meanings are: Virtually certain: >99% probability of occurrence; Very likely: 90 to 99% probability and Likely: 66 to 90% probability.

Thus, climate change-induced alterations in the agricultural environment will affect the agriculture sector in southern Africa in the following ways (CEEPA 2002):

- Decrease in agricultural productivity and crop yields as temperature increases; this is most likely to happen in the tropics and subtropics where crops have reached their maximum temperature tolerance.
- Reduction of soil productivity and crop yields as a result of an increase of intense storms that wash away topsoil and soil nutrients.
- Proliferation of pests and diseases under climate change-induced temperature increases and changes in humidity, which also negatively impact crop and animal production.
- Limited water availability due to downward trend in rainfall in southern Africa combined with recurrent droughts, which negatively impact both crop and livestock production.
- Acceleration of organic matter decomposition under increased temperature and reduced soil moisture conditions, which results in reduced soil fertility.

- Heat stress on animals, and impacts of changed climatic conditions on availability and quality of feed, will affect livestock productivity.
- More favourable conditions for the proliferation of vector borne diseases, such as malaria, are projected in some areas in relation with temperature increases and humidity brought on by climate change, and this will negatively impact on the availability of human resources to work in the agricultural sector.

In Africa, the impact of these adverse effects of climate change on agriculture is also exacerbated by the lack of adaptive strategies, which are limited due to the lack of institutional, economic and financial capacity to support such actions. Moreover, although the effects of climate change are expected to be negative for agriculture as a whole, the impacts are expected to be especially severe for small-scale farmers due to the many disadvantages that they face, including poverty, lack of capital and knowledge, and limited alternative livelihood options. Climate change may affect small-scale farmers in the following ways: (Parry *et al.* 1998; Maddison 2006; Shewmake 2008; Dube and Sekhwela 2007):

- Increased likelihood of crop failure;
- Increase in diseases and mortality of livestock, and/or forced sales of livestock at disadvantageous prices;
- Increased livelihood insecurity, resulting in assets sale, indebtedness, out-migration and dependency on food aid; and
- Downward spiral in human development indicators, such as health and education.

Such impacts would aggravate the stresses already associated with subsistence production, such as isolated location, small farm size, limited resources, informal land tenure, etc. and make smallholder farmers particularly risk-prone in the face of climate change (IPCC 2007c).

Furthermore, it is foreseeable that climate change will have a gender-differentiated impact. As women produce 60 to 80% of the food crops in Africa (FAO 1995), any changes in agricultural production as a result of climate change will have considerable effects on them. Because women tend to have less financial, physical and human resources than men, they will have fewer options to respond to the challenges brought by climate change and hence risk becoming poorer and further marginalised (FAO 2008). The gender-differentiated impacts of climate change mainly result from pre-existing inequalities but may also exacerbate these inequalities.

4.3 Experiences of climate change in the agriculture sector in southern African countries

Southern Africa is extremely vulnerable to climate change due to the high poverty levels and heavy reliance on agriculture as a source of livelihoods for the majority of the population (IPCC 2001). There is documented evidence that farmers in different countries worldwide and in southern Africa are experiencing declining agricultural production due to climate change (ActionAid 2008; Giles 2007; WFP 2008; Ziervogel and Taylor 2008). Climate change projections for most countries in southern Africa paint a negative picture for agriculture. Since the beginning of the new millennium, erratic rainfall has led to increased food shortages in southern Africa where droughts devastated maize crops in Lesotho, Namibia, Mozambique, Swaziland, Zimbabwe and South Africa (Mannak 2009), resulting in a shortfall of 2.18 million metric tonnes of maize in 2006 in southern Africa.

The implications and experiences of climate change in different southern African countries, and how farmers are coping with changing climatic conditions, are highlighted below:

4.3.1 South Africa

According to information summarised by the Bureau for Food and Agricultural Policy (BFAP) (2007), the forecast for South Africa includes:

- Temperature increases of between 1°C and 3°C by the end of the 21st century;
- Reduction in rainfall by about 5 to 10%, increased rainfall variability and a reduction in mean annual rainfall;
- A generally drier and hotter climate with longer drier spells;
- Increases in the severity of flood events;
- An increase in the frequency of heavy rainfall events (>20mm per day); and
- Marginal western production areas are likely to become unsuitable for maize production in the future.

As a consequence of these changes, maize production in South Africa is expected to decrease by approximately 10 to 20% (Du Toit *et al.* 2000), resulting in an estimated economic impact of between R46 and R681 million per annum (Turpie *et al.* 2002).

Box 1: Experiences of climate change in Sekhukhune District, Limpopo Province, South Africa

Sekhukhune lies in the summer rainfall region of South Africa, receiving a mean annual rainfall of between 500 and 800 mm (DWAF, 2005). Downscaled climate scenarios indicate an increase in rainfall, particularly in the summer and autumn months (when most rain is received), a change in stream flows (expected monthly quantities will shift a month or two earlier). Currently sparse rainfall and high evaporation rates limit the success of subsistence farming activities, which include growing maize, pumpkins, and sorghum and rearing cattle, goats, and chickens. Soil erosion is a concern in Mohlotsi, a village in Sekhukhune District, especially after heavy rainfall, as this reduces soil quality. Although climate change was not mentioned as one of the key stressors, there were a number of references to its effects, particularly on water resources as well as on village infrastructure during floods.

Source: Ziervogel and Taylor (2008, p. 34-36)

4.3.2 Malawi

Malawi's agricultural sector is presently experiencing significant impacts from climate change and weather extremes, resulting in chronic food shortages and hunger (ActionAid 2008). Vulnerability and adaptation studies undertaken in Malawi predict that temperatures are likely to increase by 1°C, 2°C and 4°C for the years 2020, 2075 and 2100 respectively and that rainfall will increase by 2% to 8% by the year 2100 (Malawi Environmental Affairs Department 2002).

Box 2: A farmer's experience of climate change in Malawi

"The weather has changed a lot since I was a small boy in the early 1940s. When I was a young man, it was very easy to predict the onset of the rains. Chizimaluphya (early rains) would come in October, and then any rains that would come thereafter in November/December would be planting rains. These would tail off in March/April, when the maize matures. The rains were consistent and predictable. This is not the case now; planting rains can come at any time from October to January, and they can stop at any time. Look, this year the rains stopped in January so that late planted maize was badly affected by drought, and hence the hunger we are talking about now. The rains are erratic, unpredictable and poorly distributed, resulting in extreme weather events".

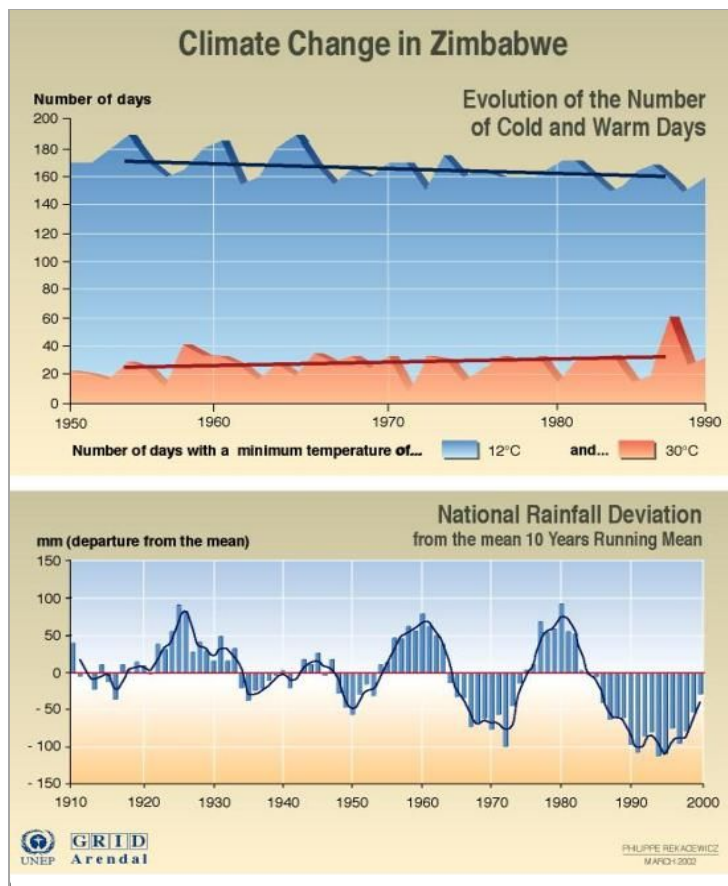
Simaewa, Village Headman of Chenyama

Source: ActionAid (2008, p.20).

4.3.3 Zimbabwe

Records from the Zimbabwean Department of Meteorological Services (UNEP/GRID-Arendal 2002b) show that Zimbabwe is experiencing more hot days and fewer cold days, and the amount of precipitation it receives is deviating from the mean more frequently (see Figure 11).

Figure 11: Climate Change in Zimbabwe



Top graphic: Number of days with a minimum temperature of 12°C and the number of days with a minimum temperature of 30°C from 1950 to 1990.

Bottom graphic: Amount of precipitation in millimetres that was a departure from the long-term mean amount for the time period 1910 to 2000.

Source: UNEP/GRID-Arendal, 2002b

Climate change projections for Zimbabwe indicate that the country is warming at a rate of 0.15 to 0.55°C per decade (Tsiko 2009). Zimbabwe has experienced its six warmest years on record since 1987 and an increase in the frequency of droughts since 1990 (annually from 1990-1995, and again in 97/98, 01/02, 02/03, 04/05, 06/07) leading to substantial drops in crop yields. The country is also experiencing an increase in the frequency of floods, mostly induced by cyclones (e.g. Cyclones Bonita 1996, Eline 2000, Japhet 2003 and Favio in 2007). Future projections also show that by 2080 annual rainfall will average 5-18% below the 1961-1990 average of 634,8 mm. In addition, the frequency and duration of dry spells is projected to increase. Extreme climate events such as dry conditions, heat waves and heavy precipitation may become more intense and frequent increasing the risk of droughts and floods (*ibid*).

Zimbabwe is divided into five agro-ecological zones based on differences in effective rainfall (from > 1000 to < 450 mm per year) (Vincent and Thomas 1960). Crop production conditions progressively deteriorate from region I to region V, and specific farming systems are recommended for each zone (from specialised and diversified farming to extensive farming). These agro-ecological zones, delineated in 1960, are reported to be changing due to changing climatic conditions (Tsiko 2009), with the moister natural region III exhibiting conditions akin to those in the drier natural region IV. Natural region III is a semi-intensive farming region currently covering 19% of Zimbabwe, whereas natural region IV is a semi-extensive farming region covering about 38% of the country (PECAD 2004). Agricultural productivity in Zimbabwe has been decreasing and predictions show that it is likely to decrease by 30% due to changing climatic conditions, thereby threatening the country's food security and potentially worsening the poverty levels of the population (Tsiko, 2009).

Box 3: Assessment from the Commercial Farmers' Union of Zimbabwe

Mr Kudakwashe Ndoro, senior economist with the Commercial Farmers Union of Zimbabwe, pointed out that changes in climatic conditions are already being experienced in Zimbabwe, and this negatively affects agriculture. He highlighted the following issues on climate change and agriculture in Zimbabwe:

- A shift in seasons has been observed, with seasons, especially summer, starting a month later than normal;
- The summer season tends to be shorter, with the season now normally ending mid-March, instead of April;
- Mid-season drought, which used to occur in January, is now being experienced in February;
- The winter months have generally been warmer, without lengthy cold spells; and
- The start of spring has also shifted by about a month.

Source: CSIR interviews for the SACAU Report on Climate Change and Agriculture in Southern Africa (2009): Appendix 1 – Stakeholder interviews, p. 66.

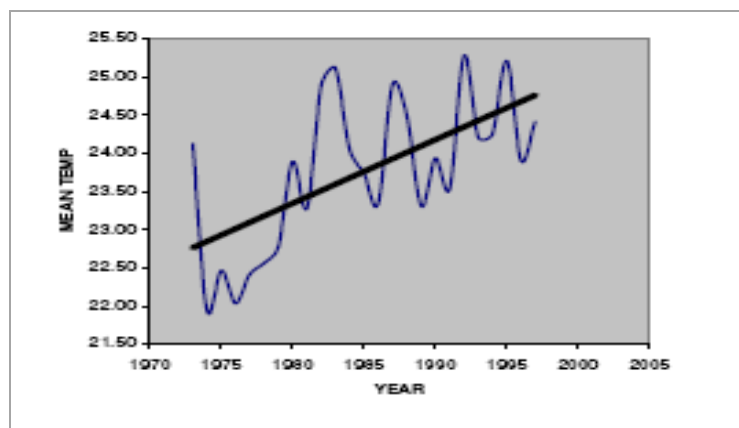
4.3.4 Zambia

Although farmers in Zambia are accustomed to dealing with dry spells and seasonal droughts, the drought frequency and intensity since the early 1990s have increased, as demonstrated by the

droughts experienced in 1991/92, 1994/95, 97/98, 2002/03 and 2005/06 (CEEPA 2006). Data from Zambia agro-ecological zones collected between 1990 and 2004 shows that at least 10 of the 14 years in each zone had below normal rainfall, resulting in the failure of food and export crops which left more than a million people in need of food aid (CEEPA 2006). On the other hand, reports from the University of Zambia (Kabange 2008) show that southern Zambia has experienced higher than normal rainfall and flooding in recent years.

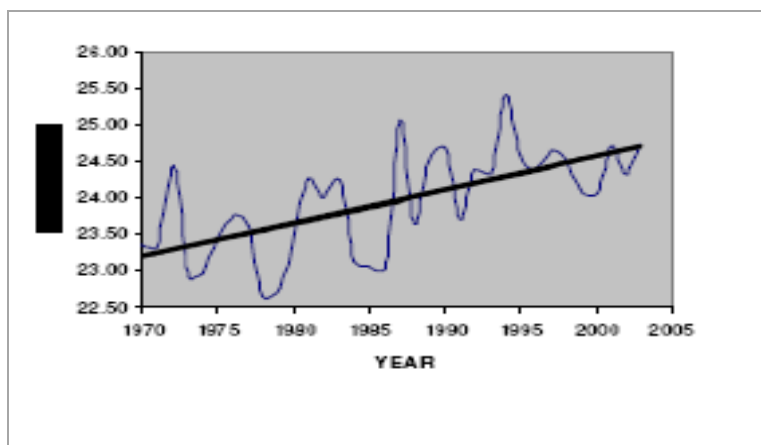
In addition to decrease in mean seasonal rainfall and mean annual runoff, and increased flooding in specific areas, Zambia has also been experiencing increases in mean surface temperature, as a result of climate change – all of which negatively affect the agriculture sector (*ibid*). Zambia's summer temperature is reported to be increasing at a rate 0.6°C per decade and this rate is ten times higher than the global rate. In southern Zambia, for example, mean seasonal temperatures are reported to have increased in the last three decades (see Figures 12 and 13).

Figure 12: November – December mean temperatures in southern Zambia



Source: de Wit, 2006

Figure 13: March – April mean temperatures in southern Zambia

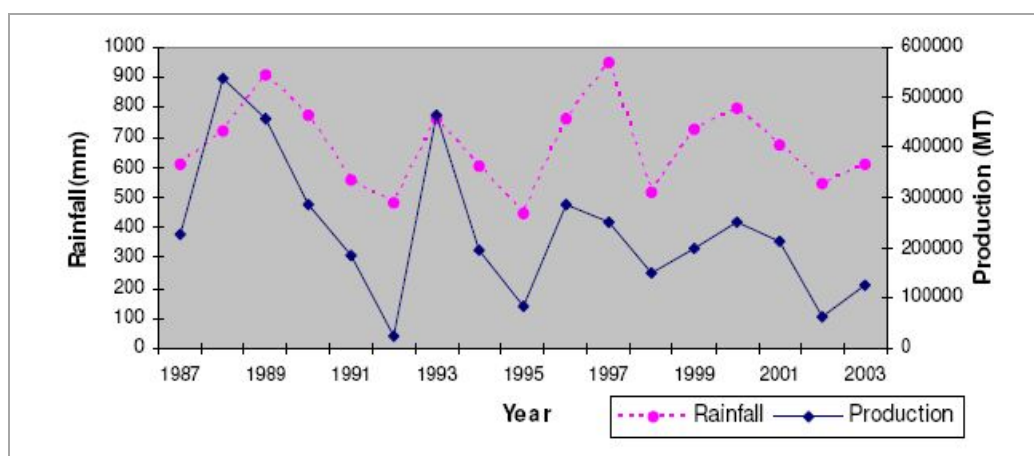


Source: de Wit, 2006

Thus, the region is likely to face a growing number of livestock deaths from thermal stress caused by heat waves, increased floods, bushfires, droughts and cyclones. These climatic conditions could be accompanied by increased transmission of vector-borne, food-borne and water-borne diseases. These changes are prompting people, largely smallholder farmers, to rearrange their livelihoods by moving to higher ground and/or applying different farming techniques, including planting early maturing or drought resistant food crops (Kabange 2008).

These changes in climatic conditions have direct implications for agriculture in Zambia. Figure 14 below shows that the total seasonal rainfall has a high positive correlation with the maize yields in southern Zambia, and that recent droughts have negatively affected the total maize output for the region. This can be extrapolated to the country as a whole.

Figure 14: Relationship between maize yields and rainfall in the Southern Province of Zambia



Source: de Wit, 2006

4.3.5 Seychelles

The impacts of climate change in the Seychelles Islands include the rise in sea level, increased flooding, changes in precipitation and elevated sea surface temperatures, which damage both natural ecosystems and man-made infrastructure (Agricole 2006). Because the economy relies mainly on tourism and fisheries, these changes have resulted in a loss of livelihoods, as beaches, wetlands and other coastal lands are lost due to rising sea levels and higher storm surges; coral reefs are lost as a result of higher water temperature; and dwindling fish stocks have been observed. Furthermore, the availability of fresh water supplies is also affected by long-term changes in rainfall patterns, evaporation, and the May to October Trade Winds that result in drier conditions, droughts and severe water shortages (*ibid*). Although Mahe and its surrounding islands are not in the direct path of tropical cyclones, they are indirectly affected by the resulting atmospheric perturbations.

In addition to the impacts of changes in precipitation patterns and increased temperatures, extreme weather events in the form of periods of excessive rainfall and severe drought brought about by climate change are also affecting the agricultural sector in Seychelles. Excessive rainfall has induced loss of soil fertility resulting in poorer crop output, while droughts have brought on crop losses (Moustache 2006). Overall, agriculture has become less productive.

Box 4: Assessment from the Seychelles Farmers' Association

Mr Serge Benstrong, the chairman of the Seychelles Farmers' Association, pointed out that changes in climatic conditions are already affecting Seychelles agriculture negatively. He highlighted the following:

- Seychelles is experiencing changes in climatic conditions; including extreme temperatures, droughts, rising sea levels and changing weather patterns;
- Extreme temperatures affect crop development and animal health;
- The changed conditions have affected seed adaptability, induced increases in pests and diseases, crop flower drops before pollination, flooding and contamination of soils; and
- Unpredicted weather conditions that affect crop production planning.

Source: CSIR interviews for the SACAU Report on Climate Change and Agriculture in Southern Africa (2009): Appendix 1 – Stakeholders interviews, p68.

4.3.6 Lesotho

A DFID report (2007) indicates that the weather in Lesotho has been unpredictable for many years, with temperature extremes swinging between 6°C and 40°C, and experiences of hail, frost and snow. Droughts and floods have also occurred, resulting in destruction and hunger. The Integrated Regional Information Networks (IRIN) (2008a) also notes that rainfall and snowfall, both important sources of water for food crops, have become less frequent every year. The situation is projected to worsen in the future as climate change scenarios predict that rainfall will be even less by 2075 (IRIN 2008a). According to DFID (2007), a 2007 drought resulted in over half a million people (almost a quarter of the population) needing emergency food aid or money to buy food. As a result of the drought, many farmers suffered heavy losses of livestock such as donkeys, horses, sheep, goats and hens – many were forced to sell their animals as a coping mechanism while other animals died. The combination of declining rainfall and high HIV/AIDS prevalence in farming communities has resulted in more frequent food shortages, while Lesotho's agricultural sector already struggles with lack of investment and migration.

4.3.7 Swaziland

Swaziland has been facing changing rainfall patterns; the first rains that usually fell between August and September now fall between October and November. This is followed by dry spells in January, just as the crops mature (IRIN 2007). The weather service reports over the last 15 years indicate a 12% increase in days with temperatures over 35°C, and up to a 50% decline in precipitation during the months of September and October, which is the start of the rainy season. On the other hand, the frequency and intensity of storms are increasing (*ibid*).

Climate change is being blamed for the increasing crop failures and food shortages in Swaziland, where droughts struck in 1981, '82, '91 to '96 and 2001 to 2007 (IRIN 2008b). The areas at high risk, or severely affected by drought, are in the *Lowveld* and lower *Middleveld* regions, where rainfall is often very low even in 'normal' rainy seasons. In 2007, the country suffered a devastating drought in all four of the country's regions, with the drought withering up to 80% of crops in some areas (IRIN 2007). Conversely, 2008 started with extremely heavy rains, hailstorms and wildfires.

4.3.8 Botswana

Botswana has experienced extreme temperatures, recurrent droughts, floods, severe thunderstorms and strong winds in recent years. Climate simulation models predict that temperatures in Botswana will on average rise by 1-3°C by around 2050. Botswana is likely to have more droughts (due to increasing El Ninos) and floods (from South East Trade Winds) (State of Environment Report 2002). Data from the Botswana Meteorological Services indicates that some stations show a trend line of general decline of rainfall and increase in temperature (*ibid*).

4.3.9 Namibia

The dry environment, persistent drought and desertification have contributed to make Namibia increasingly vulnerable to the effects of climate change. A 1998 Climate Change Country Study found that the resources most vulnerable to climate change in Namibia are water resources, marine resources, biodiversity ecosystems, and coastal zones and systems, and that the most vulnerable sectors are agriculture, health and energy (MET no date).

Considerable changes in vegetation structure and function are projected in many parts of Namibia by 2080. Climate change simulations project that Namibia's dominant vegetation type (the Grassy Savanna) is likely to lose its spatial dominance to desert and arid shrub land vegetation types under existing climate conditions. Vegetation is projected to suffer some reductions in cover and a reduced net primary productivity throughout much of the country by 2050 (more pronounced by 2080), with important implications for the faunal component of Namibia's ecosystems as well as the agricultural sector (SANBI 2005).

4.3.10 Madagascar

Madagascar is already experiencing changing climatic conditions that result in changes in rainfall, temperature patterns, and increases in the frequency and severity of droughts, floods and cyclones. Based on 30-year data, an increase in the mean temperature of about 0.5 to 3.0°C and average increases in of 0.7°C for the mean minimum temperature and 0.3°C for the mean maximum temperature have occurred (Razafindrabe no date). Projections for the year 2100 indicate a mean temperature increase of +2.5 to 3°C in most areas. Projections also show a decrease in mean annual rainfall, with more pronounced decreases during the dry season but significant increase during the rainy season. The other main climate risks for Madagascar are cyclones, floods and droughts.

Impacts of climate change affect Malagasy livelihoods, especially in rural communities. The changing climatic conditions have already resulted in decreasing agricultural productivity, watershed degradation and land erosion (Razafindrabe no date).

5. Responses to Climate Change: Mitigation and Adaptation

Mitigation and adaptation are the two strategies that are generally employed for dealing with climate change. Mitigation of climate change is a human intervention aimed at reducing the sources or enhancing the sinks of greenhouse gases (IPCC 2007c). Adaptation, on the other hand, comprises actions to reduce vulnerability or enhance resilience (Adger *et al.* 2001). Building resilience entails increasing the ability of a social ecological system (i.e. a system with a social and an ecological component – an agricultural system, for example) to withstand shocks and surprises and to revive itself if damaged.

5.1 Mitigation in the agricultural sector

5.1.1. Climate change mitigation strategies

Mitigation strategies fall into two categories: primarily technological solutions, and those that involve changes in economic structure, societal organisation or individual behaviour (Swart *et al.* 2003). In the agriculture sector for example, the introduction of zero or reduced tillage would be a technological mitigation strategy that aims to reduce energy use, while building soil carbon sequestration, as soil disturbance tends to stimulate soil carbon losses through enhanced decomposition and erosion (Madari *et al.* 2005) (see section 3.1 Soils, for more details). Policies, such as market-based trading schemes (see section 6.3) that could encourage farmers to reduce emissions by earning then selling carbon offset credits, is an example of a mitigation strategy that involves changes in economic structures and individual behaviour.²

5.1.2. Mitigation options in the agricultural sector

Several mitigation options exist for reducing GHGs emitted by agriculture (see section 3.1 for more details on GHG emissions from agriculture). Such practices able to abate agricultural GHG emissions include: improving livestock and manure management, improving cropland and grassland management (e.g. improving agronomic practices including nutrient use, tillage and residue management, restoring drained organic soils for crop production, restoring degraded lands, reducing fertiliser related emissions, etc.), expanding agro-forestry, which increases sequestration of carbon in agro-ecosystems; and producing fossil fuel substitutes (UNFCCC 2008, p.5).

The FAO (2007a, p.18) has compiled the best practices for climate change mitigation in the agricultural sector as follows:

Reducing emissions of carbon dioxide through:

- Reduction in the rate of deforestation and forest degradation;
- Better control of wildfires;
- Avoiding the practice of burning crop residues after harvest;
- Avoiding pasture degradation;

² The Saskatchewan Soil Conservation Association in Canada for instance encourages farmers to adopt zero tillage practices in return for carbon-offset credits (Smith *et al.* 2007).

- Reduction of emissions in arable farming by adoption of no-till systems; and
- More efficient energy use by commercial agriculture and agro-industries.

Reducing emissions of methane and nitrous oxide through:

- Improving nutrition for ruminant livestock;
- More efficient management of livestock waste;
- More efficient management of irrigation water on rice paddies; and
- More efficient management of applications of nitrogen fertiliser and manure on cultivated fields.³

Sequestering carbon through:

- Afforestation, reforestation and improved forest management practices;
- Introduction of integrated agro-forestry systems that combine crops, grazing lands and trees in ecologically sustainable ways;
- Use of degraded lands for productive planted forests or other cellulose biomass for biofuels;
- Improved management of pastures and grazing practices on natural grasslands, including by optimizing stock numbers and rotational grazing; and
- Use of techniques such as conservation agriculture to improve soil organic matter management with permanent organic soil cover, minimum mechanical soil disturbance and crop rotation.

While current technologies can be effectively employed in climate change mitigation, research can also explore possible options for mitigation, e.g. strategic livestock feed supplementation to reduce emissions from enteric fermentation, manure management to avoid methane formation, precision fertilisation techniques to reduce nitrous oxide emissions, or technologies to enhance carbon sequestration in soils or in agro-plants. Although research mostly takes place at the global level,⁴ it could also be applicable to southern Africa.

Another mitigation potential of agriculture, which has recently received wide publicity, is biofuel production. Biofuels (i.e. liquids produced from plant matter that can substitute for fossil fuels, such as petrol or diesel) are promoted as an effective mitigation strategy on the premise that they can reduce greenhouse gas emissions in comparison to burning fossil fuels. However, some argue that biofuels could actually exacerbate climate change, as total GHG emissions from biofuel production and utilisation seem higher than those from burning petrol (Leahy 2009). Staley and Bradley (2008) note that recent research suggests that, after accounting for the carbon emissions that result from all the land-use changes from expanded biofuel production, most of today's biofuels actually lead to an increase in GHG emissions compared to fossil fuels. This is in relation with the fact that biofuel production competes with food production for land, thereby exerting additional pressure on land resources, which leads to the conversion of grasslands and forests to croplands, and this

³ For example, the use of slow or controlled release nitrogen fertilisers or the use of nitrification inhibitors (these slow the microbial processes leading to nitrous oxide formation) are technologies that improve nitrogen use efficiency and eventually allow for reduced nitrous oxide emissions (Smith *et al.* 2007).

⁴ The Consultative Group on International Agricultural Research (CGIAR) is notably engaged in research to address climate change mitigation (CGIAR 2009).

clearing of forests and grasslands eventually releases carbon dioxide into the atmosphere. Not all biofuels have the same impact, however; for example, the energy and carbon benefits of biodiesel (i.e. biofuel produced from vegetable oil such as soybean, rapeseed, jatropha, sunflower or palm oil) vary widely depending on the feedstock used (*ibid*). Thus, biofuel production as a climate change mitigation strategy needs to be carefully analysed to ensure selection of appropriate crops to grow for feedstock, as well as adequate production methods that are not carbon intensive.

5.1.3. Constraints to mitigation potentials of the agricultural sector in Southern Africa

Smith *et al.* (in IPCC 2007c) note that, although there is significant technical potential for mitigation in agriculture, there is evidence that little progress has been made in the implementation of mitigation measures at global scale; this is equally true for southern Africa. While southern African agriculture could achieve significant carbon sequestration and reduced carbon emissions through activities such as afforestation and reforestation, improved livestock management, rehabilitation of degraded crop and pasturelands and agroforestry, this potential is not being realised. Due to poverty and pressures to earn livelihoods, African farmers are seldom in a position to invest in practices that could contribute to climate change mitigation. Therefore, it is essential that they be compensated for their mitigation activities, as this would not only benefit them but also the planet (IFAD 2008).

There are various schemes designed to fund climate change mitigation activities – these schemes are extensively discussed in section 6. The Clean Development Mechanism (CDM) is the principal mechanism in which developing countries can participate. However, to effectively involve farmers, particularly smallholder farmers, it is important to help them to overcome barriers, such as very high transaction costs, associated with participating in these schemes. Also, some of the key problems that characterise small-scale farming in developing countries, including insecure property rights, poverty, lack of information and risk aversion, need to be addressed (IFAD 2008). As a result, southern Africa, and actually sub-Saharan Africa as a whole, is not significantly participating in climate change mitigation initiatives. As of October 2008, only 1.4% of all registered CDM projects worldwide were located in sub-Saharan Africa (Bryan *et al.* 2008), and only six of the 30 projects from southern Africa⁵ that were in the CDM pipeline (i.e. under validation, registration request or registered) were agriculture/forestry-based, involving biomass energy production from forest residues and crops, reforestation and afforestation, and/or biogas production from animal manure (UNEP 2008a). For the CDM mechanisms to extend mitigation opportunities to millions of smallholder farmers and pastoralists in Africa through their roles as sequesters of carbon via agroforestry, reforestation or improved management of grasslands, there is a need to revise the CDM rules (Bryan *et al.* 2008).

5.2. Adaptation in the agricultural sector

5.2.1. What is adaptation to Climate Change?

According to the *IPCC Third Assessment Report* (IPCC 2001b), climate change is a present reality that will continue, even if global greenhouse gas emissions are curtailed significantly. It is therefore imperative to find ways to survive climate change. In Africa, lack of financial resources, political instability, poverty, inequitable access to resources, and HIV/AIDS – among other challenges –

⁵ Namely from Madagascar (1), Mauritius (1), Mozambique (1), South Africa (25) and Tanzania (2).

imply that many African countries lack the adaptive capacity to cope with and adjust to climate change compared to more developed countries. As far as the agricultural sector is concerned, factors such as poverty, institutional weaknesses, and lack of investments, coupled with high dependence on natural resources and an overdependence on rain-fed agriculture, mean that agriculture in many African countries is highly vulnerable to climate change.

Adaptation methods are those strategies that enable the individual or community to cope with or adjust to the impacts of climate change (Nyong *et al.* 2007). There are two distinct forms of adaptation: 'autonomous adaptation' and 'planned adaptation' (Easterling *et al.* 2007). Autonomous adaptation refers to the ongoing implementation of existing knowledge and technology in response to the changes in climate experienced. Planned adaptation is the increase in adaptive capacity by mobilising institutions and policies to establish or strengthen conditions that are favourable to effective adaptation and investment in new technologies and infrastructure (FAO 2003).

In climate change discourse, 'adaptation to' and 'coping with' climate change are terms that are often used loosely, and in some cases interchangeably. The Merriam-Webster Online Dictionary (2009) defines 'cope' as to, '*deal with and attempt to overcome problems and difficulties*' while 'adapt' is defined as, '*to make fit (as for a specific or new situation) often by modification*'. Given these definitions, 'coping with' climate change would be more aligned with 'autonomous adaptation' as defined above, while 'adaptation' would relate more to 'planned adaptation'.

5.2.2. What are the possible adaptation strategies for agriculture in Africa?

Coping with climate variability is not something new in Africa, where farmers and rural households have survived droughts and other adverse climatic conditions for decades by using various strategies that enable them to reduce their vulnerability to climate variability and change (Nyong *et al.* 2007). However, these strategies – although adequate in the past – may not be enough for future changes in climate (IPCC 2007c). That is why planned adaptation has become imperative.

Autonomous adaptations are still highly relevant for smallholder farmers, who are mostly located in areas of ecological fragility and tend to have an extensive knowledge base to draw upon in coping with adverse environmental conditions and shocks. Autonomous adaptation options include:

- Changing inputs such as crop varieties and/or species and using inputs with increased resistance to heat shock and drought; altering fertiliser rates to maintain grain or fruit quality consistent with the climate, and altering amounts and timing of irrigation and other water management practices;
- Making wider use of technologies to 'harvest' water, to conserve soil moisture (e.g. crop residue retention) and to use water more effectively in areas where there is a decrease in rainfall;
- Utilising water management to prevent waterlogging, erosion and nutrient leaching in areas where there is an increase in rainfall;
- Altering the timing or location of cropping activities;
- Diversifying income by integrating into farming activities additional activities (e.g. gardening), non-agricultural income generating activities (e.g. crafts), and off-farm employment; and
- Using seasonal climate forecasting to reduce production risk.

A fieldwork conducted by the international NGO ActionAid in agri-based developing countries confirms that climate-induced declines in crop production are presently occurring in Africa and other parts of the world and shows that in the face of this threat, farmers have begun to respond to failing crops by adopting sustainable low-input agricultural techniques that increase food security (ActionAid 2008). There is also evidence of community efforts to adapt to climate change that build resilience and manage the risks associated with climate change. For example, in Bangladesh where flooding due to climate change is having a particularly devastating impact, some farmers increase their resilience by changing the way they cultivate their land and by raising the beds of their vegetable plots or modifying their cropping patterns (ActionAid 2008, p.12-13). In Vietnam, floods, storms and typhoons are a recurrent phenomenon, and farmers have responded by establishing flood and storm prevention committees, which play a major role in disseminating information on flood prevention and educating communities on agricultural practices that reduce risks from natural hazards (ActionAid 2008, p.23-25). In Brazil's semi-arid region, farmers are responding to decreases in food production through risk reduction strategies of water conservation and crop diversification (ActionAid 2008, p.14-16). These could be replicated in the African context.

Planned adaptation measures, on the other hand, are conscious policy options or response strategies aimed at changing the adaptive capacity of an agricultural system or facilitating specific adaptation (FAO 2007b). Planned adaptation is usually the result of deliberate policy decisions made by a public agency, based on an awareness that conditions are about to change or have changed and that action is required to minimise losses or benefit from opportunities (IPCC 2007a). Planned adaptation can be reactive or anticipatory (i.e. undertaken before impacts of climate change are apparent). Initiatives such as adjusting agricultural research priorities, increased training and education and deliberate crops selection and distribution strategies across different agro-climatic zones to deal with climate change are examples of planned adaptation strategies (Easterling 1996).

In support of planned adaptation, knowledge and technology emerging from research can be used to make agriculture more climate-resilient. For instance, research can develop drought-tolerant or early maturing tropical crop varieties. There are also research efforts to select livestock breeds that are better suited for environments where drought is becoming more prevalent due to climate change. Research can also examine the likely effects of climate change on pests and diseases of both crops and livestock. Enhancing the productivity of water in agriculture is also a main focus of research institutions working to increase the climate-resilience of agriculture.⁶

Climate change research initiatives can also inform policy issues. For example, the Canadian International Development Research Centre (IDRC) and the UK Department for International Development (DFID) jointly fund a research programme to bring scientists and governments together to share expertise and develop policies to tackle extreme weather and its effects on Africa's poor (DFID 2006). The CGIAR also has a research programme aiming to evaluate global and national policies for GHG emission reductions in the context of enabling the improved adaptation of rural communities (CGIAR 2008).

⁶ For instance, the Consultative Group on International Agricultural Research (CGIAR) is carrying out research exploring ways of helping vulnerable rural communities adjust to global changes in climate (CGIAR 2009).

5.2.3. How are farmers in southern Africa adapting to changing climatic conditions?

As farmers in southern Africa already experience the change in climatic conditions (see section 4.3), they have started to make changes in the way they farm in order to continue to survive. Here are some accounts of adaptation strategies that emerge from different countries in southern Africa.

> South Africa

In Maitsheni, Eastern Cape, farmers have had to change their practices in order to cope with declining rainfall and frequent droughts. The changes they have made include (Giles 2007, p. 3):

- Changing cropping practices, e.g. crops are planted farther apart so that moisture is available for each row increasing the likelihood that they will survive a period of drought;
- Maize varieties that mature faster have been brought in to limit the threat of dry spells;
- Local people have set up a commercial cooperative so that if the village produces excess maize in a certain year, the group transports the crops to market, earning money that can be used to buy food when yields are lower; and
- Livelihoods are diversified, i.e. people seek work elsewhere and do not completely rely on agriculture.

> Malawi

In response to changing climatic conditions, farmers in Malawi have employed the following strategies (ActionAid 2008, p. 20-22):

- Diversification of agricultural production: growing a variety of crops to ensure that if some fail there are other crops available;
- Intensification of activities takes place when the weather is favourable;
- Exploring methods to improve soil fertility using organic manure (e.g. composting innovations) instead of chemicals;
- Cultivation of winter crops using residual soil moisture from river banks and flooded areas, e.g. second maize crops are planted at the end of rains in March and harvested in winter; and
- Livelihood diversification (e.g. gardens and other income generating activities) to reduce reliance on agriculture.

> Zimbabwe

The Commercial Farmers Union of Zimbabwe indicate that, due to changing climatic conditions, farmers have to adjust operations to fit into the short seasons cycle and invest in drought mitigating techniques including irrigation, adoption of moisture conservation techniques and using short season varieties. The changing climatic conditions were perceived by the Commercial Farmers Union of Zimbabwe as wholly disadvantageous to agriculture in Zimbabwe (CSIR 2009, p.66).

> Zambia

Zambian farmers have adopted coping strategies such as planting short season crop varieties, planting drought resistant food crops and water harvesting. Holes and furrows around their settlements are used to direct floodwater to their gardens. Farmers line dams with thin plastic sheets to ensure that they hold water for longer periods, and evaporation during warm periods is minimised by covering the dams with grass. There are efforts by the Zambian National Association

for Peasant and Small-Scale Farmers to encourage farmers to reduce deforestation and to plant two trees whenever they cut one for firewood (Kabange 2008).

> *Lesotho*

Farmers in Lesotho have had to find ways to cope with less rainfall and reduced crop yields. To this end, in some areas farmers have had to learn to use wetlands as a source of water for irrigation (IRIN 2008). Another coping strategy is livelihood diversification; for example, instead of relying solely on farming, people also make and sell handicrafts. According to IRIN (2008), the government has identified several ways of adapting to climate change such as developing high yield crop varieties, conserving rangelands to prevent erosion and afforestation. People are being trained in conservation farming to minimise the negative impacts of climate change. In addition to government initiatives, agencies such as DFID, FAO and others are supporting local level initiatives to help farmers cope with climate change. One example of a local level initiative is the keyhole garden: a small specially constructed productive vegetable garden that needs little water and tending (DFID 2007).

> *Madagascar*

Actions to reduce vulnerability and to adapt to changing climatic conditions include changes in agricultural practices, such as earlier planting, more use of compost, and crop diversification including increased reliance on root crops such as cassava (Tanintsika *et al.* 2008). Non-agricultural measures are also used as adaptation strategies, such as increased investment in alternative livelihoods like crafts, charcoal production and trading activities.

5.2.4. *What should adaptation strategies aim to achieve?*

If it is to be sustainable adaptation should not only react to climate change, but should also focus on building farmers' adaptive capacity. Climate change is a long-term process and adaptation thus needs to have a long-term focus. In that regard, adaptation support for building farmers' adaptive capacity should particularly focus on sharing and strengthening existing knowledge about climate variability, its impacts, and local adaptation strategies. In addition, knowledge sharing about the local adaptation needs and actions, and policy and investment processes on national and international levels needs to take place (Both Ends 2007). The importance of information sharing networks for climate change initiatives is illustrated in Bangladesh, where a community's flood early warning system has helped communities to adapt better to the risks of floods and cyclones (UNFCCC 2006, p.15). In the past, communities obtained flood forecast information from sources such as word of mouth, traditional knowledge and local media, and these sources were unreliable, late or difficult to understand for local people. The community flood early warning system has shown that timely flood warnings can prompt communities to protect crops, habitats and livestock.

Although adaptation is underway, enabling conditions that encourage holistic approaches can further these efforts. The most effective adaptation approaches are those that address a combination of factors, e.g. alleviating poverty, enhancing food security and water availability, combating land degradation and soil erosion, etc. (FAO 2008). As demonstrated by the example above, dissemination of forecast information using local languages and indigenous networks and strategies to ensure the information's accessibility empowers farmers and strengthens their adaptive capacity, by providing accurate information, which is central to sound decision-making and planning.

6. Institutions and Initiatives addressing Climate Change

There are attempts by many institutions through various initiatives – from local to global level – to address climate change in an organised and coordinated way. In order to effectively participate in climate change initiatives it is necessary to be aware of what is happening across the climate change institutional landscape. This section highlights some of the main climate change actors and initiatives at the global, African and southern African levels.

6.1. The Intergovernmental Panel on Climate Change (IPCC)

One of the central players in addressing climate change is the Intergovernmental Panel on Climate Change (IPCC). The IPCC is a scientific intergovernmental body established by the World Meteorological Organisation (WMO) and by the United Nations Environment Programme (UNEP) in 1988. The IPCC was established to provide decision-makers and other stakeholders interested in climate change with an objective source of information about climate change. Thus, the IPCC assesses, on a comprehensive, objective, open and transparent basis, the latest scientific, technical and socio-economic literature produced worldwide relevant to the understanding of the risk of human-induced climate change, its observed and projected impacts, and options for adaptation and mitigation. The IPCC provides assessment reports at regular intervals, which provide standard works of reference and are widely used by policy-makers, experts, students and different interest groups. To date, the IPCC has produced four assessment reports, between 1990 and 2007, the first of which, published in 1990, played a decisive role in leading to the United Nations Framework Convention on Climate Change. (UNFCCC 2009a)

6.2. The United Nations Framework Convention on Climate Change (UNFCCC)

The UNFCCC is an international environmental treaty aimed at

...the stabilization of greenhouse gas (GHG) concentration in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner (UNFCCC 2009b).

The UNFCCC came into force on 21 March 1994 and a total of 192 countries have signed it internationally (UNFCCC 2009c). It allows for the introduction of protocols to the Convention, the first of which is the Kyoto Protocol (UNFCCC 2009d). All SADC and COMESA member countries have signed and ratified the UNFCCC (Nyirenda 2008), and all have signed the Kyoto Protocol, but some, e.g. Zimbabwe, are yet to ratify it.

The global climate change negotiations to consider the requirements for reducing global warming and to set targets for reducing GHGs are held under the auspices of the UNFCCC. The negotiation processes encompass the Conference of the Parties⁷ (COP), the Meeting of the Parties to the Kyoto Protocol, subsidiary bodies meetings and workshops (UNFCCC 2009e).

⁷ A party is a state (or a regional economic integration organisation such as the European Union) that agrees to be bound by a treaty and for which the treaty has entered into force.

The UNFCCC has designed the Least Developed Countries Fund (LDCF) to help these countries, which are especially vulnerable to the adverse impacts of climate change, to cope with its related threats. The LDCF was established to fund the preparation and implementation of the National Adaptation Programmes of Action (NAPAs) that identify urgent and immediate adaptation, i.e. those for which further delay could increase vulnerability or lead to increased costs at a later stage (UNFCCC 2007). The least developed countries are required to have completed their NAPA before applying for any adaptation fund. As of April 2009, 41 countries had submitted their NAPAs to the UNFCCC, including, in southern Africa, DRC, Lesotho, Madagascar, Malawi, Mozambique, Tanzania and Zambia⁸. The LDCF, which is managed by the Global Environment Facility (GEF), has been allocated USD 172 million, while USD 500 million is needed to finance the implementation of all NAPAs. As the financial mechanism of the Convention, the GEF also manages other funds aiming to support climate change adaptation under the auspices of the UNFCCC, including the Strategic Pilot on Adaptation (SPA) and the Special Climate Change Fund amounting to USD 50 million and USD 32 million respectively. (GEF 2007b)

Box 5: Examples of NAPA-integrated projects in Africa

- The largest project in Eritrea's NAPA is in the north-western lowland, which is characterised by low and extremely unpredictable rainfall and a high frequency of droughts. It aims to establish spate-irrigated cereal crop production systems, increase livestock production by improving the rangeland, restock the population of small ruminants, provide machinery and initial agricultural inputs, and establish effective community-based institutions. The project intends to reduce vulnerability to climate variability and drought and to cope with climate change in the long term through measures to increase crop productivity and provide fodder for livestock.
- In Mozambique, the government has drawn up massive plans for the sustainable development of the coastal region, which deal with climate risks in an integrated manner, across seasonal, inter-annual and multi-decadal time scales. These plans include major infrastructure investments (transportation, drainage and water supply), land use changes, and soft options to manage beach erosion.

Source: UN DESA (2009a)

6.3. The Kyoto Protocol

The Kyoto Protocol is an international agreement linked to the UNFCCC. It was adopted in Kyoto, Japan, on 11 December 1997 and entered into force on 16 February 2005. The Kyoto protocol sets binding GHG emission targets for 37 industrialised countries or countries in economical transition, such as the USA, Australia, Japan, Canada, the Russian Federation, and the European community. These countries, referred to as 'Annex I' countries in the Kyoto Protocol (also sometimes referred to as 'Annex B' countries), have agreed to reduce their collective GHG emissions by 5.2% compared

⁸ The NAPAs can be downloaded from the UNFCCC website:

http://unfccc.int/cooperation_support/least_developed_countries_portal/submitted_napas/items/4585.php

to the year 1990 over the five-year period 2008-2012. National commitments however vary from nation to nation, with 5% being the average emission reduction target. Developing countries (referred to as 'Non-Annex I' countries) do not have emission restrictions. (UNFCCC 2009f)

184 signatories of the UNFCCC have ratified the Kyoto Protocol to date (UNFCCC 2009g), hence binding themselves to the legal obligations of the Protocol. Of note is the fact that the United States, one of the major industrialised countries and a major emitter of carbon dioxide in the world, has not ratified the Kyoto Protocol. The United States objects that countries like China and India, despite being major GHG emitters, are not bound by the Protocol's restrictions on GHG emissions due to their categorisation as developing countries (i.e. within the framework of the Kyoto Protocol, they are not seen as the main culprits for emissions during the period of industrialisation thought to be the cause of the current climate change).

Thus, the Protocol takes cognisance of the fact that developed countries are principally responsible for the current high levels of GHG emissions in the atmosphere as a result of more than 150 years of industrial activity and places a heavier burden on developed nations under the principle of '*common but differentiated responsibilities*' (UNFCCC 2009f).

The Kyoto Protocol is currently the only international agreement that calls for actions to reduce emissions of carbon dioxide. Negotiations for a new global treaty to take effect when the Kyoto Protocol ends in 2012 are under way and will culminate in talks in Copenhagen in December 2009.

6.4. The Kyoto mechanisms

Under the Kyoto Protocol, Annex I countries must meet their targets primarily through national measures. However, these countries have additional means of meeting their targets, by way of three market-based mechanisms under Kyoto:

- Emissions trading – also known as 'the carbon market';
- The Clean Development Mechanism (CDM); and
- Joint Implementation (JI).

These mechanisms are meant to help stimulate green investment worldwide and help Annex I countries meet their emission targets in a cost-effective way.

Kyoto Protocol parties also established an Adaptation Fund to finance concrete adaptation projects and programmes in developing country parties that are particularly vulnerable to the adverse effects of climate change.

6.4.1. Emissions trading or the carbon market

Kyoto's Annex I countries have accepted targets for limiting or reducing their GHG emissions. These targets are expressed as levels of allowed emissions, or 'assigned amounts', over the 2008-2012 commitment period. The allowed emissions are divided into 'assigned amount units' (AAUs). Emissions trading, as set out in Article 17 of the Kyoto Protocol, allows countries with AAU to spare (i.e. countries below their permitted GHG emission targets) to sell this excess capacity to countries that are over their own targets. Thus, a new commodity was created in the form of GHG emission

reductions. Since carbon dioxide is the principal greenhouse gas, reference is simply made to trading in carbon for these sales of emission units between countries. As a result, carbon is now tracked and traded on the 'carbon market', like any other commodity on its respective market,

For example, in December 2008, Poland announced the sale of an undisclosed amount of AAUs to Ireland for €15 million. The deal was struck through the Multilateral Carbon Credit Fund, managed by the European Investment Bank (EIB) and the European Bank for Reconstruction and Development (EBRD) The proceeds of the sale would be used for green initiatives through the Green Investment Scheme (Carbon Finance 2009).

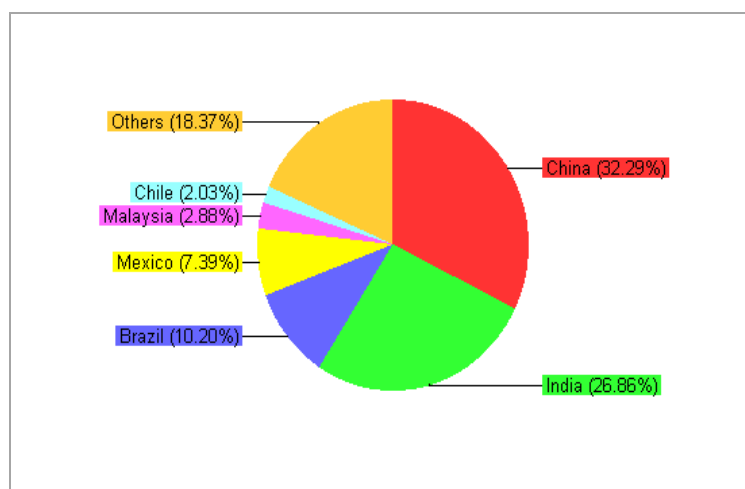
Trading of AAUs does not presently concern developing countries, since they do not have emission targets imposed by the Kyoto Protocol. However, the carbon market that results from this scheme is open to developing countries through the mechanisms described below.

6.4.2. The Clean Development Mechanism (CDM)

The Clean Development Mechanism (CDM), defined in Article 12 of the Kyoto Protocol, is an arrangement that allows industrialised countries with greenhouse gas reduction commitments (Annex I countries) to invest in projects that reduce emissions in developing countries (Non-Annex I countries) as an alternative to engage in more expensive emission reductions in their own countries. Such projects can earn saleable certified emission reduction (CER) credits, each equivalent to one tonne of carbon dioxide, which can be counted towards meeting Kyoto targets. Thus, the CDM offers Annex I countries a flexible and cost-efficient means of fulfilling a part of their Kyoto commitments, while the host Party (Non-Annex I country) benefits from foreign investment and technology transfer.

The CDM is the largest market-based initiative targeting developing countries. Currently there are 1530 registered CDM projects in the world, with annual average CERs of nearly 278 million, and expected CERs of over 1.52 billion by the end of 2012. The CDM trade is dominated by Non-Annex I countries in Asia and the Pacific region (see Figure 15), while Africa only accounts for 1.9% of all registered CDM projects (UNFCCC 2009h).

Figure 15: Registered CDM projects by host party (total 1530)



Source: UNFCCC, 2009h

The CDM also provides for adaptation funding through feeding the UNFCCC Adaptation Fund with 2% of the CERs issued for any CDM project activities, except if implemented in a least developed country.

6.4.3. Joint Implementation

The mechanism known as “joint implementation” (JI), defined in Article 6 of the Kyoto Protocol, allows an Annex I country to earn emission reduction units (ERUs) from an emission-reduction or emission removal project in another Annex I country. Similarly, each ERU is each equivalent to one tonne of carbon dioxide, and can be counted towards meeting its Kyoto target. As a mechanism only engaging Annex I countries, the JI it does not concern developing countries directly, but can nevertheless affect them through the carbon market.

6.4.4. The Adaptation Fund

The Adaptation Fund was established by the parties to the UNFCCC Kyoto Protocol to help developing country parties to cope with adverse impacts of climate change. It is designed to finance concrete adaptation projects and programmes on the basis of the developing country parties’ needs, views and priorities in terms of adaptation to climate change.

The Adaptation Fund’s primary funding comes from a 2% share of proceeds of all CERs issued under the CDM, except when issued for a project implemented in a least developing country. The World Bank serves as trustee for the Adaptation Fund, and its Treasury conducts CER sales for the Fund.

6.4.5. Land-use, land-use change and forestry (LULUCF) activities under the Kyoto Protocol

Of particular interest for the agricultural sector, articles 3.3 and 3.4 of the Kyoto Protocol state that Annex I countries may use biospheric carbon sinks activities (i.e. land-use, land-use change and forestry) that remove carbon dioxide from the atmosphere in achieving their quantified emission reduction commitments. Under Article 3.3, forestry activities, however limited to afforestation, reforestation and deforestation that have occurred since 1990, may be included in the accounting of emissions and assigned amounts from the first commitment period (2008-2012) onwards. Under Article 3.4, other activities, known as ‘additional human-induced’ activities (i.e. those relating to agricultural soils, land-use change and forestry), may also be included.

6.4.6. How have the Kyoto mechanisms worked for African developing countries, especially in the agricultural sector?

Countries in sub-Saharan Africa have not participated effectively in global carbon markets. As of October 2008 sub-Saharan Africa accounted for only 1.4 % of all registered CDM projects (Bryan *et al.* 2008). Moreover, most of these projects (14 out of 18) were located in South Africa, and only six were agricultural related – i.e. involving biomass energy production from forest residues and crops, reforestation and afforestation and biogas production from animal manure (UNEP 2008a). The African Ministerial Conference on the Environment preparatory meeting to the 12th session of the COP expressed concern over participation by African countries in the CDM and noted the need to advance regional equity in the distribution of CDM projects and called for urgent measures to increase Africa’s participation in the CDM (UNEP 2006).

Participating in the CDM is complicated, and most African organisations find it difficult to meet the conditions. Box 6 below, which presents the CDM project cycle conditions as stated by the UNFCCC, shows that it could indeed be difficult for many organisations in African countries to meet the conditions of participating in the CDM.

Box 6: The CDM project cycle

Participants must prepare a project design document, including a description of the baseline and monitoring methodology to be used, an analysis of environmental impacts, comments received from local stakeholders and a description of new and additional environmental benefits that the project is intended to generate. A designated entity accredited by the CDM Executive Board (also referred to as Designated Operational Entity (DOE)) will then review this document and, after providing an opportunity for public comment, decide whether or not to validate it.

When a project is duly validated, the operational entity will forward it to the CDM Executive Board for formal registration. Unless a participating Party or three Executive Board Members request a review of the project, its registration becomes final after eight weeks.

Once a project is running, it will be monitored by the participants. They will prepare a monitoring report, including an estimate of CERs generated by the project, and will submit it for verification by a DOE. To avoid conflict of interest, this will usually be a different operational entity to that which validated the project. Following a detailed review of the project, which may include an onsite inspection, the operational entity will produce a verification report and, if all is well, will then certify the emission reductions as real. Unless a participating Party or three Executive Board members request a review within 15 days, the Board will issue the CERs and distribute them to project participants as requested.

Finally, CERs generated by CDM projects will be subject to a levy known as the 'share of the proceeds'. 2% of the CERs from each project will be paid into the Adaptation Fund to help particularly vulnerable developing countries adapt to the adverse effects of climate change. Projects in least developed countries are exempt from paying this share of the proceeds. Another percentage, yet to be determined, will be levied on projects to cover the CDM's administrative costs. In the meantime Parties have been urged to help finance these expenses by making voluntary contributions to a UNFCCC Trust Fund for Supplementary activities.

Source: UNFCCC 2003, p.21

Some of the important barriers to sub-Saharan Africa's contribution to reduction in GHGs through the CDM, outlined in Box 6, include:

- The requirement for establishing a clear baseline for a project and demonstrating that emission reductions would not have occurred in the absence of the project (i.e. the 'additionality rule');
- Lack of technical training and support for many developing countries in setting benchmarks;
- Poor availability and quality of data in most developing countries;
- High transaction costs in participating in CDM projects - i.e. cost of providing information about carbon benefits to potential buyers (Annex I countries), communicating with project partners, and ensuring parties fulfil their contractual obligations; and

- The costs of required measurement and monitoring are often considerable.

(Bryan et al. 2008, p.2)

The CDM generally benefits projects dealing with energy and power sources, overlooking soil carbon sequestration projects and avoiding deforestation projects, which are those carrying significant potentials for climate change mitigation in many African countries (Bryan *et al.* 2008). As of November 2008, only 5% of the projects in the CDM pipeline (under validation or registration request, or being registered) were agriculturally based projects (UNEP 2008b).

To some extent the problem lies with the European Union's Emission Trading Scheme (EU ETS), which is the largest multi-country, multi-sector greenhouse gas emission trading scheme worldwide, and does not allow the purchase of carbon credits from forestry, agriculture or "agroforestry" projects (but only from industrial sources).⁹ Some of the reasons for avoiding soil carbon sequestration and other agriculture-based projects include lack of reliable methods for measuring carbon stored in trees or soil, particularly if it is stored on small landholdings, such as the farms typical of sub-Saharan Africa. However, this rationale may no longer be justified as scientists can now use satellite imagery and infrared spectroscopy to determine the amount of carbon captured by small farms in Africa (Science and Development Network 2007).

6.5 Main climate change players and initiatives in Africa

6.5.1. The New Partnership for Africa's Development (NEPAD)

The NEPAD Environment Division identified climate change as a major component in its programme of work and NEPAD addresses climate change at policy level through its *Environment Action Plan*, as well as its *Sub-Regional Environment Action Plan*. NEPAD has also fostered collaboration on various issues including climate change with institutions such as the United Nations Environmental Program (UNEP) and the United Nations Environmental Commission for Africa (UNECA), and programmes such as the Climate Change for Adaptation in Africa (CCAA) programme aimed at generating information and data on climate change.

The major challenge NEPAD faces with regard to addressing climate change is limited data on the subject matter and lack of awareness on the issue. Also, there is currently limited capacity at NEPAD Secretariat to deal with climate change; however, efforts are underway to increase human resource capacity in the Environment Unit in order to deal better with climate change (Nyirenda 2008).

6.5.2. The Southern African Development Community (SADC)

Climate change is not covered comprehensively by any of the SADC policies. The SADC policy on environment and sustainable development makes reference to climate change, but there are no SADC-level climate change initiatives, programmes or projects. SADC is, however, currently

⁹ The EU-ETS commenced operation in January 2005 and currently covers more than 10,000 installations in the energy and industrial sectors which are collectively responsible for close to half of the EU's emissions of CO₂ and 40% of its total greenhouse gas emissions. More information is available at: http://ec.europa.eu/environment/climat/emission/index_en.htm.

developing a *Protocol on Environment and Sustainable Development*, which will also address climate change.

According to Nyirenda (2008), there are currently no collaborative mechanisms for climate change within SADC, and member states only meet at the bilateral level to prepare for UNFCCC COP meetings. At a technical level, National Meteorological Services (NMSs) meet for regional seasonal climate forecasts under the auspices of the Drought Monitoring Centre. Nyirenda (2008) also notes that limited by financial and human resource capacity, the SADC Secretariat is currently not well poised to deal with climate change issues.

6.5.3. The Common Market for Eastern and Southern Africa (COMESA)

The Secretariat for the Common Market for Eastern and Southern Africa (COMESA) has developed a comprehensive approach and programme initiative to address climate change within the context of its responsibilities and strategy for promotion of the Comprehensive Africa Agriculture Development Programme (CAADP). The Climate Initiative is run in partnership with other institutions, among them NEPAD, the TerrAfrica support structure, World Wide Fund for Nature (WWF), World Agro-forestry Centre (ICRAF), International Food Policy Research Institute (IFPRI), the Food, Agriculture and Natural Resources Policy Analysis Network (FANRPAN), the Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA), Forum for Agricultural Research in Africa (FARA), International Finance Corporation (IFC), and African Development Bank (AfDB).

The overall goal of the Climate Initiative is to contribute to the establishment of sustainable landscapes and livelihoods, including adaptation and mitigation to climate change. According to COMESA, this initiative will have multiple benefits, including the promotion of sustainable agriculture and land-use practices, biodiversity conservation, maintenance of environmental services, successful adaptation to climate change, and improvements in rural livelihoods. In addition, it will enable the delivery of cost-effective and verifiable reductions in GHG emissions. The COMESA Climate Initiative also aims to address the challenges constraining African agriculture and forestry projects from participating in the CDM and to promote the acceptance of agricultural and land use projects into the world's carbon markets (COMESA 2008).

6.5.4. Other institutions addressing climate change in southern Africa

Climate change is being addressed by a variety of institutions including national and local governments in different countries, non-governmental and community-based organisations, research and academic institutions, and bilateral and multilateral agencies operating at different levels. A list of some of the main institutions addressing climate change issues in southern Africa is provided in Appendix 1.

6.5.5. Specific initiatives to improve Africa's participation in carbon markets

There have been recent efforts to get more African countries to participate in carbon markets, and particularly for the markets to recognise African carbon sequestration projects in view of the December 2009 Copenhagen COP that will decide on a new climate treaty to replace the Kyoto Protocol.

The Africa Bio-Carbon Initiative

This initiative, championed by COMESA on behalf of 26 African countries in eastern and southern Africa, was launched at the COP 14 meeting in December 2008 in Poznan, Poland. The launch of the initiative was preceded by the Nairobi Declaration of 7 November 2008, which was made by a meeting of the COMESA ministers of agriculture and environment in preparation for the COP 14 meeting. The declaration advocates for the expansion of eligible categories of projects to benefit from carbon credits and other international incentives in the post-Kyoto treaty to include sustainable land management, including sustainable agriculture, sustainable forest management, afforestation and reforestation, reduced emissions from deforestation and forest degradation, thereby enabling 'greener agriculture' and promoting agricultural productivity in a way that improves resilience and adaptation to climate change. The declaration also addresses obstacles to the participation of African countries in carbon markets, e.g. engaging regional and international organisations to assist in developing methodologies for monitoring carbon sequestration in agricultural and agro-forestry systems, which are simple enough to allow wide participation in the carbon trading business.¹⁰

The Africa Bio-Carbon Initiative is premised on the fact that agriculture, forestry and all types of land use provide important opportunities to mitigate climate change and incentivise sustainable land use throughout the developing world. However, the initiative made little headway at Poznan, as there were concerns from some groups about:

- Conversion of natural grasslands to monoculture industrial timber plantations;
- Conversion of natural forests and formerly forested lands into monoculture industrial plantations;
- Heavy use of toxic chemicals associated with reduced tillage; and
- Accurate measurement of reductions due to the broad range of activities included in the bio-carbon initiative.

The Africa-wide Civil Society Climate Change Initiative for Policy Dialogues (ACCID)

The Africa-wide Civil Society Climate Change Initiative for Policy Dialogues (ACCID) is an initiative supported by SADC and COMESA, and coordinated by FANRPAN. The goal of the initiative is to achieve a post-2012 climate change framework that acknowledges and rewards African countries that contribute to addressing climate change through sustainable agriculture, forest management, and other environmental conservation practices. The initiative mobilises governments and civil society organisations (CSOs) to discuss the Africa Bio-Carbon proposal. The main objective of this dialogue is to ensure the alignment of African governments and CSOs regarding Africa's approach to tackling the current and future climate change negotiations. The dialogue should result in a common approach to advocating for a post-2012 protocol that includes sustainable agriculture and forestry management.

The initiative also calls for release of funding for research and the development of demonstration activities to enhance learning and ensure that agriculture/forestry/land use activities are rewarded and eligible for funding in the international post-2012 framework.
(ACCID 2009)

¹⁰ http://about.comesa.int/attachments/060_Nairobi%20DECLARATION_november2008.pdf

7. Climate Change-related Opportunities for Agriculture in Southern Africa

7.1 Mitigation opportunities

7.1.2. Participation of southern African farmers in carbon markets

Some agriculture, forestry, and other land use-based interventions provide an important opportunity to mitigate greenhouse gas emissions (see section 5.1.). These interventions are an approved approach for implementing sections of the Kyoto Protocol — specifically activities facilitating the removal or sequestration of CO₂ from the atmosphere through projects facilitating photosynthesis (e.g. afforestation). Under the Kyoto Protocol (Article 3.4) and other GHG protocols, these CO₂ removals are tradable as emission offset credits.

When the IPCC (IPCC 2000b) examined land conversion as means of sequestering carbon, it found that the greatest potential was in the conversion of previously degraded lands into well-managed agro-forestry systems. The conversion of unproductive croplands and grasslands to agro-forestry has the highest potential to sequester atmospheric carbon – reaching rates of three tons of carbon per hectare per year (Verchot *et al.* 2007). This conversion process can be encouraged by replenishing the soil fertility of smallholder farms in sub-Saharan Africa, and in implementing tree-based alternatives to slash-and-burn agriculture at the margins of the humid tropical forest worldwide.

In theory, given the genuine potential of agriculture and forestry to sequester carbon and reduce emissions on one hand, and Africa's vast forest and agricultural lands on the other hand, there are substantial opportunities for farmers in southern Africa to benefit from climate change mitigation schemes such as the CDM, as farmers in other parts of the world have benefited. For example, in the USA, the North Dakota Farmers Union's Carbon Credit Program allows agricultural producers and landowners to earn income by storing carbon in their soil through no-till crop production, conversion of cropland to grass, sustainable management of native rangelands and tree plantings on previously non-forested or degraded land (NDFU 2009). In addition, capturing methane from anaerobic manure digester systems can also earn carbon credits.

In practice, African participation in carbon markets has been negligible (see section 6.4.6). Despite the best efforts of proponents of the scheme, the poorest regions of the world with significant potential carbon offsets are being shut out of a market now valued in excess of USD 64 billion (World Bank 2008b). Under the terms of the Kyoto Protocol, credits can be issued for afforestation, reforestation, agro-forestry, enhanced natural regeneration, re-vegetation of degraded lands, reduced soil tillage, and other agricultural practices to increase soil carbon or extend lifetimes of wood products (known together as LULUCF). Carbon markets, however, have failed so far to capitalise on this opportunity. The participation by the least developed countries has been constrained by:

- The absence of cost-effective measurement and monitoring systems for LULUCF projects;
- Lack of knowledge of sustainable land management technologies, techniques and practices that sequester carbon;

- Weak institutional capabilities and frequently perverse policies regarding sustainable land management, agro-forestry, forestry and often even the rural poor in most developing countries;
- Slow adoption of agro-forestry and livelihood strategies for sustainable land management; and
- Relatively slow maturation of carbon markets for agricultural and land use projects.

The constrained involvement of African countries in the carbon markets is particularly unfair to the millions of small-scale farmers in Africa, whose livelihoods and food security are threatened by climate change caused by emissions from wealthy nations. However, the current international climate negotiations that will result in a post-Kyoto framework provide an opportunity to advocate for the inclusion of African farmers in carbon markets. To this end, there are international efforts to ensure the recognition of Africa's unexploited potential in global mitigation efforts and the inclusion of REDD (Reducing Emission from Deforestation and Degradation) and AFOLU (Agriculture, Forestry and Other sustainable Land Use) approaches in global protocols.

Given the prevailing situation in the carbon markets, southern African farmers and their organisations need to join advocacy efforts for the expansion of carbon trading mechanisms to reward sustainable farming practices in Africa. These efforts should influence the current climate negotiation processes so that the post-Kyoto treaty is more favourable for agriculture in general, but particularly for the participation of African farmers in the carbon trade.

Changing mindsets and behaviours of both African farmers and policy-makers in favour of climate-friendly agricultural practices and policies are an important aspect of the global mitigation efforts. In many African countries, like Kenya and Malawi, farmers and policymakers are beginning to view agro-forestry as an environmentally sustainable way to boost income and production on small farms (Verchot *et al.* 2007). Among the most popular applications are those that also efficiently trap and store carbon, including fodder trees that provide feed for dairy cows, fruit and nut trees that produce food, home gardens that supply a variety of products to enrich diets, etc. The return on investment from these projects can be substantial; however returns can also take several years to recoup. Subsistence farmers might be more willing to invest in them if they knew that their land and the trees they plant might generate revenue as a carbon credit. Rich countries eager to reduce their emissions through offsets would also benefit from engaging with developing countries and their farmers through the carbon market.

The agricultural sector in southern Africa also has to prepare itself for participation in carbon markets by addressing capacity needs to ensure that the sector is able to meet requirements for participation in terms of skills and knowledge. Mechanisms to ensure that the requisite skills are available must be established. Above all, farmers need to have the knowledge and skills to practise sustainable land management practices. To this end, African countries should identify and assess their strengths in terms of LULUCF and invest in those areas to ensure maximisation of their existing potential through participation in the carbon markets.

To achieve this maximised potential of carbon markets for African farmers, the various issues related to participation in carbon markets should not be treated in isolation of the other agricultural issues. For example, strengthening institutions, capacitating the agricultural sector to be more

involved in, and to better manage, agricultural value chains to ensure that they are carbon efficient from start to finish could build significant opportunities to benefit from the carbon trade.

7.1.2. Other ways

Organic agriculture is also gaining credit as a valid mitigation and adaptation strategy for developing countries. By enhancing biodiversity, biological cycles and soil biological activity, the production process of organic farming implies lower greenhouse gas emissions and more resilient production systems. Empirical evidence has also shown that in many instances organic farming can be more productive and profitable than conventional agriculture (ICTSD 2008).

Ecolabelling schemes could also constitute an incentive for African farmers and other stakeholders in the food supply chain to adopt climate-friendly practices. By signalling that a certain product is eco-friendly, ecolabels can attract the preference of some consumers. Currently, ecolabelled goods only capture niche market (mostly in western countries), and their percentage of the total demand is marginal. Nonetheless, as consumer awareness is raised by the many campaigns that are being conducted within the framework of the global mobilisation against climate change, demand for such products could increase. In addition, ecolabels should be equitable so as to benefit producers from developing countries, i.e. they should be fair in terms of trade impact and market access. Current labels often refer only to the transport aspect of produce, which is just one component of the carbon footprint – the component in which developing countries have a distinct disadvantage. The standards for carbon labels, often set by private initiatives, can thus become a non-tariff barrier to market access, and as such be detrimental to farmers from the South (ICTSD 2008).

This disadvantage is in spite of the fact that, when considering the entire supply chain, agri-exporters operating in developing countries often produce less carbon emissions (Business Daily 2009; Ghisu 2009). Therefore different labelling schemes that consider the entire 'life cycle' of food commodities in the value chain and its related carbon emissions should be advocated for to benefit African farmers (Ghisu 2009). As there is a high degree of national interest in ensuring market access, African governments should be more involved in standards improvement and ecolabelling schemes for agricultural products (Maur 2008).

7.2 Adaptation opportunities

Multilateral funds, including the UNFCCC Adaptation Fund and the Least-Developed countries Fund, the GEF Strategic Pilot on Adaptation and Special Climate Change Fund, are available to facilitate adaptation. The World Bank Group also uses numerous instruments – grants, concessional credits, various types of loans and guarantees, equity, carbon finance, etc. – to help developing countries finance adaptation to climate change. For example, the Pilot Program for Climate Resilience (PPCR) under the Strategic Climate Fund will provide about USD 500 million for scaled-up action in integrating climate resilience into national development planning in nine developing countries. It is designed to complement existing sources of adaptation funding and to deliver a package of funding at scale to help transform national development planning to make it more climate resilient, including promotion of institutional change, capacity building and learning through implementation of climate resilient national development priorities. In southern Africa, Mozambique and Zambia will be part of the pilot intervention (World Bank 2008c).

Many other development agencies, including bilateral cooperation interventions and international NGOs, are also active in addressing adaptation issues in southern Africa (See Appendix 1). The farmers of southern Africa and their organisations should engage with these initiatives in order to get as much information and support as possible to adapt to climate change.

However a huge gap remains between needed and available funds for adaptation. For instance, the total amount of resources committed to adaptation through the UNFCCC channels over the past ten years is less than USD 400 million, whereas the World Bank's initial estimates of the cost to developing countries' adaptation ranged from USD 10 to 40 billion annually (World Bank 2006). Moreover, there is a clear imbalance between the resources directed to adaptation versus mitigation. In the GEF, for instance, a total of USD 90 million has been earmarked for mitigation activities, whereas only USD 20.4 million has been directed to adaptation measures (ICTSD 2008).

Even if temperatures are contained, many developing countries, including in southern Africa, will still suffer significant climate change despite having minimum responsibility in comparison to developed countries (UN DESA 2009b). Therefore, increased financial resources to assist these countries to adapt to and mitigate the effects of climate change within their development framework can be considered as a moral obligation from industrialised countries.

It has been established that agriculture in southern Africa will be profoundly impacted by climate change. Given agriculture's role in ensuring social peace, economical growth and political stability in most countries in the region, farmers should ardently advocate for additional funding – on a massive scale – to enable adaptation measures for the region's agricultural sector. Moreover, as some interventions, such as appropriate irrigation development, have long gestation lags, these additional funds should be rapidly and transparently made available.

Finally, as costs of adaptation are likely to be high in the region, and solutions will involve difficult choices and trade-offs, effective strategic planning is also required in addition to sufficient resources. Therefore, farmers' representatives should lobby policy-makers at all levels so that they develop comprehensive and inclusive institutional responses to climate change that incorporate adaptation measures into wider development planning and budgeting processes, positioning agriculture as a priority.

7.3 Broadening the scope of opportunities

Technology plays an important role in the potential solutions to both mitigate and adapt to climate change. However a number of economic, technical, policy, regulatory and institutional barriers still persist regarding the development or transfer of climate change-friendly technology in developing countries. International trade negotiations, including those concerning intellectual property rights (IPR) and Environmental Goods and Services (EGS), along with supportive global, regional and national policies, could be instrumental in developing and disseminating the appropriate technologies in the South. However, in developing countries both the causes and impacts of climate change have other major underlying causes (e.g. rapid, uncontrolled urbanisation and natural resources degradation, linked to unemployment, low-skilled labour, and access to land), the provision of appropriate technologies is accompanied by the need to provide these countries with the technical assistance, capacity building and foreign direct investments they crucially need to

address these underlying causes of climate change-inducing trends and challenges that they face (ICTSD 2008).

The above introduces the important role of the private sector in terms of investment and technology transfer. As such, it is imperative that the private sector views initiatives like the Clean Development Mechanism as a profitable opportunity and an important tool for technology transfer; it must also be encouraged to consider global emission trading schemes as an integral part of future business interactions and trade architecture (ICTSD 2008).

Other financial resources linked to various areas of research and development could also be accessed and/or mobilised as the climate change issue is broadly intertwined with other critical issues for the South, namely social and economic development and trade issues. On the development front, the United Nations now promotes 'climate-smart development' that aims to mainstream climate change in any development process, emphasising the need for more innovative and regular sources of multilateral funding to meet the adaptation challenges (UN DESA 2009b). The Overseas Development Assistance (ODA) initiatives should follow suit, at least in the way it is packaged. Nonetheless, the UNFCCC stipulates that climate change-related assistance to developing countries should be additional to – and not a reclassification of – usual development assistance, and Annex I countries should be urged to meet their commitments. In that regard, G77 and China have suggested that OECD countries devote another 0.5 to 1% of their growth national income (GNI) exclusively for climate change related assistance (*ibid*). Another option lies in international taxes or levies on carbon emission. UN estimates calculate that more than USD 500 billion per annum could be generated in OECD countries through carbon imposition, of which a significant share could be devoted to climate change related assistance to developing countries (*ibid*).

In relation to trade, the international community committed to scale up Aid for Trade within the framework of WTO (ICSTD 2008). In order to enhance the competitiveness and resilience of developing countries, it could be advocated that Aid for Trade packages focus on climate-adapted policy, diversified productive structure and resilient and climate adapted infrastructure. Particularly, trade and climate change-related financing mechanisms could be synergistic if directed to strengthen the supply side constraints of developing countries (ICTSD 2008). Recognised and well-managed collaborations between funding could increase the overall positive impact of funding in terms of long-term sustainable development (Maur 2008).

8. Lessons Learned and Looking Ahead

As established throughout this document, climate change impacts many aspects of the agricultural and agri-related sectors. Addressing climate change effectively necessitates the application of diverse strategies and drawing from various sources of information and experiences. Based on issues discussed in this document, this section summarises key points to take into account when considering and approach to climate change in the southern African agricultural sector.

Need for a long-term planned approach to adaptation

Many rural communities and indigenous peoples in southern Africa have maintained a balance between natural resource use and sustainable development for centuries, adapting autonomously

to natural climate changes. While many of these measures have been effective in ensuring survival under diverse climatic conditions, they may be ineffective in the face of current acceleration climate change. A longer-term concretely planned and institutionalised approach for adaptation is therefore needed to secure farmers' sustainable livelihoods. It must incorporate additional information, technologies and investments, infrastructures and institutions and integrate them with the decision-making environment. Insurance, safety nets and cash transfers to reduce vulnerability to shocks are also part of the solution (UNFCCC 2007).

Enhancing opportunities for multi-dimensional adaptation

Impacts of climate change on agriculture in the region will not only be long-term but also of a multi-dimensional nature. Thus, strategies for dealing with climate change have to focus on a wide range of issues. In terms of technical options for example, any planned approach to climate change adaptation has to include various components, including new cultivation practices, new seed varieties, etc. It also must include an appropriate incentive structure, such as targeted payment for environmental services, which can expand farmers' options for both adaptation and mitigation. The various potential outcomes make adaptation a complex and a case-specific undertaking, which requires extensive planning and simulation of adaptation activities.

Increasing availability of and access to knowledge and information

High-quality climate change information at all levels, and tools for risks management that help to improve climate predictions, are essential for farmers to deal with climate change. In Malawi, for instance, information on rainfall and storm patterns was essential for agricultural planning to avoid food shortages (ActionAid 2008). However, information should not be restricted to climate forecasts, as it is imperative to take advantage of all available knowledge and information when addressing climate change. Local people often have considerable knowledge of weather-related hazards and time-tested adaptation techniques. This information needs to be harnessed effectively and combined with other forms of knowledge. It is necessary to build capacity at local level to advocate action and contribute to raising climate change awareness (Commonwealth Secretariat 2006).

Because it is not possible to predict exactly how, where, and/or when the impacts of climate change will occur, it is necessary to involve and develop the capacities of local, national and regional level institutions to undertake long-term analysis of climate impacts, and then link the findings to climate change projections. Increasing awareness of climate change among all stakeholders is a key component of addressing climate change. Nhemachena and Hassan (2007) report that awareness of climate change is an important determinant of farm level adaptation in southern Africa.

Enhancing farmers' capacity to address climate change

Responding to climate change is likely to be hampered by lack of capacity in governments and farmers communities to deal with the complexities of this phenomenon. In some particularly vulnerable areas, e.g. among smallholder farmers, climate change impacts are already so severe and resources so scarce that some communities are forced to merely cope with impacts (ActionAid 2008). The adaptive capacity required to respond to the magnitude of the present climate change-related risks makes it necessary to enhance farmers' and governments' institutional and human resources to ensure an effective and coordinated response. Given the socio-economic weaknesses

that characterise most southern African countries international financial resources would need to be made available to facilitate these capacity building efforts.

Addressing the gender differentiated impact of climate change

Climate change will not affect women and men in the same way. Women are indeed those most engaged in agricultural activities that highly rely on natural resources and climatic conditions. It is crucial that all aspects related to climate change such as mitigation, adaptation, policy development and decision making include a gender perspective. To be sustainable, climate change initiatives need to be gender sensitive.

Reaching vulnerable groups

Despite the national and global discourses on the importance of adaptation to climate change, measures taken by governments and donors are not reaching the most vulnerable groups, such as poor farmers in remote areas (ActionAid 2008). Increased efforts need to be made to reach the vulnerable farmers so that they too can get assistance in adapting to climate change.

Acknowledging and practicing the value of collective actions

Adaptation work carried in Africa indicates that communities seem to adapt best when working as a collective rather than as individuals (ActionAid 2008; Giles 2007). The main strategies of collective adaptation include changes to agricultural practices; formation of social networks; seeking commercial products, such as investing in livestock and livelihood diversification, e.g. seeking off-farm employment.

Fostering mitigation practices through enhancing carbon trade opportunities

While agriculture is one of the sectors contributing to climate change through greenhouse gas emissions, the sector can play a key role in climate change mitigation. The potential financial compensation for climate change mitigation activities, which could be obtained through the international carbon trade, could make it economically attractive for farmers to engage in climate change mitigation through the carbon trade.

However, it is currently extremely difficult for agricultural projects in Africa to benefit from the global carbon trade due to numerous and varied constraints. These constraints include absence of cost-effective measurement and monitoring systems for agricultural projects; lack of knowledge and weak institutional capabilities with regards to sustainable land management technologies, techniques and practices that can sequester carbon; and relatively slow maturation of carbon markets for agricultural and land use projects. Efforts should be directed at addressing these obstacles to ensure that farmers have the skills and on-going support required to ensure that they are prepared to utilise opportunities in the carbon trade when they arise in order to secure sustained success in their climate change and development efforts.

Facilitating the promotion of appropriate technology

Technology can play an important role in exploring potential solutions to both mitigate and adapt to climate change. However, the development or transfer of climate change-friendly technology, as well as its adaptability to developing countries, need to be enabled by lifting the economic,

technical, policy, regulatory and institutional barriers that still exist. This requires supportive global, regional and national policies as well as favourable outcomes during the international trade negotiations, particularly regarding IPR and EGS. Moreover, there is a need to more fully engage the private sector through investment in the development and transfer of technologies that could contribute to addressing climate change challenges.

Climate change mainstreaming

Agricultural policy, research and resource allocations must take account of climate change models that minimise impacts on food security and seize opportunities offered by both traditional and alternative crops (Commonwealth Secretariat 2006). As agriculture is also one of the main drivers of economic growth in most southern African countries, the impacts of climate change on commercial crops should also be looked at and addressed by all sectors (public, research, civil society, etc.).

Furthermore, because agriculture is central to most southern African economies, policies concerning agriculture and climate change should not be addressed in isolation of other sectors and initiatives, but needs to be linked collaboratively with other development initiatives such as the Millennium Development Goals (MDGs) or the Aid for Trade. Climate change needs to be addressed using a multi-sectoral approach and should be mainstreamed in any national, regional or continental development planning frameworks and programmes, including Poverty Reduction Strategy Papers (PRSPs), the SADC Regional Indicative Strategic Development Plan (RISDP), COMESA Medium Term Strategic Plan, and the NEPAD-CAADP.

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Glossary of Terms

Adaptation: Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. (UNFCCC, 2009i)

Aerobic: Living or active only in the presence of oxygen. A life or process that occurs in and is dependent upon oxygen. (Merriam-Webster's Online Dictionary, 2009)

Afforestation: the act or process of establishing a forest especially on land not previously forested. (Merriam-Webster's Online Dictionary, 2009)

Anaerobic: A condition in which no oxygen is available in any form for example anaerobic environment. Organisms that grow in the absence of dissolved oxygen are called *anaerobic*. (Merriam Webster's Online Dictionary, 2009)

Anthropogenic: Resulting from human activities. In the context of greenhouse gases the term would refer to emissions that are produced as the result of human activities. (IPCC, 2007; Webster's Online Dictionary, 2009)

C market: A popular, but misleading, term for a trading system through which countries may buy or sell units of greenhouse gas emissions in an effort to meet their national limits on emissions, either under the Kyoto Protocol or under other agreements, such as that among member states of the European Union. The term comes from the fact that carbon dioxide is the predominant greenhouse gas and other gases are measured in units called "carbon-dioxide equivalents". (UNFCCC, 2009i)

C sequestration: The process of removing carbon from the atmosphere and depositing it in a reservoir. (UNFCCC, 2009i)

C sink: Any process, activity or mechanism that removes a greenhouse gas, an aerosol or a precursor of a greenhouse gas or aerosol from the atmosphere. (IPCC, 2007)

Certified Emission Reduction (CER): A Kyoto Protocol unit equal to 1 metric tonne of CO₂ equivalent. CERs are issued for emission reductions from CDM project activities. Two special types of CERs called temporary certified emission reduction (tCERs) and long-term certified emission reductions (ICERs) are issued for emission removals from afforestation and reforestation CDM projects. (UNFCCC, 2009i)

Clean Development Mechanism (CDM): A mechanism under the Kyoto Protocol through which developed countries may finance greenhouse-gas emission reduction or removal projects in developing countries, and receive credits for doing so which they may apply towards meeting mandatory limits on their own emissions. (UNFCCC, 2009i)

Climate change: Change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable periods. (UNFCCC, 2009i)

Conference of the Parties (COP): The supreme body of the UNFCCC. It currently meets once a year to review the Convention's progress. (UNFCCC, 2009)

The word "conference" is not used here in the sense of "meeting" but rather of "association," which explains the seemingly redundant expression "fourth session of the Conference of the Parties".

Coping strategy: The application of indigenous knowledge in the face of hazards and other threats. Strategies can be economic/material, technological, social/ organisational and cultural. (Twigg, 2004)

Equivalent carbon dioxide (CO₂) concentration: The concentration of carbon dioxide that would cause the same amount of radiative forcing as a given mixture of carbon dioxide and other greenhouse gases. (IPCC, 2007)

Equivalent carbon dioxide (CO₂) emission: The amount of carbon dioxide emission that would cause the same integrated radiative forcing, over a given time horizon, as an emitted amount of a well mixed greenhouse gas or a mixture of well mixed greenhouse gases. The equivalent carbon dioxide emission is obtained by multiplying the emission of a well-mixed greenhouse gas by its Global Warming Potential for the given time horizon. For a mix of greenhouse gases it is obtained by summing the equivalent carbon dioxide emissions of each gas. Equivalent carbon dioxide emission is a standard and useful metric for comparing emissions of different greenhouse gases but does not imply exact equivalence of the corresponding climate change responses. (IPCC, 2007)

Global warming: is an average increase in the temperature of the atmosphere near the Earth's surface and in the troposphere, which can contribute to changes in global climate patterns. Global warming can occur from a variety of causes, both natural and human induced. In common usage, "global warming" often refers to the warming that can occur as a result of increased emissions of greenhouse gases from human activities. (US-EPA, 2009)

Greenhouse gas: The atmospheric gases responsible for causing global warming and climate change. The major GHGs are carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (N₂O). Less prevalent – but very powerful – greenhouse gases are hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF₆). (UNFCCC, 2009i)

Greenhouse effect: Greenhouse gases effectively absorb thermal infrared radiation, emitted by the Earth's surface, by the atmosphere itself due to the same gases, and by clouds. Atmospheric radiation is emitted to all sides, including downward to the Earth's surface. Thus, greenhouse gases trap heat within the surface-troposphere system. This is called the greenhouse effect. Thermal infrared radiation in the troposphere is strongly coupled to the temperature of the atmosphere at the altitude at which it is emitted. In the troposphere, the

temperature generally decreases with height. Effectively, infrared radiation emitted to space originates from an altitude with a temperature of, on average, -19°C , in balance with the net incoming solar radiation, whereas the Earth's surface is kept at a much higher temperature of, on average, $+14^{\circ}\text{C}$. An increase in the concentration of greenhouse gases leads to an increased infrared opacity of the atmosphere, and therefore to an effective radiation into space from a higher altitude at a lower temperature. This causes a radiative forcing that leads to an enhancement of the greenhouse effect, the so-called enhanced greenhouse effect. (IPCC, 2007)

Kyoto protocol: an international agreement standing on its own, and requiring separate ratification by governments, but linked to the UNFCCC. It sets binding targets for 37 industrialised countries and the European community for reducing greenhouse gas (GHG) emissions (UNFCCC, 2009i). It was adopted in Kyoto, Japan, on 11 December 1997, entered into force on 16 February 2005 and will expire in 2012. Negotiations for a new global treaty to take effect at its expiration are under way and will culminate in talks in Copenhagen in December 2009. The three mechanisms for the Kyoto Protocol are i) Emissions trading – known as “the carbon market” ii) Clean development mechanism (CDM) and iii) Joint implementation (JI).

Land use change: refers to a change in the use or management of land by humans, which may lead to a change in land cover. Land cover and land use change may have an impact on the surface albedo, evapotranspiration, sources and sinks of greenhouse gases, or other properties of the climate system and may thus have a radiative forcing and/or other impacts on climate, locally or globally. (IPCC, 2007)

Land use, land-use change, and forestry (LULUCF): refers to the total of arrangements, activities and inputs undertaken in a certain land cover type (a set of human actions). The term land use is also used in the sense of the social and economic purposes for which land is managed for example grazing, timber extraction and conservation. (IPCC, 2007)

Mitigation: Structural and non-structural measures undertaken to reduce the adverse impact of natural hazards, environmental degradation and technological hazards (UNISDR, 2002). In the context of climate change, mitigation is human intervention to reduce the sources or enhance the sinks of greenhouse gases. (UNFCCC, 2009i)

Natural disaster: a serious disruption of the functioning of a community or household causing widespread human, material, economic or environmental losses which exceed the ability of the affected community/household to cope using its own resources (UNISDR, 2004). Disaster is what occurs when the impact of a hazard on a community (or section of community) overwhelms that community's ability to cope.

Reforestation: Action of renewing forest cover (as by natural seeding or by the artificial planting of seeds or young trees). (Merriam-Webster Online Dictionary, 2009)

Resilience: the capacity of a system, community or society to resist or to change in order that it may obtain an acceptable level of functioning and structure. This is determined by the degree

to which the social system is capable of organising itself and the ability to increase its capacity for learning and adaptation, including the capacity to recover from a disaster. (UNISDR, 2004)

Risk management: the systematic management of administrative decisions, organisation, operational skills and responsibilities to apply policies, strategies and practices for disaster risk reduction. (UNISDR, 2002)

Technology transfer: A broad set of processes covering the flows of know-how, experience and equipment for mitigating and adapting to climate change among different stakeholders. (UNFCCC, 2009i)

UNFCCC: The United Nations Framework Convention on Climate Change is an international environmental treaty aimed at stabilizing greenhouse gas (GHG) concentration in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system (UNFCCC, 2009b). It came into force on 21 March 1994 and a total of 192 countries have signed it internationally (UNFCCC, 2009c).

Vulnerability: The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity. (UNFCCC, 2009i)

Appendix : Main organisations involved in climate change initiatives in the agricultural sector in southern Africa (southern African countries indicated with grey highlight).

Organisation	Type	Countries of operation	Main Activities
African Agricultural Technology Foundation	Public-private partnership	Kenya, Mozambique, South Africa, Tanzania and Uganda	Climate change adaptation – development of drought-tolerant African maize using conventional breeding and biotechnology
ACMAD (Africa Centre for Meteorological Applications for Development)	UN Department	Based in Niger but serves all African countries	Gathering, collating and disseminating weather forecast information.
ActionAid	NGO (International antipoverty agency)	Some African countries including Malawi, Mozambique, Tanzania and Zambia	Various activities to end poverty including food security and adaptation to climate change
DFID Department for International Development (UK)	Aid Agency	Africa (incl. all SADC countries), Asia, Latin America and the Caribbean.	Various development activities including funding the Climate Change Adaptation in Africa Programme and the Regional Hunger and Vulnerability Programme
ECA (United Nations Economic Commission for Africa)	UN Commission	Africa	Developing appropriate climate change response policy and intervention agenda for the African region, including: <ul style="list-style-type: none"> .-mainstreaming climate change into development policy, strategies and programmes; .mitigation and support to negotiations and international agreements on climate change; .developing strategies for helping African countries to benefit from carbon market
FAO (The United Nations Food and Agriculture Organisation)	UN Agency	Africa (incl. all SADC countries), Asia, the Pacific, Latin America and Caribbean.	Support food security in Member Countries. Undertakes a range of activities and recently launched a climate change adaptation strategy aimed primarily at focusing the appropriate units and their efforts within the organisation. FAO does not specifically apply climate change projections in its agricultural support programs.
IFAD	Specialised UN Agency	Africa (incl. all SADC countries), Asia, the Pacific, Latin America and Caribbean.	Working with farmers to address climate change at the local level. Developing financing mechanisms for smallholder farmers to mitigate the effects of climate change.

Organisation	Type	Countries of operation	Main Activities
International Development Research Centre (IDRC) (Canada)	Development Agency – Research focus	Africa (incl. Botswana, Malawi, Mozambique, South Africa, Zambia and Zimbabwe), Asia, Latin America & the Caribbean.	Funding Climate Change Adaptation in Africa Programme – Programme aims to improve capacity of people and institutions to adapt to climate change. CCAA supports a number of activities that build research capacity and provides evidence to strengthen adaptation policies and plans.
South South North (SSN).	Functions as both a local NGO (SSN Africa) and an international network (SSN group)	South Africa	Use of climate change projections for adaptation planning e.g. use of climate forecast information by rooibos farmers.
START International: (Global Change SysTem for Analysis, Research and Training)	International Research and Analysis Organization	Africa, Asia, Oceania, Mediterranean region	Research activities in Africa covering food and water security and vulnerability to climate change impacts. START also promotes regional networks and research to inform policy.
Stockholm Environment Institute (SEI)	International Research Institute	International	Focus on adaptive resource management, particularly related to climatic risks, with expertise in water, food security and livelihoods. Involved in African agriculture through a number of projects such as the Climate Adaptation Plan for Ghana.
Swiss Agency for Development and Cooperation	Development Agency	South America and Caribbean, Asia, Middle East and Africa, incl. Angola, Zambia, Zimbabwe, Mozambique, Tanzania, Madagascar	Supports climate change mitigation and adaptation initiatives covering energy efficiency, renewable energy resources, agriculture and forestry
University of Cape Town – Climate Systems Analysis Group (CSAG)	University Research Department	Research covers whole of Africa	Engaged in empirical downscaling activities for climate change and climate projection scenarios



Southern African Confederation of Agricultural Unions

P.O. box 10480

Centurion 0046

South Africa

Tel: +27 (0) 12 644 08 08

Fax: + 27 (0) 12 644 83 86

Email : info@sacau.org

<http://www.sacau.org>