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GENERAL NOTICE

NOTICE 500 OF 2015

DEPARTMENT OF AGRICULTURE, FORESTRY AND FISHERIES

DRAFT CLIMATE CHANGE SECTOR PLAN FOR AGRICULTURE, FORESTRY AND FISHERIES

I, Senzeni Zokwana, Minister of Agriculture, Forestry and Fisheries hereby invite all interested parties to submit written inputs and comments on the **Draft Climate Change Adaptation and Mitigation Plan**.

Inputs and comments must be submitted in writing for attention IkafengK@daff.gov.za / SenzoM@daff.gov.za and Mittaa@daff.gov.za respectively within *60 days* from the date of this publication. Alternatively inputs and comments can be sent to:

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MINISTER OF AGRICULTURE, FORESTRY AND FISHERIES



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forestry & fisheries**

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Agriculture, forestry & fisheries
REPUBLIC OF SOUTH AFRICA

**DRAFT CLIMATE CHANGE ADAPTATION
AND MITIGATION PLAN FOR THE SOUTH
AFRICAN AGRICULTURAL AND
FORESTRY SECTORS**

MAY 2015

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ABBREVIATIONS

ACRU	Agricultural Catchments Research Unit Agrohydrological Simulation Model
AFOLU	Agriculture, Forestry and Other Land Use
AgriBEE	Agricultural Black Economic Empowerment Programme
ARC	Agricultural Research Council
CA	Conservation Agriculture
CBD	UN Convention on Biological Diversity
CBO	Community Based Organisation
CCAMP	Climate Change Adaptation and Mitigation Plan (this document)
CCSPAFF	Climate Change Sector Plan for Agriculture, Forestry and Fisheries
CDM	Clean Development Mechanism
CoP	Conference of Parties
DAFF	Department of Agriculture, Forestry and Fisheries
D: CCDM	Directorate of Climate Change and Disaster Management
DEA	Department of Environmental Affairs
DoE	Department of Energy
DST	Department of Science and Technology
DTI	Department of Trade and Industry
DWA	Department of Water Affairs
FSA	Forestry South Africa
GCM	General Circulation Model (also Global Climate Model)
GDP	Gross Domestic Product
GEF	Global Environmental Facility
GHG	Greenhouse Gas (Emissions)
ICFR	Institute for Commercial Forestry Research
IDP	Integrated Development Plans
IPCC	Intergovernmental Panel on Climate Change
IPCC FAR	Intergovernmental Panel on Climate Change Fourth Assessment Report
JI	Joint Implementation
KP	Kyoto Protocol
LADA	Land Degradation Assessment in Drylands Project
LTAS	Long Term Adaptation Scenarios
LTMS	Long Term Mitigation Scenarios
MAI	Mean Annual Increment
NCCRWP	National Climate Change Response White Paper
NGO	Non-Governmental Organisation
PCUs	Positive Chill Units
PFM	Participatory Forestry Management
R&D	Research and Development
RDI	Research, Development and Innovation
REDD	Reducing Emissions from Deforestation and forest Degradation
REDD+	Reducing Emissions from Deforestation and forest Degradation, plus Conservation
SAEON	South African Environmental Observation Network
SARVA	South African Risk and Vulnerability Atlas
SASRI	South African Sugarcane Research Institute
SAWS	South African Weather Service
SNC	South Africa's Second National Communication to the UNFCCC
SOC	Soil Organic Carbon
SRES	Special Report on Emission Scenarios
SSA	Sawmilling South Africa
SSSFs	Small Scale Subsistence Farmers
STEP	Subtropical Thicket Ecosystem Project

TNA	Technology Needs Assessment
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
WGCC	Working Group on Climate Change
WNCTs	Water and Nutrient Conservation Technologies
WOCAT	World Overview of Conservation Approaches and Technologies
WRC	Water Resources Commission

1. INTRODUCTION

1.1 Climate and Climate Change as Drivers of Agricultural Production in South Africa

There are many “drivers” of the agricultural sector in South Africa, each of which can have wide-ranging repercussions not only in the production of food, fibre and forests, but also on GDP, employment or foreign exchange earnings. One such “driver” that already varies from year to year, and within any given year, is climate. Climate is vital for the selection of appropriate crops for a given locality or site, irrespective of whether farmers are planning for maximum economic returns or for sustaining their immediate family’s livelihood, and the more detailed the knowledge, the more intelligently the land use can be planned on all scales, be they at the macro, farm or plot scales. Climate information is equally important for optimising agricultural practices and for day-to-day operational planning ranging from when and how much to irrigate, to timing of fertiliser application, the selection of cultivars / varieties or to deciding when to plant. The influence exercised by climate on living organisms is, however, exceedingly complex, not only because the individual climatic variables play important roles, but also because of the constant interaction between the variables.

Through direct and indirect human activities which are altering the composition of the global atmosphere, climate drivers such as rainfall, temperature and atmospheric carbon dioxide (CO₂) concentrations that affect agricultural activities and output, are projected to change non-uniformly in magnitude, direction and variability over the next few decades, not only on a global scale, but more particularly so regionally and locally within South Africa. Such human-induced climate change is projected to occur in addition to the already high natural climate variability which we experience, and in addition to the other stresses that beset the agriculture sector in South Africa.

Climate change, often perceived and described by many simply as “global warning”, has climatic ramifications well beyond merely averaged temperature increases, and through higher order perturbations in rainfall and temperature characteristics these changes present serious challenges to agriculture and forestry, which are the providers of food, feed, fibre, timber and energy, and which contribute significantly to the GDPs of economies worldwide, either directly or through knock-on effects. As such, climate change is causing grave concern at all levels of society worldwide because plants and animals may not be able to cope with, and adapt to, the progressive and projected changes in climate as well as we humans can and this poses a serious threat to ecosystems. Climate change dynamics are extremely complex and not yet well enough understood, especially regarding the extent, timing and impacts of projected changes. South Africa’s already high risk climatic environment by virtue of its straddling the 20 - 35°S latitudinal range which is transitional to winter, all year and summer rainfall producing synoptic regimes, renders it particularly sensitive and vulnerable to geographical shifts in climates. What is currently known, however, points to many serious effects that climate change can have on South Africa’s food security, socio-economic activities, human health, water resources, extreme weather events, low lying areas and infrastructure. The effects are not necessarily always negative, however, and positive spin-offs are likely to occur. These need to be identified and maximised.

As agriculture and forestry are the mainstay of livelihoods and economic growth, the Department of Agriculture, Forestry and Fisheries (DAFF) as well as other non-governmental role players (NGOs) in the broader agricultural sector have been proactive in initiating sector related climate change strategies and scenarios to promote climate change awareness and knowledge, advocate sustainable terrestrial and aquatic ecosystems-based production practices which minimise emissions of greenhouse gases, conserve the sector’s natural environments, promote adaptation and mitigate effects of climate change as far as possible.

Contributions towards reducing the levels of anthropogenic greenhouse gas production need to be actively encouraged. These include innovative alternatives in a fossil fuel-based economy. Adaptation strategies need to be developed and applied simultaneously, in order to deal with the vagaries of climatic variation and any negative impacts of severe weather events on both first and second economies. These need to be informed by vulnerability assessments and a comprehensive vulnerability audit for agriculture and forestry. This document sets out to address the above issues in a South African agricultural context and to formalise them through this Climate Change Adaptation and Mitigation Plan (CCAMP), the background, aims and objectives of which are described in the section which follows.

1.2 Background, Aims and Objectives

In implementing an effective climate change programme in compliance with the National Climate Change Response White Paper (NCCRWP, 2012) and in support of disaster risk management, DAFF has developed a Climate Change Sector Plan for Agriculture, Forestry and Fisheries (CCSPAFF, 2013). DAFF has, furthermore, also conducted numerous research projects on climate change including the Agricultural Greenhouse Gas Inventory and the “*Atlas of Climate Change and the South African Agricultural Sector: A 2010 Perspective*” (Schulze, 2011). The outputs of all of the above, as well as other cited literature, serve as a baseline for, and inform the development of, this CCAMP, which addresses agriculture and forestry, but not fisheries, and which simultaneously feeds from, and feeds into, the CCSPAFF.

1.3 Clarifying Terminology

Key concepts relating to climate change and its manifestations which are of critical importance to the agriculture and forestry sectors are clarified in Annexure A.

1.4 The Science of Climate Change: A Brief Overview from a South African Perspective

1.4.1 Climate Projections into the Future

Climates are changing as a result of an increase in concentrations of greenhouse gases (GHGs; i.e. methane CH₄, carbon dioxide CO₂, nitrous oxide N₂O, etc.) in the earth's atmosphere. This increase has occurred over the past two centuries due to anthropogenic (human driven) factors, particularly industrialisation through burning of fossil fuels such as coal, oils and natural gases mainly for energy generation, but also to unsustainable land use systems and clearing of forests, all resulting in increasing the concentration of GHGs. Such GHG emitting activities have significantly increased the atmosphere's absorption of the earth's outgoing infrared radiation, thereby enhancing the existing greenhouse effect, and then re-radiating part of it back to earth, resulting in a rising trend in global temperatures. Climate change thus refers to the changes of climate which are attributed directly or indirectly to human activities that alter the composition of the global atmosphere. This change in climate is superimposed onto natural climate variability which is experienced world-wide, but which is particularly severe over South Africa.

Future climate *projections* (which are NOT forecasts nor predictions) are scenario descriptions of possible future conditions based on the current understanding of the physics of the atmosphere, on assumptions about changing GHG emissions and their atmospheric concentrations, as well as on assumptions of future technological, economic and demographic trends. The skill of projections (i.e. their accuracy) depends strongly on how far into the future projections are made, which of a number of possible future GHG emissions pathways is considered, and on the climate variable considered (e.g. temperature projections are generally thought to be more skilful than rainfall projections). Deriving key regional messages about future potential change thus requires assessing multiple lines of evidence. Climate projections are assessed here from a range of climate models generically

termed GCMs, i.e. General Circulation Models or Global Climate Models, as it is not possible to identify a 'best' model for all relevant climate variables for South Africa (Schulze, 2012).

Projections of impacts in these sectors in South Africa are often complicated by different scientists applying different sets of climate scenarios and using different modelling approaches, thus making it challenging to extract coherent key messages. Climate projections used in the agricultural impact studies reported in this CCAMP have been based on the Intergovernmental Panel on Climate Change's (IPCC) Special Report on Emission Scenarios (SRES) so-called A2 emission scenario, which is essentially a "business as usual" scenario (or "storyline") representing CO₂ equivalent levels of above 500 ppm by 2050. Other scenarios are available, and new ones are being developed, and climate projections based on those should be used in follow-up studies.

Most of the impacts results reported in this document have been based on daily climate variable outputs from five IPCC (2007) GCMs, viz. CGCM3.1(T47), CNRM-CM3, ECHAM5/MPI-OM, GISS-ER and IPSL-CM4 (Schulze, 2011; 2012). Output from GCMs were statistically downscaled to over 2 600 rainfall and over 400 temperature stations by the Climate Systems Analysis Group at the University of Cape Town. Other GCMs, representing respectively drier and wetter future conditions, and based on other downscaling techniques (e.g. dynamic downscaling) are currently also used in South Africa. Most results reported in this document used the daily downscaled values from the five GCMs for present (1971 - 1990), intermediate future (2046 - 2065) and more distant future (2081 - 2100) time slices, with spatial representation of results for 5 838 relatively homogeneous agricultural zones, called Quinary Catchments, covering South Africa. From output of these multiple GCMs into crop yield and water related models median values of projected changes were computed.

Future rainfall projections remain challenging because complex rainfall-generating processes such as cloud formation and land surface-atmosphere interactions are not yet fully understood and resolved in climate models. Projections for South Africa's winter rainfall region in the southwest of the country consistently suggest future rainfall decreases, while summer rainfall region projections deviate less from present rainfall, with possible increases in rainfall amounts. Some key findings, elaborated upon in **Section 3**, show the following:

- All regions are very likely to be warmer in the future.
- Distinct patterns of projected decreases in winter rainfall in the southwest are a consistent message across GCM, RCM and statistically downscaled scenarios
- Similarly, projected increases in summer rainfall in the east seem stable and physically consistent with the projected circulation changes; however, there remains uncertainty in the magnitude of responses and with some local scale deviations.
- There is uncertainty about the location of the boundary between regions that show less rainfall in the west and similar or more rainfall in the east.
- The roles of mountain ranges and topography are critically important, especially in enhancing the projected east coast increases in precipitation and ameliorating the projected rainfall reductions on the Cape Mountains in the southwest of the country.

1.4.2 Are Changes in Climate as well as in Agricultural and Forestry Output Already Being Observed over South Africa?

Farmers already perceive changes in weather and climate characteristics to have taken place in the past few years / decades (See **Annexure A** for more details). Perceptions are just that, however, and it is the scientifically founded observations on changes in climate across South Africa over the past number of decades that are summarised below.

Temperature and temperature derivatives

It has been well established that observed surface air temperatures over land, and derived temperature measures which are relevant to agriculture (e.g. the number of days in winter and summer below or above critical thresholds; the number of frost occurrences per season;

first and last frost dates; heat units and positive chill units) have changed with statistical significance across South Africa since 1950 (Warburton *et al.*, 2005). These changes are consistent with, and have sometimes exceeded, the rate of mean global temperature rise.

In South Africa's Second National Communication (SNC, 2010) to the UN Framework Convention on Climate Change (UNFCCC) it is reported that within the subcontinent, a comprehensive analysis of recent trends (New *et al.*, 2006) showed patterns of temperature extremes to have changed that are consistent with warming over most of the region, with a large proportion of stations showing statistically significant trends for all temperature indices. From 1961 to 2000, the occurrence of extreme cold days and nights decreased by 3.7 and 6.0 days / nights per decade, respectively, and the occurrence of extreme hot days and nights increased by 8.2 and 8.6 days / nights per decade, respectively. In another recent study on South African temperature trends, Kruger and Shongwe (2004) detected a positive annual average temperature trend at 24 out of 26 stations. Warming trends are more obvious over the western interior, western and southern coastal regions, and less so over the central interior. Almost 90 % of the stations recorded positive annual mean maximum temperature trends. Some 81 % of the stations had positive mean minimum temperature trends. Urban stations showed lower trends than did non-urban stations, indicating that these average trends are not the result of the urban heat island effect. Trends suggest that most of this warming occurred during the early 1980s. Observed minimum temperature trends generally appear to be higher than maximum temperature trends, and therefore negative trends in the diurnal temperature range are observed. Hot days have increased in frequency over the past 44 years, while days with lower temperatures have decreased in frequency (Kruger and Shongwe, 2004).

On the other hand, Hoffman *et al.* (2011) have shown that in recent years evaporation and windiness have both declined significantly in the Western Cape, in contrast to the positive linear trend in surface wind speeds observed in South Africa's southern coastal regions from 1982 to 2007 (Rouault *et al.*, 2009). A reduction in evaporative losses over the past few decades seems to be a world-wide observation, resulting mainly from reductions in windiness, or "wind stilling". However, based on the above studies across southern Africa, the key messages are that clear, large-scale temperature related changes already exist..

Rainfall

Annual rainfall has generally shown no consistent trends across the southern African region, but there have been statistically significant changes in shorter time signals. These changes are consistent with current theoretical understanding of human-caused climate change (Zhang *et al.*, 2007). For example, Hewitson *et al.* (2005) have shown clear historical regional trends per decade of mean *monthly* precipitation totals, mean monthly *number of raindays* and mean monthly *dry spell durations*. Additionally, and using a split-sample analysis of 1950 - 1999 of rainfall over South Africa's 1 946 Quaternary Catchments, Warburton and Schulze (2005) showed, *inter alia*, that some areas of the country displayed marked increases and other areas marked decreases over time of *median annual rainfall*, *lowest annual rainfall in 10 years*, *lowest and highest rainfalls in 10 years in the summer months*, *winter median rainfall*, *lowest winter rainfall in 10 years*, the range between one in ten low and high summer rainfalls, and for *daily rainfall events in excess of 25 mm*. Furthermore, Kruger (2006) has shown that in certain sub-regions in South Africa, climate station data displays spatially coherent, and in some cases statistically significant, drying trends, and these areas include some of the key upland watersheds for the major river systems. However, the very high inter-annual variability over South Africa under present conditions does not yet allow a clear overall signal of changes in rainfall variability to be identified.

Runoff

The Jonkershoek (South Africa) data sets of over 70 years of detailed data show rainfall there to have declined by ~ 14%, and the runoff to have declined by ~ 20%. On average 500 mm rainfall equivalent per annum has been lost since the Jonkershoek research began, which is significant because the high mountains are the sources of water for irrigation in the lower catchments (Chapman, 2008)

Agricultural production and yields

Significant relationships have been found between grain crop production and rainfall in all provinces that contribute 20 % or more to national production. These include maize in the Free State (40 %) and Mpumalanga (21 %), and wheat in the Western Cape (35 %) and Free State (37 %; Blignaut *et al.*, 2009). A decline of 1.16% in maize production and 0.5% in wheat production for every 1 % reduction in rainfall was projected from these trends. In the winter rainfall region, export quality apple production seems to have already been adversely affected by warming trends, owing to its sensitivity to positive chill units, which have decreased significantly in recent decades (ERC, 2007).

Forestry

Commercial forest productivity has, to date, remained unaffected despite significantly wetter and hotter trends having been recorded in the southwestern Cape and a drier and warmer trend in the northeast over the past 50 years. There has been a noticeable escalation in the number of non-native pests and diseases as well as outbreaks arising from host shifts; and pathogens are spreading much faster than before and with increased intensity. This often results in forests being clearfelled and / or taken out of production following an adverse event. A similar trend is evident in the increasing frequency and level of devastation of forest fires (SNC, 2010). As the impact of climate change-associated pests, diseases and fire occurs at the landscape level, all forestry beneficiaries are affected.

1.5 Global Aspects of International Co-operation Regarding Climate Change in Respect of the South African Agriculture Sector

South Africa's cooperation and participation in the various forums and with the relevant international organisations and scientific bodies such as the UN Framework Convention on Climate Change (UNFCCC), ensures numerous benefits, *inter alia*:

- Access to the most current updated information and technologies,
- Streamlining and coordination between climate change activities of South Africa and those of international organisations and other countries, and
- Promoting a coordinated approach towards the adaptation and mitigation of climate change amongst the various conventions and countries, in an attempt to maximise benefits derived from the limited resources and avoid duplication.

The Department of Environmental Affairs (DEA) is South Africa's focal point for environmental conventions and they co-ordinate actions and monitor compliance with international obligations related to climate change. With South Africa being signatory to both the UNFCCC and the Kyoto Protocol the requirements of these are discussed briefly:

1.5.1 United Nations Framework Convention on Climate Change (UNFCCC)

The UNFCCC entered into force in 1994, with the South African Government ratifying the Convention in 1997. The main objective of the UNFCCC is to stabilise atmospheric concentrations of GHGs at a level that would prevent dangerous anthropogenic interference with the climate system. Article 12 of the UNFCCC requires countries to communicate their measures by developing National Communications within a specified time, with countries required to communicate to the UNFCCC's Conference of Parties (CoP) the following elements of information: A national inventory of anthropogenic emissions by sources and removals by sinks of all GHGs; a general description of steps taken or envisaged by the

country to comply to the requirements of the Convention; any other information that the country considers relevant to the achievement of the objective of the Convention.

1.5.2 Kyoto Protocol (KP)

The Kyoto Protocol (KP) is an international agreement that is separate from, but linked to, the UNFCCC. South Africa acceded to the Kyoto Protocol in July 2002. It is a legal instrument that sets binding targets for industrialised countries and the European community for collectively reducing greenhouse gas (GHGs) emissions.

The KP identifies policies and measures that can be adopted for countries to meet their targets primarily through national measures. However, the KP offers them an additional means of meeting their targets by three markets-based mechanisms, viz. emissions trading, i.e. "the carbon market"; the clean development mechanism (CDM); and Joint Implementation (JI). The underlying rationale of these mechanisms helps stimulate green investment and help countries or parties meet their emission targets in a cost-effective way.

1.6 Legislative Tools within South Africa

The Department of Environmental Affairs, in addition to being the country's focal point for coordinating international conventions, also co-ordinates actions and monitors compliance within the country, and individual State departments are mandated to provide sector-specific strategies and action plans. The main legislative tools are summarised below.

1.6.1 South Africa's National Communications to the UNFCCC

Our National Communications report on the national circumstances, the national inventories of greenhouse gases, the country's vulnerability to climate change and its capacity to adapt, the systematic observation and research undertaken in this field, the education, training and public awareness programmes required, projections and policies made and measures taken, mitigation options and possibilities for adaptation and a preliminary needs assessment. From this work, in conjunction with information generated from the IPCC, DEA, in consultation with other government departments and stakeholders, developed an updated National Climate Change Response White Paper (NCCRWP, 2010) to be reviewed on a regular basis, thereby empowering government committal to this important subject and placing climate change on the agendas of all government departments.

1.6.2 The National Climate Change Response White Paper (NCCRWP)

1.6.2.1 Some background

The NCCRWP (2010), developed using country study reports compiled on a sectoral basis together with information from the IPCC, recognises that climate change is a cross-cutting issue that has ramifications for diverse activities in other government departments. It thus requires the joint action of government departments in a coordinated manner, to ensure that response measures are acceptable to all and synergistic towards a clear national focus. The NCCRWP calls for the formulation of policies that will adequately address climate change adaptation and mitigation in all sectors. With a number of key interventions on various adaptation and possible mitigation options proposed, the strategy also calls for the development of detailed action plans (including ones for agriculture and forestry) with defined time scales which can, potentially, boost sustainable economic and social development, thereby supporting, *inter alia*, New Growth Path objectives of government including poverty alleviation and the creation of jobs.

1.6.2.2 General mandates from the National Climate Change Response White Paper as they apply to the agricultural and forestry sectors

The following general mandates from the NCCRWP apply to agriculture and forestry:

- Ecosystems provide important services to society, and agricultural ecosystems include the utilisation of water in the provision of food, wood, fibre and fuel.

- The rate of change to the earth's climate compromises the ability of service providing ecosystems, including agriculture, to function effectively and can exceed the capacity of ecosystems to adapt.
- South Africa's agriculture is highly vulnerable and exposed to the impacts of climate change due, on the one hand, to our socio-economic context (e.g. the many land-dependent rural poor) and, on the other hand, to an already high risk natural environment (including high season to season climate variability, extreme weather events, times of severe water stress).
- Agriculture urgently has to strengthen its resilience to climate change impacts and has to develop and implement policies, measures, mechanisms and infrastructure that protects its various components (commercial, emerging, rainfed, irrigated, crops, livestock, plantation forestry etc).
- This strengthening of resilience is to be done cognisant of
 - the IPCC's conclusions on unequivocal global warming forced by anthropogenic (human) activities;
 - the threat that climate change becomes to undermining South Africa's positive development goals;
 - our continued legally binding obligations to strengthening and ensuring full implementation of our international commitments to, for example, the UNFCCC and the Kyoto Protocol through
 - Formulating, implementing, publishing and regularly updating policies, measures and programmes to mitigate our emissions of GHGs and to adapt to the adverse effects of inevitable climate change;
 - Monitoring and periodically reporting to the international community the country's GHG inventory;
 - Managing, conserving and enhancing GHG sinks and reservoirs sustainably, including those from agricultural (terrestrial) ecosystems and forests;
 - Developing a climate change response plan to address, *inter alia*, the agriculture sector, also in its integration with land protection / rehabilitation and water resources;
 - Mainstreaming climate change considerations into social, economic and environmental policy;
 - Promoting and cooperating in the development, application, diffusion and transfer of GHG emission mitigation technologies, practices and processes;
 - Further developing and supporting research and systematic observation, research and technical capacities within South Africa and beyond its borders; and
 - Developing and implementing education, training and public awareness programmes on climate change within the broader agriculture sector and its highlighting its effects in order to promote and facilitate scientific, technical and managerial skills as well as public access to information, public awareness of and participation in addressing climate change.

1.6.2.3 Agriculture and forestry specific mandates from the National Climate Change Response White Paper

- In both the agriculture and commercial forestry sectors there exists synergy and overlap between adaptation and mitigation measures.
- Climate-resilient sectoral plans such as this one have the potential to directly address the plight of those most impacted by climate change, e.g. the rural poor.
- Climate resilience needs to address issues of strategic national importance, e.g. to food security and its links to water, health (human, livestock and plant) and land reform.
- Being the largest consumer of water in South Africa (mainly through irrigation), agriculture is vulnerable to changes in water availability as well as increased chemical water pollution and soil erosion, from a combination of projected spatial changes in rainfall patterns, increases in intense rainfall events and increased evapotranspiration.

- Under-resourced, small-scale and subsistence farmers are particularly vulnerable to the impacts of climate change.
- Commercial agriculture is a significant contributor to GDP and to employment. With its full contribution, including multipliers, agriculture contributes up to 12% of South Africa's GDP and 30% of its national employment. Crop failures through the vagaries of climate can therefore have a significant impact on the nation's economy.
- The following should be considered, explicitly or implicitly, in this CCAMP in light of projected climate change:
 - Climate-resilient agricultural responses depend on the recognition that agriculture provides not only food, but also other environmental and socio-economic benefits.
 - Important as input-intensive commercial agriculture is, it can sometimes have negative environmental, social and economic externalities, which may be exacerbated by climate change.
 - The appropriate use of small-scale labour-intensive agriculture techniques and its various overall benefits (e.g. job creation, empowerment, food security, contribution to biodiversity) should also be considered from a climate change perspective.
 - Modelling of climate change scenarios is vital to informing land use planning decisions in agriculture in as much as they that determine the mix of livestock and crop cultivation, as well as the types of crops that are likely to be commercially viable under projected future climate scenarios.
 - Impacts of alien invasive plant species, which reduce streamflow and may consequently compromise already scarce water resources as well as reducing biodiversity, need to be evaluated through a climate change lens.
 - The overall role of carbon sequestration in agriculture needs to be reviewed. More specifically, the role of natural and plantation forests functioning as carbon sinks, thereby reducing the effects of enhanced GHG emissions in the atmosphere, need to be assessed, as does the effect of deforestation and REDD+.
 - The potential for sustainable biofuel production under conditions of climate change, and its possible impacts on food security, needs to be evaluated.
 - Issues surrounding grassland degradation through injudicious grazing and burning regimes, as well as the reversal of those negative effects through veld rehabilitation, need to be addressed from a climate change perspective.
 - An updated inventory of agriculturally related Greenhouse Gas emissions needs to be one of the background documents to this Plan.

1.6.3 The Long Term Mitigation Scenarios (LTMS)

Following a Cabinet mandate to develop possible realistic greenhouse gas emission scenarios for the future, informed by the best available research and information, in order to define our future commitments under international treaties as well as shape our long term climate change policy, the LTMS process was launched in which DAFF, among other stakeholders, provided inputs. The following points summarise the possible roles and responsibilities for climate change mitigation in regard to DAFF and the agriculture sector:

- Development and implementation of policies, strategies, action plans and / or regulations to mitigate GHG emissions from changes in land use (i.e. land use changes that convert to sources), enteric fermentation (i.e. emissions from livestock), intensive tillage, stubble and trash burning (e.g. sugarcane burning), emissions from fossil-fuel and / or powered agricultural equipment and appliances;
- Ensuring agricultural policy and strategy alignment with the NCCRWP;
- Monitoring and reporting agricultural GHG emission reduction interventions;
- Incorporating forestry-related aspects, including fire alerts and REDD+ initiatives; and
- Monitoring and reporting agricultural GHG emissions to the national GHG inventory.

1.6.4 The Long Term Adaptation Scenarios (LTAS)

The *purpose* of the LTAS was to project and evaluate the socio-economic and environmental implications of potential impacts of anticipated climate change and climate variability, and

the adaptation response options available, for identified sectors in South Africa over the short (next decade), medium (next 2-3 decades) and long term (mid- to end of century), as required by NCCRWP (2010).

Its objectives were as follows;

- To quantify in socio-economic terms, where feasible, the potential impacts of a common set of climate change scenarios on key sectors, public goods and sustainable development goals over three policy-relevant time frames;
- To identify key adaptation responses / strategies relevant to all three time frames and assess their potential effectiveness over each time frame, in terms of their feasibility, implementation costs, mitigation implications, avoided damages and additional benefits;
- To identify adaptation gaps and opportunities that require research, development and capacity building to increase resilience to climate change across all three time frames;
- To use integrated assessment approaches where feasible to identify potential key cross-sectoral impacts and related adaptation policy / planning implications of climate change;
- To enhance coherence and synergy in adaptation planning and approaches;
- To conduct an assessment of climate change vulnerabilities in the region, with a detailed scenario planning process to define potential regional response strategies; and
- To develop information products for policy-makers about climate change impacts risks and appropriate adaptation goals and investment needs relating to alternative global mitigation goals.

The main products of the LTAS included climate change scenarios, climate change impacts scenarios, adaptation response options and opportunities, economic modelling of the costs of impacts and costs and avoided damages of adaptation, spatially explicit products on the SARVA platform that synthesise adaptation guidelines and potential adaptation response plans to be made available at a range of spatial scales, and sub-regional assessments.

In the *First Phase* (2012-2013) a set of scenarios was selected that represent an expert consensus, deemed necessary for comparable analysis of impacts and vulnerability between key sectors and which were to represent a key step forward in a holistic assessment of coherent adaptation scenarios for South Africa; impact scenarios were assessed for 3 sectors, viz. agriculture, water and health; adaptation responses were identified for biodiversity, agriculture, water and health; and economic scenarios were developed for biodiversity (which will serve to pilot possible approaches). The *Second Phase* (2013-2014) conducted impact and economic scenario work on the remaining sectors; conducted an "avoided damages" economic analysis on all sectors, to allow an overall assessment of the economic cost / benefit of climate change adaptation responses, and terminated with an overall synthesis on adaptation scenarios undertaken in both phases, and the translation of key information into a format suitable for dissemination on the SARVA platform.

By the end of this process a more coherent view was gained of South Africa's climate change vulnerabilities in the context of the region over the short, medium and long terms, including the associated economics; a credible set of products was developed that informs and guides adaptation options, contains useful toolkits and approaches, and with impacts and vulnerability maps delivered through the SA Risk and Vulnerability Atlas; an effective network of adaptation research, practitioner and management stakeholders evolved who are more aligned in their objectives; and a knowledge base was established that can, for example, inform South Africa on the appropriateness of the 2° C global warming goal, and that will support the Third National Communication to the UNFCCC.

1.6.5 The Climate Change Sector Plan for Agriculture, Forestry and Fisheries

The CCSPAFF (2013) was developed by DAFF in line with the National Disaster Management Framework of 2005 and in fulfilment of the requirements of the NCCRWP. It

was considered desirable to put into place a climate change-related plan of action to increase climate intelligence through awareness and knowledge of anthropogenic activities impacting the future, and to plan actions related to that. The basic approach of the sector plan is climate smart agriculture, which entails the integration of land suitability, land use planning, agriculture and forestry to ensure that synergies are properly captured and that these synergies will enhance resilience, adaptive capacity and mitigation potential.

The major challenge to the CCSPAFF (2013) is to take prompt, cost-effective steps which will contribute to substantial and long-term reduction in net global GHG emissions and to reduce the causes of climate change; to recognise that delayed action will increase the risk of adverse environmental effects which are likely to incur a greater costs; to adapt to its impacts; to build a scientific / technological capacity enabling innovative solutions to mitigate and adapt to adverse effects of climate change; and to ensure that climate change issues are included in all relevant national agricultural / forestry strategies and action plans.

1.6.6 Other Initiatives within the Agriculture and Forestry Sectors

In its attempt to create awareness on the impacts of climate change DAFF, in partnership with the Agricultural Research Council (ARC), established the Working Group on Climate Change (WGCC) which is convened, coordinated and chaired by the Directorate Climate Change and Disaster Management (D:CCDM) and initially comprised of the DAFF directorates Land Use and Soil Management, Water Use and Irrigation Development and Policy Research Support. That Working Group developed the climate change discussion document titled "*Climate Change and the Agricultural Sector in South Africa*", which sought to synthesise activities in the sector and create awareness on the current perceptions and follow-up actions necessary to address the risks and challenges relating to the impacts of climate change on agriculture. Another DAFF initiative was funding the "*Atlas of Climate Change and the South African Agriculture Sector: A 2010 Perspective*" (Schulze, 2011), from which large amounts of information are drawn in the present document.

Other formal research based initiatives include those from the

- sugarcane sector through a SASRI funded project titled "*Climate Change and the South African Sugarcane Sector: A 2010 Perspective*" (Schulze, 2010); the
- forestry sector via an FSA project titled "*Climate Change and the South African Commercial Forestry Sector: An Initial Study*" (Warburton and Schulze, 2007); the
- Water Research Commission through projects such as "*Adaptive Interventions in Agriculture to Reduce Vulnerability of Different Farming Systems to Climate Change in South Africa*" (WRC Project K4/1882; 2009 - 2014); and
- a series of papers on, *inter alia*, fodder banking, maize, forage yields and optimum tree growth under climate change conditions for the Long Term Adaptation Scenarios

2. VULNERABILITIES AND CHALLENGES RELATED TO THE SOUTH AFRICAN AGRICULTURAL AND FORESTRY SECTORS

2.1 The Backdrop

South Africa's agriculture is particularly vulnerable to climate change, as productive farming is affected directly by the quality of the rainy season, by temperature, climate variability, extreme weather events and CO₂ concentrations in the atmosphere. These impacts extend beyond food shortages and negatively affect national economies by reducing the country's ability to export crops and generate foreign revenue, while food has to be imported. It is, above all, poorer population groups that will be the most adversely affected by climate change since they suffer most from its impacts, in being mostly directly dependent on the natural environment and ecosystem services for their survival and livelihoods. The on-going process of climate change will impact both. As a result of poverty, insufficient knowledge, financial constraints and poor infrastructure, there is little chance of switching to other

sources of income. This is why the balance between the three pillars of sustainability, *viz.* people, prosperity and the planet is so important in South Africa as a developing country.

2.2 Vulnerability in the Agricultural and Forestry Sectors: Concepts and Definitions, Particularly within the Context of Climate Change

Many natural systems, as well as the human drivers and respondents of such systems, are able to adapt naturally to change and, if they can do so, it is likely that they will be less vulnerable to potential impacts of climate change. However, many systems are likely to be vulnerable to certain climate impacts and not be able to adapt adequately or rapidly enough themselves. Within the context of the South African agricultural sector it is therefore important to identify who and what is most vulnerable to impacts of climate change, so as to support for adaptation can be targeted appropriately (Ziervogel, 2008).

Vulnerabilities to climate change in the South African agriculture sector will depend on many unique features, including whether one is dealing with dryland (i.e. rainfed) or irrigation farming, supplementary or permanent irrigation, crop or livestock farming, summer or winter crops, commercial or subsistence farming, phenologically sensitive or less sensitive crops, highly productive areas vs areas already climatically marginal, and the potential for irrigation (from remote sources or locally dependent) vs no potential.

In identifying vulnerability within the South African agriculture sector it should be further borne in mind that it varies at different scales; is place-based, i.e. it is determined largely by locale; may be viewed as the "end point" of a particular climatic hazard or event (i.e. as the residual of climate change impacts minus adaptation); or viewed as the "starting point" (i.e. where a state is assumed to exist within a system *before* it encounters a hazard event, with this approach thus identifying and diagnosing inherent social and economic processes of existing marginalisation and inequalities as the causes of climate vulnerability, and then seeking to identify ways to address these processes (Ziervogel, 2008; Schulze, 2011). Approaches to vulnerability assessment thus attempt to explore who and what are vulnerable; to what are they vulnerable; the degree of vulnerability; causes of vulnerability; and what actions could reduce their vulnerability (Gbetibouo and Ringler, 2009).

2.3 Vulnerability in Practice within the South African Agriculture and Forestry Sectors: The Commercial Farmer vs Small Scale Subsistence Farmer Duality

Agricultural production practices in South Africa may be broadly differentiated into a commercially oriented sector that services national food requirements and brings in export earnings; and a small-scale and homestead based farming sector that constitutes a high proportion of the (mainly subsistence) farming population that rely largely on traditional agriculture methods. The historical and socio-economic realities in South Africa between commercial farmers and small-scale subsistence farmers are thus vastly different and this hugely affects how they farm now, what opportunities they have to progress and what their capacity will be to adapt to projected climate changes.

2.4 Vulnerabilities and Challenges Facing the Agriculture and Forestry Sectors in South Africa: Some Common Denominators

Rainfall is, to a large extent, the most important factor in determining potential agricultural activities and suitability across the country. Rainfall variability introduces an inherently high risk to climate change at many time scales, especially in transitional zones of widely differing seasonality and amount of rainfall. These transitional zones seem particularly sensitive and vulnerable to geographical shifts in climate.

Coupled with unreliable rainfall is the exceedingly high atmospheric demand, i.e. the potential evaporation, in South Africa at 1 400-3 000 mm/yr, often resulting in semi-arid conditions on grounds of high evaporation rates alone and despite often adequate rainfall. Dependence on water represents a significant current vulnerability for almost all agricultural

activities, with irrigated agriculture being the largest single surface water user consuming ~ 60 % of total available water, and with all agriculture related activities consuming ~ 65%.

Agriculture's vulnerability is exacerbated by soil properties and topographical constraints that limit intensive crop production. South Africa's soil mantle is complex, diverse, often thin, and susceptible to degradation. Soil organic matter is vulnerable to increasing temperatures that adversely affect soil biological, chemical, and physical properties; resulting in more acid soils, soil nutrient depletion, a decline in microbiological diversity, a weakened soil structure, a lower water-holding capacity, increased runoff, and soil degradation. Increasing population pressure, unsustainable land use and increasing competition for agricultural land resulting in land use change and poor economic decisions, are leading to land degradation, aggravated by bush encroachment and invasive alien plants.

2.5 Vulnerabilities and Challenges Common to Both Small Scale Subsistence Farmers as well as Larger Scale Commercial Farmers in South Africa

2.5.1 Climate Related

The uncertainty about climate change: Questions arising on the "when, where, how much, what impact and / or how to adapt" in regard to climate change are placing uncertainties in commercial farmers' minds and they feel vulnerable to an unknown climate future. Many crops have critical thresholds of temperature which, when exceeded, severely reduce yields. Wheat, for example, is vulnerable to maxima > 32°C. Through frost occurrences, and especially its timing with respect to very early or late frosts, farmers incur major economic crop losses. It is especially the variability in numbers of frost events per annum, particularly in areas with less frequent / less persistent frost occurrences, that introduces uncertainty in planting decisions. On the other hand, a positive of frost is that it kills off pests or breaks their breeding cycles. A late start to the rainy season (after December planting is seldom still possible in the summer rainfall region), or too little rain at the critical planting stage (poor germination) and flowering stage results in yield reductions, mainly through plant stress.

2.5.2 Rainfall Variability, Persistence of Raindays, Rainfall Intensity and Seasonal Distribution of Rainfall

The high season-to-season as well as within-season rainfall variability within South Africa, result in unreliable yields of staple food crops and thus uncertain household food security, with rainfall variability already being perceived to be increasing over time

Multiple days of steady, gentle rains, while good for recharging groundwater reserves, result in waterlogging, farmers' inability to perform in-field operations and enhance plant diseases. Farmlands are vulnerable to rainfalls of high intensity, e.g. thunderstorms (nowadays already perceived to be more intense in the winter rainfall region than previously), as they result in surface runoff, soil erosion and in mudslides / landslides. Crop development (hence yield) is vulnerable to rains falling at the wrong time in the growing season and the intra-season rainfall distribution is thus vital. In the winter rainfall region, for example, low summer rainfall is detrimental for many, but not all, crops

2.5.3 Water Related

Both SSSFs and commercial farmers are vulnerable to too much water through flooding of fields, resulting in reduced yields; waterlogged fields, making planting and in-field operations difficult; large flood events which cause soil and gully erosion; and long periods of heavy rainfall, which can result in animal diseases. This includes low water levels in the soil, streams, springs and boreholes, resulting in crop stress, as well as irrigation and household water demands not met. Many smaller rivers are already drying up (in the winter rainfall region in summer and in the summer rainfall region in winter) because of upstream land uses and dams, posing the question whether more 1st order streams will dry up in future.

2.5.4 Crop Related

Both SSSFs and commercial farmers are vulnerable to ever increasing fertilizer, pesticide and transport costs. Sub-division into smaller and smaller farms or plots renders farmers vulnerable in regard to both economic viability and environmental sustainability. A case in point is the subdivision of sugarcane farms along the coast of KwaZulu-Natal.

For historical or cultural reasons and lack of in-depth knowledge on climatic characteristics, crops are frequently planted in climatically marginal areas in which year-to-year variability in yields are high, yields are low or complete crop failures recur, with farming enterprises then placed at risk. Farming in marginal areas furthermore diminishes soil productivity and enhances land degradation.

2.5.5 Biofuels Related

If large scale agricultural production for biofuels is considered a viable option in South Africa then, of the biofuel feedstocks promoted in the National Biofuels Strategy of 2007, viz. sugarbeet, sugarcane and grain sorghum, sugarbeet is most vulnerable even under current climatic conditions because of high input costs and overall climate non-suitability for large scale production. Of the three biodiesels promoted, canola is climatically vulnerable in that it requires relatively low temperatures, soybean as a biodiesel may be an unconvincing option as the country is already at present a net importer and sunflowers under marginal climatic conditions (where it would not compete with staple food crops), produce relatively low yields. Legislatively related vulnerabilities to large scale biofuel production is the (present) exclusion of maize (despite frequent surpluses) and the blocking of irrigation for biofuel crops, while questions remain on the actual availability of "new" land for a viable biofuels industry.

2.5.6 Livestock Related

South African rangelands (i.e. un-transformed ecosystems that support extensive grazing and browsing) include diverse ecosystems comprising Savanna, Grasslands, Nama- and Succulent Karoo biomes. These extend across low arid and semi-arid rainfall areas into some high rainfall areas. In the short-term, their composition and productivity are influenced primarily by climatic conditions, grazing regimes and fire, while over longer periods changes in climate (rainfall and temperature) and atmospheric CO₂ levels will play a greater role. South African rangelands support a range of economic activities including conservation, tourism as well as commercial and smallholder livestock systems.

South African rangelands are often considered environmentally and economically marginal, particularly where there is a high dependence of people supporting livestock. The link between rainfall, land use and degradation is important, since year-to-year climate variability can modify both the magnitude of, and frequency with which, thresholds that may initiate desertification processes are exceeded. For example, a higher frequency of dry spells or a lower rainfall can affect vegetation cover, with implications for both erosion and livestock production. In an area under pressure from overgrazing, and thus vulnerable, climate variability can amplify desertification.

Degraded state of rangelands (veld), loss of and low herbage yields

Overstocking (with stock unit rates generally high in South Africa and far exceeding the theoretical grazing capacity), hence overgrazing, other unsustainable management practices such as injudicious burning, as well as natural climate variability with regular periods of severe drought and high energy rainstorms have, in combination, led to bush encroachment, widespread denudation and soil degradation through soil nutrient and soil organic matter content depletion, as well as a shift in species composition towards an abundance of unpalatable plants. These serious problems facing rangelands, plus external stressors such as economic change, shifts in yields and land uses are further negatively impacting on the productivity of these rangelands and, hence, the livestock industry.

Persistent overgrazing and / or injudicious veld burning practices alluded to above result in lowering of and losses in herbage yields. The increased erosion and denudation results in enhanced surface runoff during the rainy season, decreases recharge into the groundwater store and, especially in the case of SSSFs, this reduction in herbage has significant socio-cultural as well as food security impacts.

Animal health

Inter- and intra-seasonal changes in rainfall and temperature impact on animal health as the distributions, competences and abundances of vectors and ectoparasites change from year to year, affecting especially SSSFs who do not always regularly dip livestock nor have the financial means to buy medicines. Furthermore, increased incidence of diseases associated with heavy floods and increased rainfall such as Rift Valley Fever can cause acute abortions.

Change in veld composition, alien invasive grass species and weed infestations in grasslands

Veld cover and composition are already changing through overgrazing and inappropriate burning practices, negatively impacting carrying capacity for livestock. Alien invasive grass species, largely unpalatable, are already a major threat to indigenous grass species, with huge losses in grazing potential as well as biodiversity. Severe weed infestations already occur and degrade ecosystems. Being mostly pioneer species, such weeds adapt more rapidly to environmental changes than indigenous flora.

Grassland / woody species dynamics, C₃ / C₄ grassland dynamics and C₃ / C₄ grasslands and fire dynamics

Grasslands are already observed to becoming woodier as a result of atmospheric CO₂ enrichment in both wet and dry conditions. C₃ and C₄ grass species generally occur within the same area and share the same resources. However, warmer regions favour the C₄ grass photosynthetic rates compared to C₃ grasses. The tall and horizontal growth form the C₄ grasses hold a competitive expansion / invasive advantage over the shorter, slower growth C₃ grasses. Fires causing loss of grazing lands frequently result from dry and hot conditions in winter / spring, especially if combined with hot gradient winds locally known as Berg winds. Where there is a high frequency of fires in C₃ / C₄ composite and / or intact grasslands, the C₃ grass competitiveness will be reduced by fires. Grasslands are more likely to dominate the landscape if the woodlands are temporarily opened after a large fire event.

Reductions in grazing areas and reduction in resilience to extremes

These are already decreasing because of urban and crop expansion. Livestock farmers are often not resilient to intense and multiple-year droughts and flooding, largely because of a tendency to denude veld conditions through overgrazing, a lack of fodder banking and often farming on already unstable and denuded soils.

2.5.7 Hazard Related

Fires, pest / disease distributions

Farmers are vulnerable to losses by fires, be they started by lightning or by other causes. SSSFs are particularly vulnerable to loss of grazing and fuel due to veld fires during dry and hot winters, which have a high likelihood of occurrence especially when veld fires are combined with hot, desiccating Berg winds. Different crop / grass species host different insects, pests and diseases which can result in significant yield losses. Plant and animal diseases and insect distributions depend on the dynamics of insect pests and disease complexes, new pests emerging while other pests may expand their ranges or increase their intensity of outbreaks and biological control agents / predators being effective in controlling the pests / diseases. Pest and disease attacks are largely climate related, with vulnerability to attacks often being high because of late identification and lack of know-how and resources to counter these.

Alien invasive plant and biodiversity loss related

Major losses of biodiversity have already occurred because of alien plant species emerging as a result of riparian vegetation being stressed by low flows or changes in channel erosion. In regard to alien invasive plants farmers feel vulnerable as in certain areas (e.g. Western

Cape) they perceive a marked growth in riparian aliens resulting from the Working for Water initiative having “come, done and gone”; alien invasives using huge amounts of water; only downstream users benefiting from upstream clearing; the problem of continued alien clearance being left to farmers, whilst clearance is costly and labour intensive; policies on clearance (e.g. subsidies) needing to be revisited; a need for a long term strategy, not just a once off clearance and the need for an economic benefit to clearing in order to make it economically worthwhile.

2.5.8 External / Finance Related

Low and / or fluctuating world and domestic commodity prices

These can reduce farmers' profitability, even leading to financial ruin (e.g. small scale sugarcane farmers) and for some agricultural commodities it could be cheaper to import than to produce locally, with dire consequences to employment. This adds an additional and uncontrollable stress to the farming sector, especially SSSFs. Escalating electricity, labour, fertilizer and fuel costs place the agricultural sector at risk.

2.5.9 Science Related

Plant breeding and re-look plant needs

Crops are vulnerable to droughts and high temperatures. There is thus a need for geneticists to breed drought / heat resistant varieties of crops and deciduous fruit, in the case of the latter requiring lower PCUs Units. However, breeding / developing new varieties needs to be done *now*, because response times for the deciduous fruit industry are long (Schulze, 2009) There is a need to re-look plant needs re. water and fertilizer requirements as well as pH.

2.6 Vulnerabilities and Challenges Facing More Specifically Small Scale Subsistence Farmers in South Africa

Presented below is a discussion of points which were identified from recent key studies in South Africa. These studies are not all-embracing and factors discussed should be viewed as a starting point for further discussions on the vulnerabilities of subsistence farmers.

2.6.1 Points of Departure

The current constraints faced by subsistence and emerging farmers (e.g. lack of finance, lack of access to markets and extension services, and being culture bound), especially when they operate in what may be termed “second” or developing economies, contribute hugely to those farmers' vulnerability to climate change. Agricultural practices, frequently associated with inappropriate farming techniques, often contribute to the steady degradation of soil (e.g. lack of nutrient replenishment), water (e.g. high sediment yields) and plant (e.g. overgrazing) resources. An understanding of how best to support these farmers who are highly vulnerable to climate stress is therefore vital, given expected increases in climate variability in future.

2.6.2 Climate Related

Direct dependence on climatic conditions, historical inertia

Much of SSSFs' vulnerability may be attributed to their direct dependency on climate. Since SSSFs already have had difficulty in coping with past disasters, they are likely to be vulnerable to climate related disasters that are projected to be faced under future climates.

2.6.3 Crop Related

Water harvesting, sustainability of farming on small plots of land

Water harvesting to capture rainfall in order to enhance yields is not practised enough and the outlay can be expensive given SSSFs financial situation. Cropping on small plots is a historical and cultural reality for SSSFs and makes it difficult to attain profits, obtain maximum production and maintain environmental sustainability.

2.6.4 Livestock Related

Water dependence on river flows

SSSFs are vulnerable to river flow levels because their domestic animals become stressed or die if flows are low, unreliable or streams dry up. Furthermore, at low flows water quality is poor. Conversely, livestock and wildlife tend to become diseased if flooding occurs.

2.6.5 Culture / Tradition Related

Traditional cultural practices - Communal lands and cattle culture

Vulnerability is enhanced through lack of land ownership in traditional areas and land distribution policies often resulting in small fields that are unprofitable. Many farmers have user rights, but not land ownership since land belongs to the chief, which in itself renders SSSFs vulnerable as it creates uncertainty and a lack of motivation. The culture of maintaining large numbers of cattle places heavy pressure on land and through degradation / soil loss increases the farmers' vulnerability, especially during drought.

2.6.6 External / Finance Related

Poverty trap and farmers' constraints

The vulnerability to the vagaries of climate faced by poorer farmers is often due to their limited opportunities in accessing resources such as fertilizer, transport and other income opportunities, which could lift them out of the poverty trap they are in.

The main constraints to SSSFs' low farm income may be attributed to three main causes:

- *poor commercialisation*, i.e. farmers' lack of knowledge about markets and their inability to make the most of the domestic and international market trends;
- *poor infrastructure*, i.e. farmers' limited access to resources such as credit, thereby inhibiting them to investment in on-farm infrastructure, and the credit system in operation not being properly equipped to support these small-scale farmers' transition to commercial production and provide them with technical advice; and
- *low farm productivity*, often a result of the reduction in the productivity of the land and of available labour resources, both of which derive from poor land and water management (or even a complete lack of it), as well as a lack of access to skilled labour when that is required and management of that labour, and inappropriate farming techniques.

Again, these causes of vulnerability can be overcome with a strong extension services and good communication and trust between local government and the entire farming community (commercial and emerging) to bring about concrete changes, and thus facilitate preparedness for climate change.

2.6.7 Knowledge and Trust Related

Use of and trust in climate forecasts

The lack of knowledge of, and trust in, climate forecasts, including limited resources to overcome the challenges of climate variability, has a great impact on SSSFs, under both present and projected future climatic change conditions. The fact that relatively few benefits are derived from present-day forecasting by poorer farmers may be attributed to the fact that they do not have enough resources to act on the climate forecasts.

2.7 Vulnerabilities and Challenges Facing More Specifically Larger Scale Commercial Farmers in South Africa

While the commercial farming sector in South Africa faces many similar challenges and vulnerabilities to those of SSSFs, there are nevertheless some fundamental differences. Discussed below are points which were identified from a number of recent key studies and workshops in South Africa.

2.7.1 Point of Departure

The point of departure in agricultural and forestry production is to optimally utilise prevailing climatic conditions in order to maximise output in a sustainable manner.

2.7.2 Climate Related

Snowfalls and chill units

Timber farmers in areas prone to snowfalls can experience entire trees or branches of trees, snapping (e.g. wattle and pines), often rendering those plantations disease prone and with resultant multi-year growth cycles / investments impacted. Deciduous fruit farmers are vulnerable to the failure of chill units to occur in the winter period April to September, and this impact detrimentally on fruit quality. Chill units are already no longer recorded in May in many parts of the Western Cape; they now start only in June. In some areas farmers are changing from apples to pears, which require fewer chill units.

Heat island effect

Urbanisation, and with that the urban heat island effect, is expanding outwards resulting in an irreversible loss of often highly fertile agricultural lands.

Droughts and long cycle crops

When farming with multi-year crops with long plant cycles of 20-30 years, such as deciduous fruit, 2 - 3 successive droughts years are critical.

Wind erosion

In many semi-arid areas farmers are vulnerable to wind erosion, especially when soils of freshly ploughed fields are dry.

2.7.3 Water Related

Competition for water where agriculture is a primary producer

Many areas in South Africa are characterised by strong competition between agriculture, urban demands and the environmental reserve for a finite quantity of water often with a highly unequal seasonal distribution. Where, in those areas, agriculture is the primary economic driver / producer, farmers' water needs to be protected / prioritised given the economic significance of agriculture and its knock-on impacts.

Flood magnitudes, effects on shallow soils

Farmers with high-value crops suffer major damage from multi-day floods which inundate fields and curtail in-field operations. While occurring throughout South Africa these floods have in recent years been a feature of the winter rainfall region. Areas with shallow soils saturate rapidly with rain, resulting in high surface runoff.

Groundwater

This is of particular importance, notably for rural water supplies; but in the predominantly hard rock geology of South Africa only ~ 20% of groundwater occurs in major aquifer systems that can be used on a large scale for agriculture. Nevertheless, many farmers are dependent on borehole water, some at 10 m, others at > 100 m depth, with water tables dropping in many borehole from over-abstraction. Groundwater often is brackish, of poor quality. A decline in water quality is increasingly constraining sustainable agriculture / development.

High salinity levels

Salination is largely due to the injudicious management of soil and water by agriculture, and is likely to occur progressively. Salinity levels (e.g. in the Berg catchment) are already high. Certain areas (e.g. parts of the Breede catchment) do not welcome widespread rains as these mobilise salts. Farmers actually prefer rains to fall upstream of irrigated areas.

High rainfall intensities, erosion and reservoir sediment yields

The convective nature of much of South Africa's rainfall in the summer rainfall region, and associated high rainfall intensities, imply high surface runoff and high levels of soil erosion of fertile topsoil off agricultural lands. A consequence is rapid sedimentation of dams which impact on the dam's yield for water supply, with significant longer term repercussions.

2.7.4 Irrigation Farmer Related

Irrigation water demand, decreased water supply from single and / or multiple dry seasons

South Africa's largely semi-arid climates imply that potential evaporation, and with that irrigation water demands, are excessively high in many areas where irrigation is practised,

implying that the yield increment per additional irrigated water is low. With irrigation being the biggest single user of water in South Africa, farmers are vulnerable to assured supplies of water for their crops at critical times in the growth cycle. Irrigators, especially from small dams, are vulnerable to diminished water supplies from dams or rivers in the low flow season or the high water demand season if a hydrological drought with diminished streamflows occurs in a given year. Lack of water can have significant economic impacts. When consecutive low flow years occur, however, consequences can be catastrophic.

Declining water quality and algal blooms, abstractions from upstream and multi-purpose dams

Downstream farmers have to cope not only with the possibility of less water being available, but through injudicious irrigation applications also with water of lower quality because of upstream leaching of nitrate or wash-off of phosphate fertilizers. Irrigators are therefore at risk of both causing algal blooms through injudicious use of fertilizers upstream of impoundments while at the same time being at risk when irrigating with eutrophied water. These can have severe repercussions for downstream irrigators, especially if those dams serve multiple purposes.

Drought curtailment

Water is often re-allocated from irrigators to other sectors during droughts. However, this is a high risk decision as long-cycle crops (e.g. deciduous fruit) suffer for up to 5 years later.

Dependence on external water sources

Many irrigated areas within South Africa with high value crops are in semi-arid regions with few local water supplies and with the water conveyed in from distant external sources. Irrigators dependent on external sources are highly vulnerable to changes in upstream water supply / demand and an apparent abundance of water in such areas can be a delusion. Water has become expensive and especially irrigators cannot carry further price increases, nor be subjected to water curtailments in times of drought, with many irrigators already using water much more efficiently than other sectors do. Any water price increases therefore have to be weighed up against the nutritional and food security value of the crop, and its possible export value or foreign exchange earning potential.

2.7.5 Hazard Related

Cost of weed control, urban sprawl

Weed control is costly because of alien invasive plants and indigenous weeds (SNC, 2010). The urban sprawl is covering valuable high potential agricultural land. Farmers recommend that the urban sprawl be replaced by urban densification, as the high potential agricultural land can never be recovered (Schulze, 2009), in addition to enhancing flooding.

2.7.6 Labour Related

Labour availability and costs, labour / hectare ratio and seasonal employment

These include issues of minimum wages and availability of labour fit for work, partially as a result of the HIV / AIDS pandemic. Certain areas have high labour / ha ratio. Because of the seasonal nature of much of agricultural employment, this needs to be considered in government decision making because livelihoods are at stake.

2.7.7 External / Finance and Markets Related

Reduction of GDP from the agriculture sector, barriers to trade

A substantial reduction estimated at 5-8% in the contribution of agriculture to South Africa's GDP is caused mainly by frequent and intense drought and floods. These are already high, and increasing, thus reducing profitability.

Competitive edge, market projections and changing markets

Farmers with export crops need to know more about their competitors, e.g. Australia and South America in the case of deciduous fruit, Brazil in the case of sugarcane. There is a need for market projections into the future. Changing markets and prices paid to farmers are already resulting in, for example, conversion from dairy to sugarcane in places. Farmers are

rendered vulnerable as subsidies in developed countries often result in agricultural commodities being cheaper to import than to produce locally.

2.8 Vulnerabilities and Challenges Facing More Specifically Commercial Farmers in South Africa: Plantation Forestry Related

Commercial plantations, woodlands, natural and urban forests are complex ecosystems providing a range of economic, social and environmental benefits and ecosystem services to a wide range of people, contributing significantly to national and provincial economies and employment (CCSPAFF, 2013). Most commercial plantations in South Africa are grown in KwaZulu-Natal, Mpumalanga and the Eastern Cape Provinces with the three major genera being *Pinus*, *Eucalyptus* and *Acacia* (wattle). South Africa's commercial production forests are vulnerable as a result of the following (DAFF, 2010):

- Geographically production forests extend over a wide area, but they are fragmented in occurrence, with only ~ 1.5% of the country climatically suitable for tree crops.
- Individual tree species have climatically optimum growth areas dependent on a combination of rainfall and temperature conditions with sub-optimum conditions the result of either drought conditions, snow / frost damage or pest / disease prevalence. Timber farmers and companies are often vulnerable by not matching site and species and thus subjecting themselves to losses and reductions in profit margins.
- Associated with the timber industry are fixed capital investments such as sawmills and pulp mills which need to be located optimally.
- The timber industry is vulnerable to competition from, and conversions to, more lucrative uses for the land, e.g. residential and industrial development, or sugarcane or sub-tropical fruit cultivation.
- Vulnerability and risks are likely to be higher on commercial plantations than on natural forests, particularly when one considers land availability, water demand, environmental sustainability and socio-economic factors.
- Plantations are, furthermore, vulnerable to lightning or arson induced fires, more so in some regions than in others, with vulnerability also strongly dependent on the degree by which pro-active fuel load reduction strategies are implemented.
- Climatically, forest plantations are also at risk of frost, snow and hail damage.
- Climate influences the survival and spread of insects and pathogens *directly*, as well as the susceptibility of their forest ecosystems, with inter- and intra-annual variations in temperature and precipitation affecting pest, reproduction, dispersal and distribution.
- *Indirect* consequences of disturbance from pests and pathogens include the impacts of climate on competitors and natural enemies that regulate their abundance.
- With forestry plantations generally using more water than the native vegetation they replace, they can significantly reduce the flow in rivers, thus making them vulnerable as a competitor for scarce water resources.
- Additionally, groundwater recharge is also reduced by plantations where roots are able to tap into the groundwater table, with forest plantations having been shown to significantly depress low flows.

2.9 Vulnerabilities and Challenges Related to Communication

Communication and open discussions must be encouraged with people who can influence environmental consciousness and matters related to water use with commercial farmers and union associations. Farmers are often at risk of unnecessary hardships and losses because they do not have access to appropriate new technologies and knowledge. This needs to be addressed.

2.10 Vulnerability of the Agriculture and Forestry Sectors to Climate Change: A Synopsis

In **Section 2** it has been shown that the South African agricultural and forestry sectors experience a range of vulnerabilities due both to diverse agricultural natural capital that supports a dualistic, two-tiered, agricultural system (commercial vs. small-scale), and also to

the wide variety and high variability of climatic conditions across the country, with approximately 90 % of the country being sub-arid, semi-arid, or sub-humid, while about 10 % is considered hyper-arid (Schulze, 2008). Only 14% of the country is potentially arable, with one fifth of this land having high agricultural potential (SNC, 2010).

In regard to climate change, the overall vulnerability of the South African agricultural sector should be viewed as representing both risk and opportunity, with risks relating to potential changes in food security through the adverse impacts of climate change, socio-political conditions, and population growth, while opportunities include those related to regional trade within sub-Saharan Africa and technology sharing (SNC, 2010). **Section 3**, in which impacts of climate change on the agricultural and forestry sectors are assessed, highlights both the risks and the opportunities associated with projected climate change.

3 PROJECTED IMPACTS OF CLIMATE CHANGE ON THE SOUTH AFRICAN AGRICULTURE AND FORESTRY SECTORS

3.1 Background Information

With global climatic changes, changes in the South African agriculture sector will be inevitable, since the regional climate in South Africa is dependent on global climate. No one knows exactly how the future global climate will develop and what the resultant consequence to South Africa's agriculture sector will be, but impacts which are projected to be considerable, with different regions of the country likely to be affected in many different ways and many knock-on effects are likely to occur.

Given the importance of agriculture in South Africa and the importance of climate in agriculture, as well as the symbiotic relationships between impacts of water on agriculture and agriculture on water, potential impacts of climate change on agriculture in South Africa have been assessed, most recently and in detail in the "*Atlas of Climate Change and the South African Agricultural Sector: A 2010 Perspective*" (Schulze, 2011) and in a range of documents to the LTAS. Because of the complexity of the country's physiography, climate and socio-economic milieu, detailed local scale analyses were undertaken to assess potential impacts.

Daily temperature and rainfall output from an ensemble of 5 state-of-the-art IPCC FAR (2007) accredited GCMs, statistically downscaled to 5 838 relatively *climatically, pedologically and agriculturally homogeneous zones within South Africa*, formed the basis of analyses which were undertaken for a present period (1971-1990), an intermediate future (2046-2065) and a more distant future (2081-2100). For a variety of causes / reasons no future climate projection derived from any single GCM is perfect and aggregated results from an ensemble of GCMs are therefore used in impact studies. It must be emphasised that *overall changes in future scenarios* of climate depend strongly on *which* GCMs were used, and *how many* GCMs are used in the ensemble, and that future analyses are therefore likely to yield results which may be different to those summarised below.

3.2 Projected Changes to Temperature and Rainfall Related Variables of Importance to Agriculture

Temperature affects a wide range of processes in agriculture and is used as an index of the energy status of the environment. *It* is the one climatic *variable* for which there is a high degree of certainty that it will increase with global warming.

Annual temperatures and their variability

Into the intermediate future *annual temperatures* are projected to increase by 1.5-2.5°C along the coast (illustrating the moderating influence of the oceans) to 3.0-3.5°C in the far interior. However, by the end of the century an accelerating increase in temperatures becomes evident with projected increases between 3.0-5.0°C along the coast and up to

6.0°C and more in the interior. Year-to-year variability of annual temperatures tends to increase in the northern half of the country and decrease in the south.

Heat waves and heat units

In regard to *heat waves* (i.e. occurrences with maximum daily temperatures $T_{mxd} > 30^{\circ}\text{C}$ on 3 or more consecutive days) and *extreme heat waves* (occurrences with $T_{mxd} \geq 35^{\circ}\text{C}$ on 3 or more consecutive days), the median number of *heat waves* per annum from the 5 GCMs used in the Schulze (2011) study is projected to increase by anything from 30% to more than doubling from the present to both the intermediate and more distant futures. In the case of *extreme heat waves*, the median number is projected to more than double into the intermediate future, with the most affected areas being those that are already hot even today, viz. the eastern and northern borders of South Africa and the Northern Cape. *Heat units*, so vital for crop growth but also for pest life cycles, are projected to increase into the intermediate future by an average of ~ 10% annually along the coast (where temperatures are modulated by oceanic influences) to > 30% in the interior. Projected increases in the summer season are more moderate, but relatively high in ecologically sensitive mountainous areas, whereas increases in the winter season are markedly higher at > 30% over most of South Africa and more than doubling in places in the Maluti and Drakensberg mountain ranges.

Cold spells

While the numbers of *cold spells* (i.e. ≥ 3 or more consecutive days with minimum temperatures $< 2.5^{\circ}\text{C}$) and *severe cold spells* (≥ 3 or more consecutive days with minima $< 0^{\circ}\text{C}$) are shown not to change along the coast of South Africa into the future, in the more continental interior a reduction to < 70% of present cold spells is projected by. Certain biennial plants with a dormant season during winter require a certain period of winter chilling for completion of their seasonal dormancy in order for fruit quality to be high. This chilling is estimated by positive chill units (PCUs), derived from hourly temperatures above / below critical thresholds. From sensitivity studies, a 2°C temperature increase results in PCU reductions ranging from 14% to > 60% in South Africa, with reductions commonly around 40%. Similarly, median reductions in ratios of PCUs computed from multiple GCMs are generally > 30% into the intermediate future, with high confidence in these projections.

Reference crop evaporation

The accurate estimation of evaporation from agricultural crops is vital, for it is the driving force of the total amount of water which can be "consumed" by a plant system through the evaporation and transpiration processes. The reference by which to estimate crop evaporation was the Penman-Monteith equation, which has become the *de facto* standard method internationally. A sensitivity analysis shows that in January (summer) a 2°C temperature increase is simulated to increase reference crop evaporation by ~ 3.5% (2.9-3.8%), while in winter (July) the percentage increases are even higher than summer. Using outputs from multiple GCMs, an increase in crop evaporation by the intermediate future of around 5-10% is projected, with the increase higher in the interior of the country. In the more distant future the projected increases range from 15-20%, again with the higher increases in the interior from ~ 100 km inland. The implications of these increases are higher water surface evaporation from dams and a more rapid drying out of soils.

Rainfall and its importance in agriculture

In agriculture, limitations in water availability are a restricting factor in plant development, since water is essential for the maintenance of physiological and chemical processes in the plant, acting as an energy exchanger and carrier of nutrient food supply in solution. In any regional study of agricultural production, rainfall, as a basic driving force and pulsar input in many agricultural processes, is therefore of fundamental importance. Focus is invariably on patterns of rainfall in time and space, by enquiring *how much* it rains, *where* it rains, *when* it rains, *how frequently* it rains, and what the *duration* and *intensity* of rainfall events are.

Annual, monthly rainfall and its variability

It is noted that even under current climatic conditions, South Africa is regarded as a semi-arid country with ~ 20% receiving < 200 mm per annum, 47% < 400 mm and only ~ 9% with MAPs > 800 mm. Inter-annual variability is high. Projected medians of changes in MAP from

the ensemble of GCMs used show relatively little change into the intermediate future, with a slight wetting in the east, particularly in the more mountainous areas. By the more distant future intensifications of changes in MAP become more evident, with areas of decrease in the west and some increases in the eastern escarpment and mountainous runoff producing areas. The period of significant change in the west appears to be in the latter half of the century. The inter-annual variabilities of rainfalls show standard deviations to be intensifying into the intermediate future and even more so into the more distant future, especially in the east, but with decreases in variability in the west. The overall increase in rainfall variability is likely to have severe repercussions on year-on-year consistency of agricultural production as well as on the management of water resources for irrigation through operations of major reservoirs as well as smaller farm dams.

Projections of monthly and seasonal changes in rainfall distribution patterns over South Africa *are not uniform*, but can vary markedly in direction, in intensity, as well as varying spatially within South Africa in a given month, between different months of the year for the same statistic, and between the intermediate future and the more distant future for the same statistic, with this last-named difference suggesting an intensification and acceleration of impacts of climate change over time. A recurring feature is a slight *wetting trend* of varying intensity and distribution *in the east*, a trend which in general could be beneficial to South Africa's agricultural production and to water availability for agriculture, but could be detrimental with flood damage. There is, however, a *drying trend* evident *in the west*, mainly towards the end of its rainy season, and also a drying trend *in the northern areas*. Combined with increases in temperature, repercussions on agricultural production, irrigation demand and water resources could thus be severe in the west. The area which is *transitional between the summer and winter rainfall* areas frequently displays marked changes in rainfall. For the period up to the intermediate future in the mid-2050s, summer and autumn months display a narrow strip of decreased rainfall variability along the coast into the future, but with a general increase over the interior which intensifies into autumn. By mid-winter virtually the entire South Africa displays significant increases in the inter-annual variability of rainfall. Over much of the country this has little impact on agriculture and water resources as mid-winter coincides with the dry season, but in the winter rainfall region of the southwest it does. By October, the start of the rainy season starts for much of the country, the eastern half of South Africa and the southwest show reductions in variability, with only the semi-arid central interior displaying averaged increases in variability.

Rainfall concentration and rainfall seasonality

The *rainfall concentration* statistic indicates whether the rainfall season is concentrated over a short period of the year or spread over a longer period. Median changes in ratios of intermediate future to present rainfall concentration indicate a slightly more even spread of the rainy seasons over much of the country by mid-century, according to the GCMs used, but in the all year rainfall belt, as well as the transitional area between winter and summer rainfall regions, the rainy season is projected to become more concentrated than at present. Large tracts of the current winter and summer rainfall regions are projected by the GCMs used by Schulze (2011) to remain as they are now. However, the models differ in their projections of changes of future *seasonality* in the transitional areas between the winter and summer regions in the west, and in the future location of the all year rainfall region.

Soil water content

Information on soil water content is vital since it determines when plant water stress sets in (and with that a reduction in transpiration losses), the need to irrigate and whether or not runoff will be generated, and how much, from a given amount of rainfall. Changes in soil water stress under projected future climates were derived from output of the multiple GCMs used as input to the ACRU agrohydrological model (Schulze, 1995).

For conditions of *no soil water stress*, the majority of South Africa is projected to experience more such days into the intermediate future, except in the southwest where desiccation is projected to result in plants experiencing fewer days without stress. For *mild stress*

conditions decreases into the intermediate future are shown along the coast and especially in the Eastern Cape and Lesotho, with the remainder of the country displaying more days with mild stress. Similarly, based on the GCM projections used, days with *severe soil water stress* show a general reduction into the intermediate future, except along the west coast where more stress days are projected. *Stress due to waterlogging* is projected to increase into the intermediate future, except along the west coast where fewer waterlogged days are projected. These patterns intensify into the more distant future.

3.3 Projected Changes Related to Components of the Agriculture Sector

In order to illustrate potential impacts of climate change on the South African agriculture sector, and as a backdrop to identifying adaptation options of the sector, projected changes in yields and of climatically optimum growth areas of selected crops, pasture grasses and commercially grown tree species, as well as changes in life cycles of selected pests and changes in irrigation requirements are presented, with results derived from various sources.

3.3.1 Selected Field Crops

Maize

As South Africa's staple food crop, maize has been under the spotlight since the late 1990s, both in regard to vulnerability research (Du Toit *et al.* 2002) and to productivity (Schulze *et al.*, 1995), as well as subsequently from a sustainability perspective (Walker and Schulze, 2006; 2008). Yields have been simulated to be sensitive to both climate and CO₂ fertilisation, with doubled CO₂ offsetting much of the reduced profitability associated with a 2°C temperature rise, especially in core areas of maize production (Walker and Schulze, 2008).

Wheat and barley

Dry spells occur naturally during the growing season in winter, and the projected decrease in winter rainfall would potentially accentuate this natural effect. In cases where areas are already close to threshold values for maximum temperature, a further temperature increase can have devastating effects on production potential (ERC, 2007). A study by Schulze and Davis (2012) using the Smith (2006) wheat yield model shows winter wheat yields to increase slightly by 0.5 to 1.5 t/ha/season into the intermediate future in the main wheat growing Swartland and Rûens regions of the Western Cape, with similar increases in the Eastern Free State wheat belt, while into the more distant future most of the Western Cape's wheat belt is projected to show decreased yields of 0.5-1.0 t/ha from the present, but with the Free State continuing to display increases.

Sorghum

Sorghum (*Sorghum bicolor*) is a relatively drought resistant crop which can tolerate erratic rainfall. Areas for sorghum suitable under present climatic conditions are projected to become unsuitable by the intermediate future along the eastern border while considerable new areas, presently climatically unsuitable for sorghum, are projected to be gained in the Free State and Eastern Cape (Schulze, 2011). Sorghum yields are projected to potentially increase by 2-4 t/ha into the intermediate future in parts of western KwaZulu-Natal, the Eastern Cape inland and eastern Free State, with some areas in the north registering losses compared with present climatic conditions. This translates to projected increases in excess of 30 % in the central growing areas, with some yield decreases along the eastern periphery.

Soybeans

For soybeans the areas lost to potential production in both the intermediate and more distant future are in the east, with an expansion of climatically suitable areas inland towards the west into the future, and with areas gained and lost being more sensitive to changes in rainfall than increases in temperatures (Schulze, 2011). Projected changes of soybean yields between the intermediate future and present climate scenarios display an *arc of yield decreases* for the climatically suitable growth areas surrounding a considerably larger *core area of median yield increases* (generally by > 30%). By the more distant future both the areas showing decreases and increases have become amplified. The implication is that while major expansion of climatically suitable areas for soybean production might occur, there is also a likelihood that the area of actual production may become more concentrated.

Sugarcane

If future climates are perturbed in accordance with the projections for temperature and rainfall used in Schulze (2011) then some major inland shifts in the climatically optimum growth areas of sugarcane may be expected. The harvest-to-harvest cycle, or ratoon, times could reduce by 3-5 months (i.e. by 20-30%) by the intermediate future and by > 5 months (i.e. > 30%) in the more distant future, while yields per ratoon are projected increase by 5-15 t/ha along the coast and by up to 20-30 t/ha in the inland growing areas by mid-century, with major implications to the sugar industry (Schulze, 2011). When a temperature increase of 2°C is associated with simultaneous changes in rainfall, yields were modelled to decrease by ca. 7% for a 10% reduction in rainfall, and to increase by a similar percentage for a 10% increase in rainfall. Median changes in ratios of cane *yields per ratoon* are projected to increase by the intermediate future by < 10% in many parts of the present cane growing areas, but by up to 30% and more in potentially new growth areas further inland. All the above projected changes are significant enough for the sugar industry to consider more in-depth studies of its entire value chain from production to transport to milling and exporting.

3.3.2 Selected Horticultural Crops

Apples

Future temperature increases are projected to cause a 28% reduction of the area suitable for apple production by as early as 2020, with suitable apple producing climates limited to the high-lying areas of the Koue Bokkeveld and Ceres by 2050 (Cartwright, 2002). This projection is consistent with observed trends of reduced export apple volumes partly ascribed to adverse climatic conditions (Midgley *et al.*, 2006).

Pears

Pears have similar climate requirements to apples, but with less stringent chilling requirements and lower sensitivity to heat stress. Overall, the risks associated with producing export-quality pears are related to cultivar-specific sensitivities, with some cultivars at more risk than others. It is very likely that, over the next 30 years, most commercial pear producers should be able to make the necessary adjustments needed to remain profitable.

Viticulture

The market is likely to dictate impacts and adaptations (ERC, 2007), with global trends in supply and demand, and resulting price volatility, being by far the most important factors in determining future profitability. Impacts and vulnerabilities will differ depending on the scale (industry-wide vs. farm level). The industry as a whole may shrink, but successful producers in core areas could capitalise on opportunities such as changing market demand due to adverse climate impacts on international competitors. Water for irrigation or rainfall in non-irrigated vineyards will be a much greater issue than temperature. Marginal non-irrigated vineyards could become uneconomical and total production area could decrease by up to 30% under projected changes by 2050, but increasing yields are possible in irrigated, well-managed vineyards in good areas.

Shifting the industry to other regions would be difficult and expensive, not so much the planting of vineyards as the re-development of infrastructure (such as cellars). The mountainous regions of the eastern Overberg offers new opportunities on old lands provided there is sufficient water. The industry could usefully re-evaluate its cultivar mix and possibly make more use of early-season cultivars to avoid damaging effects of heat waves in mid-summer. Even within cultivars, the style of wine will likely change. There are new opportunities to acquire cultivars (or breed locally) with pest / disease resistance without forfeiting high quality and yield. It takes ca. ten years to source, quarantine, register, and certify a new cultivar for release.

3.3.3 Rangelands and Planted Pastures

Rangelands

Climate change (including effects of increased atmospheric carbon) may complicate the existing problems of bush encroachment and invasive alien species in rangelands. Rising atmospheric CO₂ levels may increase the cover of shrubs and trees in grassland and savanna, with mixed effects on biodiversity and possible positive implications for carbon sequestration (Bond *et al.*, 2003). Increased temperatures are likely to provide a more conducive niche for a variety of pests and pathogens critical to agricultural and livestock activities, including those undertaken in rangelands. Increased temperatures and increased evaporation may increase the incidence of heat stress as well as livestock water requirements in the extensive livestock production that takes place in rangelands.

Eragrostis curvula pasture

Eragrostis curvula is one of the economically most important and highly productive pasture grasses in South Africa, yielding > 12 t/ha/season in the cooler wetter areas but tapering off to < 4 t/ha towards the western parts of its growth area (Schulze, 2011). In both the intermediate and more distant future, areas lost to potential *E. curvula* production are found in the east, but with significant areas becoming climatically suitable mainly in the west. From multiple GCM analyses, *E. curvula* yields into the intermediate future are projected to decrease by ~ 10% in an arc from north to southeast around the core climatically suitable growth area, but to increase by up to 4-5 t/ha/season, in the core area. One implication may be that while major expansion of climatically suitable areas for *E. curvula* might occur, there is also a possibility that the area of actual production may decrease (Schulze, 2011).

Kikuyu pasture

Kikuyu (*Pennisetum clandestinum*) has become an important pasture grass in South Africa because it provides palatable and highly nutritious material, with yields into the intermediate future projected to decrease in an arc from the northwest through north to the southeast around the core climatically suitable growth area, but to increase by up to 3-5 t/ha/season in the core area. Into the more distant future the climatically suitable area for kikuyu becomes spatially more compact (Schulze, 2011). Kikuyu yield changes are relatively more sensitive to simultaneous changes in rainfall and temperature than to temperature alone. As was the case with *E. curvula*, major expansion of climatically suitable areas for kikuyu is projected to occur into the intermediate future, but there is also a possibility that the area of actual production may decrease (Schulze, 2011).

3.3.4 Livestock

Relevant climate impacts include high temperatures in conjunction with humidity conditions and insufficient water that cause heat stress in animals. This negatively affects animal production as feed intake and reproduction are lowered, mortality rates increase, and growth is slowed (Brown-Brandl *et al.*, 2005). To estimate the effects of climate change on the livestock sector, several approaches and simulations have been used in South Africa to develop heat stress (maximum ITH) and humidity (THI) indices for livestock (Brown-Brandl *et al.*, 2005; Chase, 2006; Christensen *et al.*, 2007). Lower and upper critical temperatures determine the thermally comfortable zone per livestock type to ensure optimum development and productivity.

Broilers

Research has shown that, with a heat stress increase of 10%, despite a 10% increase in energy consumption for additional ventilation, each crop of broilers took a day longer to reach the target weight. Considering an expected 2.5-3°C rise in temperature, substantial mortality can be expected. Options to be considered by farmers would be a reduction of stocking density by 12%, thereby reducing the frequency of heat stress to baseline levels, or improving ventilation, which implies a capital investment (SNC, 2010).

Pigs

Increased heat stress was found to result in a small reduction in growth rate because of reduced food intake, with piglets taking one day longer to reach target weight. Solutions to counteract heat stress include a reduction in stocking rates per housing unit, so that the level of gross stress is reduced significantly, or to improve ventilation, which would require capital investment and elevated running cost (SNC, 2010).

Feedlot cattle

Feedlot cattle are adversely affected by high temperatures, relative humidity, solar radiation, and low wind speeds. Tolerance thresholds have been reached in the North West, Northern Cape and Free State during the summer months of 1980-1999. It is projected, using climate scenarios, that thresholds can be expected to be exceeded in these provinces towards the end of the century (SNC, 2010).

Dairy cattle

The present climate scenario (1980-1999) indicates that the northeastern parts of the Northern Cape are experiencing moderate to severe heat stress, while this was less severe in Mpumalanga, northern Free State and much of KwaZulu-Natal. Projected scenarios indicate that stress levels could increase to mild stress levels with a minimal effect on milk production. To counter-balance harmful effects without jeopardising milk production, high milk-producing exotic breeds have been cross-bred with heat-tolerant indigenous breeds.

3.3.5 Selected Pests and Diseases

Stages in the development, or durations, of entire life cycles of agricultural pests and diseases are closely related to temperature thresholds, and are thus affected by global warming. Examples of some impacts follow (Schulze, 2011):

Eldana saccharina

The African sugarcane stalk borer *Eldana saccharina* is one of the most serious sugarcane pests in South Africa, causing substantial losses in yields. Crucial to eldana infestations are the number of mating hours per annum. These depend on hourly night-time temperature thresholds being exceeded, with mean annual number of eldana mating hours ranging from < 200 hours in the cooler inland regions of South Africa to > 1 000 hours in the hotter eastern parts of the region, with the so-called 'sugar belt' coming in at > 800 hours per annum (Schulze, 2011). When of the annual mating index of eldana is assessed in regard to projected changes into a warmer future by the GCMs used in Schulze (2011), these increase throughout the climatically suitable area for sugarcane by ~ 10% along the east coast to > 30% further inland. This indicates that compared with present conditions the 'new' inland climatically suitable areas for cane are relatively more vulnerable to eldana infestations.

Codling moth (Cydia pomonella)

The growth and development of many organisms is dependent on temperature. For codling moth, the lower and upper temperature (°C) thresholds and accumulated degree days for one life cycle are, respectively, 11.1°C, 34.4°C and 603 °days. Under current climatic conditions the number of life cycles per annum of codling moth ranges from < 2 in the cooler mountainous areas of South Africa to > 6 along its northern and eastern borders (Schulze, 2011). Using output from the ensemble of GCMs used in Schulze (2011), the number of life cycles per annum of the codling moth by the intermediate future is in excess of 30% of the present over the central areas of South Africa, 20-30 % along the periphery of the country and 10-20 % along the coast of KwaZulu-Natal and patches elsewhere.

Oriental fruit moth (Grapholita molesta)

In the case of the oriental fruit moth, which affects apples, the lower and upper temperature (°C) thresholds and accumulated degree days for one life cycle are, respectively, 7.7°C, 32.2°C and 535 °days. Under current climatic conditions the number of life cycles per annum of the oriental fruit moth ranges from < 3 in the cooler mountainous areas of the RSA and Lesotho to > 9 and even 10 along the northern and eastern borders of the country (Schulze, 2011). Projections into the intermediate future climate scenarios indicate increases in the number of life cycles per annum of the oriental fruit moth by < 1.2 in the southwest, ~ 1.5 life cycles along the east coast and then increasing almost parallel to the coast to > 2 additional life cycles in the central north, with confidence in these projections being high.

3.3.6 Net Irrigation Demand

Using demand irrigation scheduling, by which irrigation water is applied to the plant just before the soil has dried to a level where crop water stress sets in, and then recharging the soil profile to its drained upper limit (field capacity), changes in net irrigation demand were

simulated with the *ACRU* model (Schulze, 1995 and updates) for all months of the year to a fully grown crop. With mean annual net irrigation demands over South Africa already high at ~ 800 mm in the wetter eastern and southern regions and up to 1 600 mm in the arid northwest, the composite results of the multiple GCMs used in the study by Schulze (2011) show a surprising reduction in supplementary water requirements of ~ 10% in areas of the central eastern parts into the intermediate future, indicating that in those areas the increased demand through higher temperatures, and hence enhanced evaporative demands, is more than offset by corresponding projected increases in rainfall. In the drier western half and the northern quarter of the country irrigation water demands are projected to increase by ~ 10%. By the more distant future two differences emerge, *viz.* that the area of reduced irrigation demand has shrunk and that in the ~ 90% of South Africa where irrigation demands are shown to increase by 10-20% and in parts of the south western Cape even > 20%.

The implications of these findings are first, that in the already drier parts of South Africa where agricultural production is very much dependent on supplementing rainfall with irrigation, even more additional water than at present will be needed, secondly, that this water cannot be sourced locally, but will need to be transferred from remote sources, and thirdly, that with even higher temperatures than at present, a conversion of crops is likely to be needed to more heat and disease tolerant crops (Schulze, 2011).

3.4 Projected Changes Related to the Forestry Sector

Impacts of changes in CO₂

Positive climate change impacts on forests arise, *inter alia*, from increases in atmospheric CO₂ concentrations enhancing photosynthesis and root growth. However, the positive effects of higher atmospheric CO₂ could be countered by increased respiration, carbon partitioning to roots and lower levels of available soil water or high vapour pressure deficits. Changes in photosynthetic efficiency may, in addition, be capped by soil fertility and nutrient supply, as soil water availability affects nutrient uptake. Under elevated CO₂ levels, N levels of forest foliage and in the litter layer decrease, resulting in higher quality litter. The effect of elevated CO₂ concentrations on nutrient mineralization and litter decomposition, however, remains uncertain.

Impacts of changes in temperature and rainfall regimes

Changes in temperature and rainfall regimes are likely to have a marked impact on the size and location of land area suitable for specific genotypes. Area selection will be exacerbated by biotic and abiotic risks to be considered, including atmospheric pollutants (SNC, 2010). A number of studies have attempted to simulate potential future impacts of climate change on the extent and productivity of plantation forestry in South Africa using simple rule-based models (e.g. Warburton and Schulze, 2008; Schulze and Kunz, 2011). Those models use annual rainfall and temperature to map areas that are potentially suitable for afforestation with a particular species. The studies have concluded that, in the medium and longer term, the total area of potential afforested land is projected to increase due to the wetting trend over the eastern seaboard and adjacent areas.

Eucalyptus grandis

Eucalypts, grown as *short rotation hardwoods* (6-10 years) for pulpwood or as *long rotation hardwoods* (20 - 25 years) as sawlogs, make up ~ 40% of the area under commercial forests in South Africa, with Mean Annual Increments (MAIs) from 14-30 t/ha/annum (Schulze, 2011). With projected perturbations of temperature and rainfall, major climatically suitable areas could be gained in the inland by the intermediate future, with possible MAI gains of 4-12 t/ha/season, while virtually no presently suitable areas for *E. grandis* are lost. A number of the above findings are significant to the commercial forest industry. They will require careful interpretation, the use of more sophisticated growth models in future and output from a wider range of GCMs run for longer time periods.

Pinus patula

Pinus species, making up ~ 49% of South Africa's commercial forests, are grown either as *short rotation softwood* for pulpwood (harvested at ~ 15 years) or as *long rotation softwood*

for sawlogs (harvested at 25-30 years), with areas climatically suitable for *Pinus patula* occurring in a strip from the Eastern Cape to Limpopo and with MAIs in a narrow range of 16-20 t/ha/annum. By the intermediate future new climatically suitable areas for *P. patula* are in the inland of the Eastern Cape and southern Mpumalanga, with yields projected to increase by ~ 3 t/ha/annum, while areas which are suitable under present conditions, but are projected to become unsuitable within the next 4 decades or so, include the coastal areas of the Eastern Cape and parts of eastern Mpumalanga and Limpopo (Schulze, 2011). A comparison of results between *Pinus patula* and *Eucalyptus grandis* shows *P. patula* to be less sensitive to climate perturbations, but with yield increases also much more muted.

Acacia mearnsii

Acacia mearnsii (black wattle) has proved to be the most drought resistant of the commercial hardwoods grown in South Africa. With a rotation cycle averaging 10 years and a MAI ~ 10-11 t/ha/annum, *A. mearnsii* is stripped for its bark in addition to being used for its timber. Major shifts in the areas climatically suitable for *A. mearnsii* are expected with areas which are presently climatically suitable being lost in an arc in the east, initially along the coast and then curving inland, while new climatically suitable areas are gained in the west, with many areas presently suitable no longer climatically suitable under projected future climates. By the intermediate future in the climatically suitable growth areas of *A. mearnsii* MAIs are projected to decrease by 1-2 t/ha/annum in the east and increase by 2-3 t/ha/annum in the newly suitable areas in the inland (Schulze, 2011).

In summary, it has been shown in **Section 3** that certain areas will be “winners” and others “losers” in regard to the climatic suitability of crops and of yields; furthermore, that some crops are highly sensitive to climate change and others more robust; and that for some commodities adaptive options are likely to be easier than for others. Proposed adaptation measures are discussed in **Section 4** which follows.

4. ADAPTATION MEASURES

4.1 Adaptation to Climate Change in the South African Agriculture and Forestry Sectors: Some Introductory Thoughts

Adaptation to climate change implies a range of measures by which to essentially cope with and even try to overcome the challenges of, and vulnerabilities to, climate change impacts, in this instance by the South African agriculture sector. By definition adaptation includes initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected *climate change* effects. Various types of adaptation exist, e.g. *anticipatory* and *reactive*, *private* and *public*, and *autonomous* and *planned* (IPCC, 2007).

It has to be emphasised that climate and climate change issues are superimposed upon the multiple other challenges, problems and stressors the South African agriculture sector already faces (e.g. globalisation, urbanisation, environmental degradation, disease outbreaks, market uncertainties, higher fuel and machinery costs, policies concerning water / veld burning / overgrazing and land redistribution, or slow responses from authorities), and that together these affect future planning strategies (Andersson *et al.*, 2009). However, up to a point, farming communities already cope with, and adapt to, a variable climate. The key to enabling communities to deal with an uncertain future climate is to understand what makes them vulnerable and to work towards reducing those factors, so that adaptation for the future is about staying ahead and being progressive (Andersson *et al.*, 2009).

Adapting to projected climate change in South Africa’s agriculture sector will be about large-scale commercial farmers staying ahead and being progressive by optimising climatic conditions to maximise output in a sustainable manner and maintaining a competitive edge. At the rural livelihood scale, on the other hand, adaptation needs to focus on the most vulnerable groups and areas, so that livelihoods are not eroded by climate events, but rather that the affected communities become more resilient to the expected changes in climate. For

both sets of farmers, adaptation will require an integrated approach that addresses multiple stressors, and will have to combine the indigenous knowledge / experiences of vulnerable groups together with latest specialist insights from the scientific community. Most agricultural programmes and information are initiated at high levels in government for regional implementation and are not always adapted to local conditions. However, all agricultural programmes and planning strategies in regard to climate change will need to focus on local conditions, as climate change has very local repercussions. Below, is a summary of findings on adaptation options, with full details available in Schulze (2011).

4.2 Strategies and Approaches Towards Adaptation to Climate Change

Adaptation plans in the South African agriculture sector aim at identifying existing climate related problems and current mechanisms of coping with those, then undertaking local assessments of vulnerability to projected changes in climate and, on the basis of those, to make recommendations on adaptation strategies for action in the future. The plans need to be joint productions of various stakeholders in agricultural and water resource management, with climate / agriculture / water resource experts acting as information providers.

4.3 Adaptation to Climate Change in South Africa: General Considerations re. Agriculture

4.3.1 Points of Departure

Adaptation: What is it all about?

For the future in agriculture adaptation is all about staying ahead and being progressive by optimising climatic conditions in order to maximise output in a sustainable manner and maintaining a competitive edge.

Adapting to climate change at the rural livelihood scale

This will be critically important in the South African context, with a focus on the most vulnerable groups, and the most vulnerable areas, so that livelihoods are not eroded by climate events, but that affected communities become more resilient to the projected changes. This requires an integrated approach which addresses multiple sectors and combines indigenous knowledge of vulnerable groups with latest scientific insights.

From rhetoric to action, adaptation to local conditions

While there is a lot of rhetoric about climate change adaptation for the long term, few farmers seem to actually be adapting for the future. Most are adapting to climate variability and some observed climate change that is being detected now. This mindset may need to be changed. Most agricultural programmes are initiated at high levels in government and are not always adapted to local conditions. All agricultural planning strategies need to focus on local conditions, especially in regard to climate change which can have very local repercussions.

4.3.2 Climate Related

Lack of predictability of rains, frost days, chill units and wind erosion

This includes information on an earlier or later start to the rainy season (with a threshold date after which planting is no longer possible), too little rain at plant and critical phenological stages (e.g. flowering in maize), or increases in season-to-season rainfall variability. Important here are overall changes to the beginning and end of the frost season as well as variability in frost occurrences per annum (particularly in areas with less frequent frost), with knock-on effects on climatic suitability of crops, plant dates or pest / disease incidence. Adaptations include the use of shade cloths to minimise frost damage, particularly for vulnerable crops or crops at a sensitive stage if growth shade cloths are being used to minimize frost damage. With chill units recorded later into autumn and are fewer in total, farmers need to adapt by having to change fruit types (e.g. from apples to pears) which require fewer chill units or move upslope to cooler microclimates or move to colder areas within South Africa. Where soils are projected to dry out more frequently or for longer, e.g. in the country's interior, measures need to be put in place to reduce enhanced wind erosion.

4.3.3 Natural Resource Base Related

Soil suitability studies and local area specific soil husbandry

In order to adapt to local climatic conditions soil suitability studies need to be undertaken prior to future land use change and land use decisions. Soils will then need to be utilised in accordance with local properties in conjunction with projected climatic regimes, e.g. shallow soils resulting in high surface runoff will need protection.

Adopting a soil protection ethos

As an adaptation strategy a soil protection ethos needs to be adopted to underpin land use decisions in the future, as this would prevent / reduce conflicts related to pressure on land, competition for land, land use change and depletion of the natural resources / environmental services if all land users are committed to preventing soil degradation and exploitation.

4.4 Adaptation to Climate Change in South Africa: Agriculture and Livestock Related

The introductory thoughts on adaptation presented above, together with the outline of strategies and approaches and the general considerations in regard to adaptation in agriculture, set the scene for more practical examples of adaptive measures, focussing first on agriculture and livestock and thereafter on forestry, followed by sections on cross-cutting and overarching themes. While the examples given below cover the main bases and often highlight the uniquenesses of the South African agricultural typologies, they should by no means be viewed as a comprehensive compendium, but rather as selected case studies.

4.4.1 Conservation Agriculture

Conservation agriculture (CA) is an integrated approach addressing multiple sectors, including in-field rainwater harvesting, roof and road runoff water collection to supplement irrigation, and organic and precision farming. The benefits of CA are well established at small scales, and are currently being quantified at commercial farm level and compared to conventional production methods (Smith *et al.*, 2010). Adoption of CA practices by the commercial and household food security sectors is comparatively low, as the adoption process is intricate and as on-farm experimentation / demonstrations are limited. However, those who have adopted and expanded these practices are reporting benefits such as crop yield even during periods of drought, productive soils, minimum input costs and thus larger profit margins, less soil degradation, better soil water-holding capacity, and all-year-round household food security. The CA adoption rate needs to be increased significantly by concerted and joint awareness campaigns and on-farm application by all agricultural stakeholders, as it is quite impossible for the limited number of extension officers to reach all food producer levels. It is true, unfortunately, that CA is not a quick fix as it takes time to restore natural biological processes conducive to CA benefits. This affects the adoption rate.

4.4.2 Water Infrastructure Related

More impoundments

Construction of more large and even farm dams has become a sensitive issue mainly for environmental reasons. However, in certain areas more water might have to be impounded as an adaptation strategy in order to cope with increased flow variability and higher irrigation demands, conditional upon required environmental flow releases being made and impoundments not being a mal-adaptive practice in regard to downstream water users.

Re-evaluation and / or infrastructure modifications of dams

Existing dams were dimensioned on historical hydrological records (re. sizing, dam safety). They will not necessarily be able to deal with future climate conditions in regard to projected increases in design floods or lower inflows. Climate change therefore needs to be included as a factor when assessing the safety of current dams and in the design of new structures.

4.4.3 Water and Water Conservation Related

Wise use of water and nutrient conservation technologies (WNCTs)

Attention must focus on water productivity, i.e. the so-called 'more crop per drop'. As an adaptation strategy WNCTs have the potential to make better use of precipitation and contribute substantially to reducing food insecurity and poverty by reducing vulnerability to risk and uncertainty. As WNCTs are agro-ecosystem specific, these technologies must be adapted to suit the biophysical and socio-economic conditions of target areas and take cognizance of the effects of climate change. Examples include are technologies to promote water use efficiency especially in irrigation efficiency, reduction in reticulation losses, socially acceptable water recycling, rainwater harvesting, adaptations such as changes in planting dates, selecting crops with shorter growing periods, high technology-intensive solutions such as the increased use of modern machinery to take advantage of the shorter planting period and groundwater management systems (notably the artificial recharge of aquifers);

Rainwater harvesting

This includes tillage practices conducive to soil water conservation and water harvesting in its many forms. These are high priority adaptation concerns in South Africa.

Wetlands conservation

Wetland conservation should be practised to ensure general environmental health and in providing food and water security, notably to the rural poor (Kotze and Silima 2003; Mondli 2009). Wetlands need to be conserved as an adaptation measure as they not only *perform vital ecosystems functions* such as water storage, flood protection, erosion control and groundwater recharge / discharge, but they also *provide a wide range of agriculturally related goods and services* in supporting livelihoods in many communities, including provision of hydrological buffers and providing food, livestock grazing, domestic water, construction material and other natural products.

Competition for water

Many areas in South Africa are characterised by strong competition for a finite quantity of water with a highly unequal seasonal distribution between the agriculture sector, urban demands and the environmental reserve. In the interests of future national food security consideration has to be given to agriculture receiving an equitable share of that water.

Drought management: Curtailment during droughts

Water for agriculture is often re-allocated to other sectors during a drought. The extent to which this is done will have to be thought through carefully, depending on the crop's value as a staple food or foreign exchange earner or its physiological response to reduced water, e.g. deciduous fruit trees may suffer for up to 5 years later after severe drought.

Flood management: Flood protection, groundwater

With flood magnitudes projected to increase over many parts of South Africa, the protection of agricultural lands will become an important component of adaptation. With many farmers dependent on borehole water drawn from widely varying depths, these will be impacted upon in different ways under future climatic conditions and farmers will need to adapt to revised groundwater recharge rates for the boreholes to remain sustainable.

4.4.4 Dryland Crop Related, Using Best Management Practices

Potential adverse impacts of climate change on food production, agricultural livelihoods and food security in South Africa, are significant national policy concerns, and are also likely to have implications across southern Africa (SNC, 2010). Overall, many agricultural sub-sectors are sensitive to projected climate change. Certain crops grown in South Africa are more resilient to climate change, others are more sensitive. Similarly, climate change impacts for some crops can be projected with more confidence than for others. Additionally, there is evidence that food production / security are at risk especially due to future projected water supply constraints, declines in water quality, and competition from other sectors. There is evidence that small-scale and urban homestead dryland farmers are most vulnerable, while large-scale irrigated production is least vulnerable to climate change - given sufficient water supply for irrigation. Intensive livestock production systems need to both reduce their water use as well as contain the GHG emissions they emit. As an overall adaptation strategy, a concerted promotion is required of best management practices based on the principles of the least possible soil disturbance, permanent soil cover, multi-cropping and

integrated crop and livestock production in order to optimise yields, as well as sequestering carbon and to minimising methane and nitrous oxide emissions. Examples are given below.

Shifts in optimum growing areas, climatically marginal land

Changes in the geographic locations crops and cultivars will need to be identified, with heat / drought tolerance and water use efficiency being paramount considerations in new or alternative crop selection, such as changing to yellow maize or late maturing fruit trees. These should be identified and crops selected accordingly, as such areas are more prone to reduced yields and even complete crop failures in light of projected increases in climatic variability, and with a view to maintaining soil productivity and preventing land degradation.

Climate-specific farms, growing indigenous species

As an adaptation strategy, farmers may need to procure "climate specific" farms for specific crop, as well as looking to other African countries to produce their crop. Indigenous species suitable for local conditions should be encouraged.

Altering planting times, altering harvesting times, diversifying crops and harvesting less often

These will have to be considered on a year-by-year basis by considering seasonal climate forecasts, which are another adaptation strategy. In drier regions harvesting less frequently should be promoted to prevent nutrient depletion.

No-till practices

Practising no-till as a soil conservation measure and following conservation laws and policies is already accepted by progressive farmers. However, many small scale farmers have limited resources and pressing needs and priorities that constrain their possibilities and motivation to put efforts into soil conservation practises as an adaptation measure.

Water harvesting, cover crops, decreasing wind erosion

In its many forms, this should be promoted to capture additional rainfall for crop utilisation. These should be encouraged in wide row crops (e.g. vines) to reduce soil water evaporation. Decreasing wind erosion (e.g. by mulch strips or shelter belts of natural vegetation) should become standard practice.

4.4.5 Dryland Crop Related: Other Adaptations

Consolidation of small plots of land

For example, for small scale sugarcane growers, small plot consolidation is an adaptation option with respect to profit, obtaining maximum production and environmental sustainability.

Genetically modified crops

Progress has been made with the development of genetically modified crops with regard to heat resistance, drought tolerance, and water use efficiency (SNC, 2010). These include potatoes, sweet potatoes, soybeans, indigenous vegetables, maize and wheat. Other notable developments include low-cost alternatives to chemicals for organic production, a reduction in water consumption by vegetables, the production of indigenous and other vegetables crops under low input-cost conditions and hydroponics.

Sorghum

With areas for sorghum cultivation suitable under present climatic conditions projected to becoming unsuitable by the intermediate future while considerable new areas, presently climatically unsuitable, are projected to be gained elsewhere and sorghum yields projected to potentially increase into the intermediate future in certain parts (cf. **Section 3**) and decrease elsewhere, farmers will need to adapt where to plant sorghum.

Soybeans

For soybeans some areas will be lost to potential production under future projected climates, other areas gained and projected changes in yields displaying an *arc of yield decreases* surrounding a considerably larger *core area of median yield increases* (cf. **Section 3**), the implication is that soybean producers will have to adapt to relocating to climatically suitable areas, with a likelihood that the area of actual production may become more concentrated.

Sugarcane

If future climates are perturbed in accordance with projections, then the major shifts in the climatically optimum growth areas of sugarcane into the inland, the reduced harvest-to-

harvest cycles by 20-30% by the intermediate future and projected yields increases per ratoon especially in the inland growing areas by mid-century (cf. **Section 3**), have major adaptation implications to the sugar industry in regard to relocation not only of production areas, but also of transport logistics, location of mills and export potential. All the above projected changes are significant enough for the sugar industry to consider more in-depth studies of its entire value chain from production to transport to milling and exporting.

Eragrostis curvula pasture

For *Eragrostis curvula*, one of the most important and highly productive pasture grasses in South Africa, in both the intermediate and more distant future production areas are projected to be lost in parts of the east while becoming climatically suitable in parts of the west (cf. **Section 3**). Producers will have to adapt to projected new optimum growing areas.

Kikuyu pasture

The projected yield changes and climatically optimum growth areas of highly palatable and nutritious kikuyu (*Pennisetum clandestinum*) pasture into the future (see **Section 3**) have been shown to more sensitive to simultaneous changes in rainfall and temperature than to temperature alone. As was the case with *E. curvula*, the projected expansion and contraction of climatically suitable areas for kikuyu will imply farmers having to adapt to future climatic conditions, with possible implications to the dairy industry. .

Rooibos tea

Rooibos tea production is vulnerable to reduced rainfall and lack of rainfall at critical times, with yields projected to decrease 40 % during a drought year (Oettle, 2006). Numerous adaptation strategies are, however, used or known by the farmers, including changes in ground preparation and tea harvesting times, wind erosion prevention measures and water conservation measures. Not all measures are implemented, often due to lack of finances.

4.4.6 Irrigation Farmer Related

Increasing the area under irrigation, integrated water use planning

Where climate scenarios project a lowering of rainfall (and elsewhere) increasing the area under irrigation is an adaptation option, but only subject to water and suitable soils being available, farming practices being efficient and expansion not leading to mal-adaptive repercussions downstream (e.g. regarding environmental flows or reductions to other users).

This is essential as an adaptation strategy, with due consideration given to

- *Decreased Water Supplies from Single Dry Seasons* (i.e. during winter in the summer rainfall region and vice-versa) as a result of projected increases in the number of single years with insufficient streamflows being generated, with significant economic impacts;
- *Decreased Water Supplies from Multiple Dry Seasons*, where these are projected and continuous periods with insufficient streamflows are experienced, with more catastrophic economic and environmental consequences;
- *Upstream Dams* and abstractions, which can have severe downstream repercussions;
- *Multi-Purpose Dams* with curtailment rules during droughts, which could affect irrigators severely; and / or
- *Dependence on External Water Sources*, where irrigated areas are actually in semi-arid areas, but with an apparent abundance of water for irrigation as a result of the water being conveyed in from external sources (as in parts of the Western Cape), and where such external water dependent areas are highly vulnerable to changes in water supply / demand elsewhere and the abundance of water in such areas being a delusion.

Conversion to drip irrigation

Conversion to drip irrigation (from overhead or flood methods) is an obvious adaptation strategy because of its high water use efficiency, but it comes with expensive capital outlays in infrastructure and installation, for which government subsidies should be considered. In the promotion of drip irrigation it should be borne in mind that water is used by the plant, not by inter-row weeds; it works well for certain crops (e.g. vines), but not for others (e.g. because of root structure); and it does have disadvantages in that it cannot be used as a cooling agent (as can sprinklers), nor can it be used effectively on sandy soils.

Application of local and crop specific irrigation scheduling

This should be practised to avoid excessive losses from irrigated fields of phosphates via surface runoff and nitrates through deep percolation.

Use of mulching / crop residue, viticulture specific

This can save up to 20% of irrigation water requirements. The mountainous regions of the eastern Overberg, for example, offer new opportunities on old lands provided there is sufficient water. The industry could usefully re-evaluate its cultivar mix and possibly make more use of early-season cultivars to avoid damaging effects of heat waves in mid-summer. Even within cultivars, the style of wine will likely change. There are new opportunities to acquire cultivars (or breed locally) with pest / disease resistance without forfeiting high quality and yield. However, it takes ~ 10 years to source, quarantine, register, and certify a new cultivar for release (SNC, 2010).

4.4.7 Water Pricing Related***Water curtailments to irrigators, water price increase trade-offs***

Adaptation plans will need to consider carefully water curtailments to irrigators in times of drought, in light of food security and conditional upon irrigators using water efficiently. Water has become expensive to irrigators and price increases will, with climate change, have to be weighed up carefully against the issues of national food security, export value and foreign earnings potential of crops. The latter is particularly pertinent to the deciduous fruit industry of the Western Cape, an area projected to experience reduced runoff.

4.4.8 Rangeland and Livestock Related

Overgrazing, desertification, natural climate variability and bush encroachment are among the most serious problems facing rangelands (SNC, 2010). External stressors such as climate change, economic change and shifts in agricultural land uses may further negatively impact the productivity of these regions and deepen pre-existing vulnerability. Adaptation interventions would benefit from an integrated approach that incorporates both ecological and socio-economic dimensions of rangeland use. A purely sectoral approach, whether targeting climate change, desertification, or addressing both phenomena, is likely to be limited in its ability to address the resilience of key processes and their related socio-economic benefits (e.g. the protection and restoration of ecosystem services). Past policy shifts relating to advised and legislated stocking rates (as informed by estimated carrying capacity) have proven effective in reversing degradation trends in certain climatic and socio-economic settings. These mechanisms would benefit from science-based insights (i.e. ongoing observations and projections) relating to current and future carrying capacities (as they may be influenced by climate change and variability), and from efforts to understand the factors that determine observance of such advice and legislation (SNC, 2010).

Changes in veld composition

Veld cover and composition are likely to change in future climatic regimes, and farmers will need to adapt their livestock (and game) densities to changing grassveld carrying capacities.

Losses of herbage yields

These may be due to overgrazing, which will need to be minimised as an adaptation strategy, as will losses due to increased erosion through more surface runoff, where that is projected, both with significant economic and sustainability consequences if not curbed.

Alien invasive grass species, weed infestations in grasslands

These are largely unpalatable and tend to respond more favourably to elevated CO₂ availability than indigenous species. They will need to be kept to a minimum as they are likely to become a major threat to indigenous species, with huge potential (and partially unavoidable) losses in biodiversity with climate change. Weed infestations in grasslands will need to be minimised as an adaptation strategy because severe weed infestations, being mostly pioneer species, tend to degrade ecosystems and adapt more rapidly to environmental changes than indigenous flora.

Fodder storage / banking

In areas of projected decreases rainfall and hence herbage yields, the need will increase to store fodder for livestock or to use alternatives such as maize stalks.

Supplemental feed and water provision

This is a further adaptation option to livestock, as is shifting of livestock to land with higher carrying capacity.

Dependence on river flows for water

This can become an important adaptation issue into future conditions, as domestic animals (and wildlife) become stressed or even die if they depend on river flows and these are low or with insufficient water.

Animal health

Adaptation will need to factor in animal health, as changes in rainfall and temperature will impact on the distribution, competence and abundance of vectors and parasites.

4.4.9 Livestock Production Related

A number of adaptation strategies can be implemented to protect intensive livestock production. Major infrastructure investment (e.g. to minimise the effects of heat stress and enhance water provision), could add substantially to the already-high input cost of intensive animal production systems and further affect profitability of already financially burdened farmers. Best management technologies should be promoted by assessing the vulnerability of smallholder livestock farmers in marginal areas, and facilitating early adaptation to the effects of climate change. Programmes could be established to breed heat-tolerant animals.

4.4.10 Subsistence Farmer Specific

Overcoming farmers' constraints and the poverty trap

The main constraints to farmer's low farm incomes may be attributed to the three main causes already elaborated upon in **Section 2.6**, viz. poor commercialization, poor infrastructure and low farm productivity – factors which largely result in a poverty trap. Adaptation strategies will therefore need to reduce or eliminate the perpetuating poverty by addressing vulnerabilities to the vagaries of climate faced by those farmers with their limited opportunities to access vulnerability reducing resources such as fertilizer, transport and alternative income opportunities.

4.5 Adaptation to Climate Change in South Africa: Plantation Forestry Related

The projected changes related to South Africa's forestry sector outlined in Section 3, with emphasis on changes in CO₂, temperature and rainfall on key commercially grown species, has provided an introduction to proposed measures of adaptation outlined below and to the often forgotten issue of potential maladaptation associated with the forestry sector.

4.5.1 Proposed Measures of Adaptation

In regard to adaptation options the following have been proposed in DAFF (2010):

Short term measures

- Strengthen community based forestry and diversification of livelihood skills, which will assist in sustainability of ecosystems and dependent communities.
- Improve inter-departmental collaboration to minimise conflict between sectors.
- Identify key strategic areas of project implementation.
- Fire mitigation, i.e. reducing losses due to fire, and rapid response to forest fires are an imperative. Already present-day initiatives to limit wildfire damage in forests include government support (the Working on Fire programme), as well as an integrated fire management approach by several industrial forestry companies. This involves the combination of pro-active fuel reduction strategies at strategically created buffer strips in the landscape combined with reactive fire fighting at these locations, which has great potential to counter (to some extent) the potential increases in fire risk and severity. Intensively managed forest landscapes may thus play a significant role in landscape fire regimes in future. However, the necessary higher investments in fire management will surely impact economically on commercial forestry (SNC, 2010);

- Reduce losses to other extreme events by benefiting from preparation for both extreme events and changes in the current average resource availabilities to ameliorate the predicted impacts of climate change such as higher incidences of drought, hail, fire, and diseases. In light of this, forest management paradigms may require revision;
 - Perform regressions with currently available data, e.g. on the impact of extreme events.
- Short Term Measures Merging into Long Term Measures**
- Integrate climate change into forestry curricula at both school and post-school levels.
 - Support ecosystems based adaptation in order to enhance biodiversity conservation, water conservation and overall environmental sustainability.
 - Plan and implement multi-objective landscape level planning, in collaboration with other sectors such as biodiversity.
 - Establish and maintain quantified baselines, i.e. long term monitoring plots / datasets.
- Long Term Measures**
- Secure long term funding for the sector as a whole, and more specifically for mitigation and adaptation research.
 - Diversify species production systems.
 - Shift the geographical location of the industry to match the area of optimum potential. Enhanced efforts to optimise site-species matching are likely to provide benefits. Empirical and mechanistic modelling techniques have to be applied to predict site suitability on a national scale and match it with available species, hybrids, or clones. First approaches in South Africa are promising (Fairbanks and Scholes 1999; Louw and Scholes 2006; Warburton and Schulze 2008), but still lack many important criteria to meet all the challenges of climate change. An integrated multi-criteria decision support system could be developed to adapt site-species matching iteratively to the latest updates of climate predictions.
 - From results already to hand (Schulze, 2011), when comparing shifts in climatically optimum growth areas of commercial tree species into the intermediate future, significant differences in the areas gained, lost and remaining unchanged occur between the three species reviewed (cf. **Section 3**). The least areas are lost by *Eucalypts* and the most by wattle. Expansion into new climatically suitable areas by the above-named two species is towards the west (i.e. inland), while for the third species, *Pinus patula* (pines), the expansion would be mainly towards the south.
 - These findings are significant for the commercial forestry sector which has to deal with long harvest to harvest cycles of 10 to 25 years as well as high transportation costs and high costs of relocating timber mills / plants.
 - Tree selection and breeding should be undertaken in light of climate change projections since tree species and provenances differ in climatic adaptability and vulnerability to hazards. Hybridisation and clonal selection provide the potential to adapt to environmental changes. Despite a projected increase of precipitation in some parts of the tree growing area, the criteria for the selection of species, hybrids, and clones will have to focus more on water efficiency, drought and fire tolerance, as well as disease resistance, as precipitation may be more erratic (SNC, 2010).

4.5.2 On Issues of Potential Maladaptation

Climate change adaptation measures in the forestry sector should consider the impact thereof on other sectors, ensuring that any actions outlined above do not have negative implications on the sustainability of other sectors. There are other issues that need to be taken into consideration before adaptation measures can be implemented (DAFF, 2010):

- Before new afforestation takes place, it should be borne in mind that forests generally use relatively large amounts of water in a catchment and under the National Water Act plantation forests are a "Stream Flow Reduction Activity" and need to be licensed, bearing in mind that many South African catchments are already water stressed.
- Before any new afforestation, consideration has to be given to competition for suitable land from other, either profitable or socially desired, land uses such as cropping, bearing in mind that food security is a priority for poverty eradication.

- Potential loss of biodiversity, especially in montane grasslands, has to be considered when planning new afforestation with exotic production forest monocultures.

4.6 Adaptation to Climate Change in South Africa: Cross-Cutting Agricultural and Forestry Issues

4.6.1 Hazard Related

Increased convectivity, coping with fire

If exposed to more frequent and / or greater extremes associated with projected climate scenarios, e.g. high intensity thunderstorms, farmers will have to adapt because of increases in surface runoff, erosion and mudslides by closer contour spacing. Adapting to the risk of more frequent and hotter fires, often started by lightning, with loss of grazing and other crops / plantations is a question of responsibility by landowners to making firebreaks and burning in the times dictated by the law, with small scale farmers needing to gain access to resources to help them prevent the spread of fires (making fire breaks) and to fight fires (fire-extinguishing equipment).

Pest control

Adaptation is required to anticipated increases in pest and disease infestations, including promotion of already tested natural remedies of pest control, which will challenge biologists as well as agricultural extension officers and advisors to keep up to date with the latest knowledge on new and suitable crop varieties and pesticides, including biological controls; and advice on new pesticides from sales representatives to (mainly) commercial farmers and official extension services (mainly) small scale farmers.

Reduction of gully erosion

Through stone packing and other means this is an adaptation measure to decrease water velocities, and should be encouraged and supported.

Water borne diseases

Adaptation will have to consider more outbreaks of insects as a result of warmer water and possibly lower flows in the dry season.

4.6.2 Alien Infestations Related

Alien invasive plants use considerable amounts of water which is then not utilisable to downstream users. Better conditions for alien species to invade may emerge with climate change in regions where riparian vegetation becomes more stressed by lower future flows or changes in channel erosion. Already farmers in the Western Cape perceive a marked growth in riparian aliens. Adaptation measures in this regard under future climates will need to include policies on clearance to be revisited (e.g. regarding subsidies for farmers to continue costly and labour intensive clearing), which implies a long term strategy with economic benefits / incentives to clearing in order to make it economically worthwhile.

4.6.3 Early Warning Systems

Early warning systems, such as seasonal and shorter-term forecasts of climate and in particular extreme events, can be effective in enabling land managers to take appropriate action to minimise the adverse impacts of negative events, while benefitting from positive events (SNC, 2010). Climate information on a day-to-day basis is vital for farm operational procedures such as irrigation scheduling, timing of fertiliser applications, in-field traffic control, cultivar and variety selection, timing of planting, and response farming. A major concern is timely early warnings of adverse weather and the possibility of related pest and disease occurrence. Timely information is of particular importance to the most vulnerable in remote areas, often without access to electronic media used to issue early warnings. Both the South African Weather Service (SAWS) and the Agricultural Research Council (ARC), which maintains the agricultural weather stations network, are providing such warnings by means of cell phones. Many food producers in remote areas, farming on marginal land, are prone to reduced yields and the impacts of climate change such as crop failure due the

increased frequency of drought, floods, and flash floods, as well as diminishing soil productivity and land degradation, will add an additional stress layer (SNC, 2010).

4.6.4 Policy and Authority Related

Agriculture as primary producer

It needs to be emphasised that agriculture in many areas of South Africa is the *only* primary producer (e.g. in the W. Cape where there are no mines etc.) and that in overall adaptation strategies to climate change the entire agriculture sector, and not only components of it, therefore requires special attention from the authorities.

Importance of integrated planning

In adaptation studies this cannot be overstressed, with agriculture, mining and municipalities needing to be planned conjunctively in regard to water quantity and quality.

Policy awareness

For easier adaptation, subsistence farmers need to be aware of policies concerning, for example, veld burning, overgrazing, or contour ploughing, as they do not always prioritise them because they tend to choose short term benefits over long-term sustainability.

Expanded extension services

In order to expedite adaptation to added uncertainties of climate change, both subsistence and commercial farmers need efficient and informative agricultural extension services to provide advice and state-of-the-art knowledge on how to adapt for climate variability and change. These services need to be strengthened in number and capacity.

Financing

Finding means to finance and to use current and new technology and practices, especially targeted towards small scale farmers, will become important instruments of adaptation.

Land claims and land redistribution

Adaptation to climate change implies an experienced, receptive, productive and adaptive farmer community. Land reform and land redistribution will need to incorporate these attributes to be effective under conditions of climatic uncertainty in order to curtail loss of production and degradation of productive agricultural areas.

The urban sprawl

Urban expansion is using up valuable high potential agricultural land which can never be recovered, in addition to enhancing flooding and reducing return flows, and should be halted by authorities in order to face national food security issues with a rapidly expanding population under future climatic conditions with greater confidence.

4.6.5 Science Related

Use of, and trust in, climate forecasts

More so than at present, if climate variability is set to increase, as projected, the use of and trust in climate forecasts (daily to seasonal) will be vital. Adaptation plans have to include more knowledge of, and trust in, climate forecasts by farmers in order to counter climate variability. The fact that few benefits are currently derived from forecasts by poorer farmers may be attributed to them not having enough resources to act on the forecasts, and this will need to be rectified. Science will need to improve the skill and lead times of forecasts.

The uncertainty about climate change

Science will need to continually improve answers on the when, where, how much, what impact, and how to adapt of climate change, including reducing uncertainties on, *inter alia*, *enhanced rainfall variability* and its impacts on crop production; *multiple year droughts and long cycle crops* when farming with crops with plant cycles of 10-30 years (e.g. commercial timber species or deciduous fruit trees) in which case successive droughts years are critical to the survival of the trees; *persistence of raindays* in regard to changes in wet / wet, wet / dry, dry / dry or dry / wet sequences or fewer long duration, multiple day gentle rains in winter rainfall region being observed; *number of raindays* and future changes thereof in the growing season; and / or the *onset and duration of the rainy season* and whether it is projected to set in earlier or later.

Understanding the CO₂ fertilization effect

A better understanding of this is required, with its anticipated enhanced growth through increased photosynthesis as a result of the higher atmospheric CO₂ concentrations and reductions in transpiration, how these interact with crop cover and plant water stress and what the acclimation effects are for annual vs perennial crops.

Changing population dynamics of grazing lands

This is pertinent especially for natural vegetation and where entire ecosystems may suffer degradation or collapse. C₃ / C₄ Grassland Dynamics need to be better understood in light of C₃ and C₄ grass species generally occurring within the same area and sharing the same resources, but with the C₄ grass photosynthetic rates favouring warmer regions compared to C₃ grasses, and with the tall and horizontal growth from the C₄ grasses holding a competitive expansion / invasive advantage over the shorter, slower growth C₃ grasses in regard to light, all in light of impacting (negatively?) on the carrying capacity for livestock and game.

Grassland / woody species dynamics

Improved understanding is required on grasslands becoming woodier with further atmospheric CO₂ enrichment, fires favouring the expansion of grasslands (both C₃ and C₄) and other related issues outlined in **Section 3**. More scientific understanding is also needed on, for example, alien invasive grass species weed infestations in grassland C₃ / C₄ grasslands and fire dynamics as elaborated upon in **Section 3**.

Livestock animal health

This is an issue where science needs to address how changes in rainfall and temperature will impact on animal health with changes in the distribution, competence and abundance of vectors and ectoparasites.

Changing pest / disease distributions

Improved science includes better understanding of *more pest attacks* being likely, with significant repercussions; *distributions* of plant and animal diseases and insects and their likely changes; *dynamics* of insect pests and disease complexes and their likely changes; *new pests* possibly emerging while other pests may expand their ranges or increase their intensity of outbreaks; and *biological control agents / predators* currently effective in controlling agricultural pests but which may lose their efficacy.

Weed control

Further understanding is required on *weeds as hosts*, i.e. where different crop / grass species host different insects, pests and diseases; and the *costs of weed control*, which could increase as alien invasive plants and indigenous weeds are expected to rapidly adapt to changing climate conditions.

Plant breeding

There is a need for *geneticists to breed more drought / heat resistant varieties* of, for example, deciduous fruit with more rapidly responding phenologies and requiring lower Positive Chill Units; with *breeding / developing new varieties to be done now*, because response times for the deciduous fruit species, for example, is long. There is the need to re-look, *inter alia*, water requirements, pH, and fertilizer requirements.

4.6.6 External / Finance Related

Financing new technologies

A means of adaptation, targeted especially towards small scale farmers, is for knowledge dissemination on, and finance to be made available for, utilisation of already established practices (e.g. soil sampling, conservation tillage), embracing new technologies and purchasing appropriate equipment.

Diversification within and outside the agriculture sector

This is especially important in areas of projected decreases in rainfall diversification of agricultural practices will need to occur, including increasing the amount of irrigated land (subject to water availability and not leading to mal-adaptation), finding new locations which are climatically suitable for crops, growing indigenous species, harvesting less often to prevent nutrient depletion, using local techniques to decrease wind erosion (e.g. mulch strips for shelter belts of natural vegetation), and planting of drought-resistant maize varieties, alternative crops or late-maturing fruit trees. Climate change and the resultant inability to

farm as before may prompt especially subsistence households to find other sources of income, through migrating for work (e.g. to urban areas) or through other activities such as making bricks, sewing, selling firewood, etc.

4.6.7 Labour Related

HIV / AIDS

Additional stresses related to climate change have to be considered on effects of HIV / AIDS on skilled and unskilled labour, which is becoming a critical issue in the agriculture sector.

4.6.8 Markets Related

Competitive edge and market projections

South African farmers with export crops need to know more about their competitors (e.g. Australia and South America in the case of deciduous fruit; Brazil in the case of sugarcane) and how global warming might change their competitive edge. There is therefore a need for market projections into the future in order to adapt.

Subsidies and changing markets

Agricultural subsidies in developed countries imply that it is often cheaper to import than to produce locally. The potential repercussions of changing climate might prompt government to re-look forms of subsidisation of key agricultural commodities as an adaptation measure. Where the market is changing (e.g. from dairy to sugarcane), the impacts of projected climate change need to be considered in the individual farmer and national interests.

4.6.9 Culture and Tradition Related

Traditional cultural practices: Communal lands and cattle culture

The lack of land ownership as well as land distribution / sub-delineation policies with resultant small fields that are generally unprofitable need to be revisited in light of additional challenges which might arise from climate change, as farmers will also need to be motivated to use their land sustainably and have certainty of ownership. In light of many factors, *inter alia*, climate change, the culture of many indigenous communities' maintaining large numbers of cattle needs to be re-visited as heavy pressure is placed on the land and risks of overgrazing / soil erosion are increased.

4.6.10 Awareness and Knowledge Related

Awareness and knowledge of the impacts of climate change are essential to make the agricultural production sector less vulnerable, to encourage the sector to adapt to climate change and, most importantly, adopt a soil protection ethos and conservation agriculture practices conducive to soil and water conservation, minimum greenhouse gas emissions, and carbon sequestration. Many within the farming community are either not aware of climate change and its impacts, or regard climate change as normal climate variability.

4.6.11 Communications Related

Experience shows that farmers not able to cope with disasters in the past are the ones less likely to be able to cope with, and adapt to, the vagaries of future climates. A clear communication strategy is therefore required in regard to climate issues. There is a dire need for scientists to create more awareness on potential climate change impacts *now*, and to get the message of the *latest available science* across to government, agri-business (e.g. seed companies), extension services and farmers in regard to issues listed in **Section 4.6.5** on onset of rains, number of raindays, persistence of raindays, enhanced rainfall variability, droughts and long cycle crops, droughts and short cycle crops and the uncertainties that remain about climate change.

An increase in communication and trust should be built up between authorities and all farming sectors (commercial and subsistence) to disseminate as much relevant knowledge on climate change in order to implement adaptation strategies. For this, human and economic resources need to be made available. Farmers should have organised and

operational networks of communication and information-sharing with one another (and extension services) regarding climate related issues (e.g. during the dry months to follow the breaking out and spread of fires) in order to help one another and surrounding small scale farmers who require mentoring.

4.7 Adaptation to Climate Change and Agriculture in South Africa: Summary and Overarching Adaptation Perspectives

4.7.1 A Summary of Findings

Potential impacts of climate change on food production, agricultural livelihoods and food security in South Africa, are significant national policy concerns, and are also likely to have implications beyond the country's borders. Overall, many agricultural sub-sectors are sensitive to projected climate change. Certain crops in South Africa are more resilient to climate change, while others are more sensitive. Similarly, climate change impacts for some crops are projected with more confidence than for others. Additionally, much of the food production and food security which may be at risk is linked to future projected water supply constraints, declines in water quality and competition from non-agricultural sectors. There is evidence that subsistence dryland farmers are more vulnerable to climate change than commercial farmers, while large-scale irrigated production is probably least vulnerable to climate change, conditional upon sufficient water supply for irrigation being available.

4.7.2 Overarching Adaptation Perspective 1: Building Resilience in Agriculture

Resilience is the capacity to accommodate stresses and disturbances while retaining or improving essential basic structures and ways of functioning, the capacity for self-organisation, and the capacity to learn and adapt to change (Adger, 2006; IPCC 2007). For agriculture, therefore, resilience is about retaining or improving the capacity of agricultural systems to provide agricultural goods and services despite climate risks. By implication it includes the following:

- the promotion of climate-resilient rural development planning to address job creation, food security, sustainable livelihoods and contribute to biodiversity;
- using the results of vulnerability and risk studies to develop short-, medium- and long-term adaptation scenarios to identify climate-resilient land uses;
- investing in and improving research into water, nutrient and soil conservation technologies and techniques, into climate-resistant crops and livestock, into agricultural production, ownership and financing models to promote the development of "climate-smart agriculture" that lowers agricultural emissions, is more resilient to climate changes, and boosts agricultural yields;
- using early warning systems to give timely warnings of adverse weather and possibly related pests and disease occurrence; and
- investing in education and awareness programmes in rural areas and link these to agricultural extension activities.

4.7.3 Overarching Adaptation Perspective 2: Promoting Climate Smart Agriculture

The *three pillars of Climate Smart Agriculture (CSA)* are increasing productivity and incomes; enhancing resilience of livelihoods and ecosystems; and reducing / removing GHG emissions and increasing Carbon sequestration. *The CSA approach* combines policy, technology and financing to achieve sustainable agricultural development under climate change, it directly incorporates climate change adaptation and mitigation into agricultural development planning and investment strategies and its practices require scaling up which is facilitated through institutional and governance mechanisms.

The science of CSA includes protocol development for quantifying GHG emissions and mitigation potential of smallholder agricultural activities; research design that combines field measurements, landscape and household surveys, and remote sensing to develop data on

indicators relevant to production, mitigation and adaptation; a framework to assess land degradation; measurements of GHG emissions (N₂O, CO₂, and CH₄); the identification of a menu of climate smart practices; and the development of training and awareness materials.

Given the above, a *CSA strategy* is thus defined by coordinating across a number of stakeholders; assessing climate risks to agriculture and food security; defining coherent policies and regulatory framework across sectors; providing environmental services; and providing credit for investment

4.7.4 Overarching Adaptation Perspective 3: Assessing Impacts of Climate Change on Food Security

Food *availability* under climate change may decrease due to a decline in food production from agriculture. Food *access* is a major constraint at household level and the situation is further compounded by the fact that at household level South Africa remains highly vulnerable to food security. Food *supply stability* is influenced by food price fluctuations. Food utilization is affected indirectly by food safety hazards associated with pests and animal as well as human diseases. Three targets for agriculture in regard to agriculture and food security would be

- Promoting carbon sequestration through conservation agriculture (e.g. zero / reduced tillage, protective crop cover and rotations),
- Increasing efficiency of resources use (e.g. through sustainable land management by optimising soil and water management in high potential, marginal areas and in intensive and extensive systems), and
- Reducing system vulnerability and increasing its resilience (e.g. through agricultural biodiversity, i.e. diversified adapted farming systems)

4.8 Adaptive Capacity

The capacity to adapt to climate change is unevenly distributed across and within the agricultural sector. Several barriers to effective climate and disaster risk management and adaptation exist. These include a lack of accessible and reliable information, lack of market access, and few social platforms to allow engagement of civil society on climate change issues. Experience with severe weather-related events suggests that adaptation capacity to such events is challenged by compounding factors such as pervasive social vulnerability, inadequate planning, constrained integrated and spatial development, as well as poor climate and disaster risk management.

Within the forestry sector the impact of climate change on is acknowledged to be complex and not fully understood, but there is a significant risk that the adaptive capacity of natural forest ecosystems will be exceeded, compromising their ability to provide vital goods and services and their responsive resilience (SNC, 2010).

5. MITIGATION MEASURES

5.1 Roles and Responsibilities of DAFF re. Mitigation

The points below outline the possible roles and responsibilities for climate change mitigation for DAFF (CCSPAFF, 2013):

- The development and implementation of policies, strategies, action plans and / or regulations to mitigate GHG emissions from changes in land use (i.e. land use changes that convert land from GHG sinks to sources); enteric fermentation (i.e. emissions from livestock); intensive tillage; stubble and trash burning (e.g. sugarcane burning); emissions from fossil-fuel powered agricultural vehicles, equipment and appliances;
- Ensure agricultural policy and strategy alignment with the NCCRWP;
- Monitor and report GHG emission reduction interventions in the agricultural sector;
- Forestry-related aspects including fire alerts and REDD+ initiatives; and
- Monitor and report agricultural GHG emissions to the national GHG inventory.

5.2 Greenhouse Gas Emissions from South Africa: An Agriculture and Forestry Perspective

From information provided in the SNC (2011) and the CCSPAFF (2013) South Africa's total emissions in 2000, calculated using the 2006 IPCC guidelines, were estimated to be 461 179 Gg CO₂ equivalents (i.e. 461 million tonnes CO₂ equivalent). Net GHG emissions (after sinks from the agriculture sector were accounted for) were classified into four categories, viz. 86% associated with energy supply and consumption, with 7% from industrial processes, 2% from waste and 5% (i.e. 20 022 Gg CO₂e) from agriculture, with emissions from agriculture (excluding forestry and other land use emissions) increasing by 9% between 1994 and 2000. It is because forestry and other land uses currently provide a net sink for greenhouse gases, that land-derived emissions are reduced to about 5%. From the 2000 inventory, CO₂ was the main GHG emitted in South Africa (79%; with a 15% increase from 1994 to 2000), followed by methane (CH₄) at 16% (74 % increase) and nitrous oxide (N₂O) at 5% (6% increase), with other gases contributing < 1% of total emissions. Early projections were that the 461 Mt CO₂e emitted at the beginning of the century would increase 4-fold to 2050 to 1 637 MtCO₂e.

In the 2000 inventory the Agriculture, Forestry and other Land Use (AFOLU) component included enteric fermentation, manure management, agricultural soils, prescribed burning of savannas and field burning of agricultural residues, as well as also including total emissions from, and removals by forest and land use change, changes in forest and other woody biomass stocks, forest and grassland conversion and emissions from, and removals, by soil. However, anthropogenic emissions from agricultural fuel combustion were reported under Energy and sewage emissions under Waste). The net AFOLU emissions of 20 022 Gg CO₂e were comprised of emissions of 40 773 Gg CO₂e and a sink of 20 751 GgCO₂e, with agricultural soils contributing 42.7% and enteric fermentation 46.5%. Methane was the dominant GHG in AFOLU, contributing 54.3% and N₂O contributing the remaining 45.7%. Sinks came from forest and crop land, respectively at 62.7% and 27.3% of the total CO₂ sequestration (SNC, 2011).

5.3 Mitigation Practices in Agriculture

Despite agriculture's relatively minor contribution to the total South African GHG emissions, its role in relation to climate change has been receiving growing attention from the both public and policy makers and given its exposure to climate change impacts, it is clear that the sector must both contribute further to emission reduction efforts and prepare adaptation strategies to cope with the risks and vulnerabilities of climate change.

Agricultural practices to mitigate GHG emissions are relatively generic and universal. Based on agricultural land management practices that can be implemented at individual farm level to contribute to climate change mitigation, **Table 5.3.1** summarises results derived in Europe by Frelih-Larsen *et al.* (2008), Karczun (2008) and Smith *et al.* (2008) which are generally applicable to South Africa and include mitigation practices from cropland and grassland management with a focus on measures related to crop choice, tillage practice, fertilizer and manure management. The table includes the mitigation potential of individual practices, their relative implementation costs, the probability of implementation, and the key co-benefits and trade-offs of implementation with regard to other environmental objectives. A brief description of the individual measures can be found in **Annexure A**.

The mitigation potentials of CO₂ and non-CO₂ gases (N₂O; CH₄) are presented separately in **Table 5.3.1** because, according to Frelih-Larsen *et al.* (2008) they are qualitatively different in that CO₂ emissions are reduced primarily through soil carbon sinks and are reversible and furthermore soil organic carbon stocks will reach a maximum, so reductions can only be achieved temporarily, i.e. they are saturating. By contrast, reductions in N₂O and CH₄ are permanent and non-saturating since they represent avoided emissions. Because livestock

management is largely excluded from this analyses (except for manure storage / application), effects of most measures on CH₄ emissions in **Table 5.3.1** are marginal.

The following points are important to note re. mitigation practices from agriculture:

- While CH₄ and N₂O are the most important GHGs *emitted* from agriculture, it is more difficult to mitigate these emissions than increasing soil organic carbon (SOC) stocks and thus compensate them through carbon sequestration (Lesschen *et al.*, 2008).
- However, although the mitigation potential for carbon is larger than for N₂O, it needs to be kept in mind that the effect on carbon is only temporary, while for N₂O the emission reduction is permanent and non-saturating.
- Besides, the sequestered SOC stocks can easily be lost again when the climate-friendly management is abandoned.
- Furthermore, while the mitigation potential of individual measures in **Table 5.3.1** is limited, the combined sum effect of individual practices nonetheless makes a significant contribution to mitigation.
- Also, the measures with high mitigation potential (zero tillage, adding legumes, reduced tillage, residue management - no removal of residues, rotation species, catch crops, fertiliser application / type) are all associated with no or low implementation costs.
- Moreover, most of these practices have multiple environmental benefits and contribute to improved longer-term productivity of soils, and should thus be considered as part of improving environmental performance of agriculture.
- Finally, large regional differences regarding mitigation potential exist, illustrating the need to tailor policy measures to regional / local conditions (Freluh-Larsen *et al.*, 2008).

5.4 Linkages Between Mitigation and Adaptation in Agriculture

Because agriculture is a highly vulnerable sector to climate change *impacts* it is also important to consider the side-effects of agricultural mitigation practices on the adaptive capacity of farmers and farming systems. The main adaptation challenges for agriculture under climate change relate to the projected intensification of the hydrological cycle leading to more intensive rainfall, possibly longer dry spells, increases in extreme high temperature events and inter-seasonal variability in temperature and rainfall (Olesen and Porter, 2008). In summary, the main adaptation options for agriculture also relevant for mitigation are measures that reduce soil erosion, measures that reduce nutrient losses, measures that conserve soil moisture, genetic diversity, micro-climate modification and land use change.

Table 5.4.1 illustrates side-effects of mitigation practices on these six categories of adaptation issues. The effects are denoted by "+" (the measure may assist adaptation) or "-" (the measure is likely to hamper adaptation). The table shows that most mitigation options can also have positive effects also on adaptation to climate change, because they increase resilience of the agro-ecosystems to perturbation by climatic variation through increasing nutrient and water retention in the systems and prevention of soil erosion and degradation. Some mitigation measures may, however, have negative effects in relation to adaptation, for example, catch crops that, while adding C to soils, also consume water which when it is scarce may reduce available soil water for the cash crops and thus negatively affect yields.

5.5 Feasibility of Implementing Mitigation Practices in Agriculture in South Africa

Based on research elsewhere (e.g. Freluh-Larsen *et al.*, 2008) the feasibility of implementing the various practices outlined above in South Africa will depend on

- *economic barriers* to implementation, which can be significant for options requiring high investments in equipment (related to manure management, for example) and for practices which reduce yields and profitability of production, as well as
- *technical barriers* related to local climate / soil characteristics which may be identified (e.g. in the case of crop rotations certain crops cannot be introduced under all conditions), and thirdly,

- *institutional barriers*, which affect potential implementation especially where there is low awareness in relevant institutions of the need / possibilities for climate change mitigation in agriculture, or where bureaucratic restrictions arise from mitigation requirements.

Table 5.3.1 Summary of mitigation practices (Modified after Frelih-Larsen *et al.*, 2008; Karaczun, 2008; Smith *et al.*, 2008)

Management Practices	Potential Implementation Cost	Probability of Implementation	Global Mitigation Potential (Smith <i>et al.</i> , 2008)			Description of Costs	Co-Benefits and Trade-Offs
			CO ₂	N ₂ O	CH ₄		
			(tCO ₂ eq/ha/yr)				
Catch crops	Low	High	0.29 - 0.88	0.10	0.00	Cost of legume seed only	Benefits water quality, soil erosion, pest control, soil productivity
Reduced tillage	Low	Medium (low in some areas)	0.15 - 0.70	0.02	0.00	Capital cost of buying or hiring new equipment. Costs decrease as more people do it. Potential for opportunity cost of lost production in areas less suited to reduced tillage via yield penalty	Benefits water conservation, soil quality, biodiversity, energy conservation. May increase fungal problems (and reduce yield) and increase need for herbicides due to reduced mechanical weeding
a. Reduced tillage							
b. Composting and returning							
Residue management	Low	High	0.15 - 0.70	0.02	0.00	No cost unless residues can be sold for other use (but usually low value)	Benefits water conservation, soil quality, biodiversity, energy conservation. May conflict with efforts to use residues as biomass for energy production.
a. No removal							
b. Composting and returning							
Extensification	Medium	Low	1.69 - 3.04	2.30	0.02	Opportunity costs of lost production	Benefits soil quality, biodiversity, water quality
Fertiliser application	No	Medium (already done in some areas)	0.26 - 0.55	0.07	0.00	Should lower costs	Benefits water quality, biodiversity
Fertilizer type	Low	Medium (already done in some areas)	0.26 - 0.55	0.07	0.00	Should lower costs unless fertilizer replacement type is more expensive	
Rotation species	No	Medium	1.69 - 3.04	0.10	0.00	Low cost unless lower production or low market value	Benefits in terms of reduced runoff and erosion, improved soil quality, higher yields, wildlife habitat
Adding legumes	Low	High	0.15 - 0.70	0.07	0.00	Cost of legume seed only	Improves soil fertility, reduces fertiliser needs, helps to protect biodiversity and water
Permanent crops	Variable	Low (reduces flexibility)	1.69 - 3.04	2.30	0.02	Depends on the crops used. Can be low cost through to high depending on market value of the crop	Improves soil quality and water balance, could also improve biodiversity depending on crop used
Agroforestry	Medium	Low (reduces flexibility)	0.15 - 0.70	0.02	0.00	Opportunity cost of lost production; cost of trees	Could improve biodiversity, depending on the permanent crop used
Grass in orchards & vineyards	Medium / high	Low	1.69 - 3.04	2.30	0.02	?	
Optimising grazing intensity	Low / medium	Medium (already done in some areas)	0.11 - 0.81	0.00	0.02 - 0.00	Low unless opportunity cost of less production per hectare of grass	Benefits for biodiversity, reduced soil erosion
Management	Potential	Probability of	Global Mitigation Potential (Smith			Description of	Co-Benefits and
			Potential (Smith			Costs	Trade-Offs

Practices	Implementation Cost	Implementation	et al., 2008)				
			CO ₂	N ₂ O	CH ₄		
			(tCO ₂ eq/ha/yr)				
Length and timing of grazing	Medium	Medium	0.11 - 0.81	0.00	0.02 - 0.00	Low unless opportunity cost of less production per hectare of grass	Benefits for biodiversity, reduced soil erosion
Grassland renovation	Low	High	0.11 - 0.81	0.00	0.02 - 0.00	Part of the normal cycle on many grasslands	Benefits for biodiversity, reduced soil erosion
Optimising manure storage	Medium / high	Medium				New storage equipment can have a large capital cost	Benefits for soil quality, air quality
Manure application techniques	Medium	Medium	1.54 - 2.79	0.00	0.00	New equipment for some techniques, e.g. direct injection	Possible trade-offs with ammonia volatilisation (transboundary air pollution issues)
Application of manure to cropland vs. grassland	Low	Medium	1.54 - 2.79	0.00	0.00	Only costs are need for additional transport from livestock to cropland on or off farm	
Organic soil restoration	Medium / high	Medium	36.67 - 73.33	0.16	- 3.32	Opportunity cost of abandoning the land; small cost of drain blocking	Benefits for soil quality and erosion protection, biodiversity, air quality, aesthetic value

Table 5.4.1 Effects of mitigation measures on adaptation (After Frelih-Larsen *et al.*, 2008; Olesen and Porter, 2008)

Mitigation Measure	Soil Erosion Control	Nutrient Loss Reduction	Soil Water Conservation	Genetic Diversity	Micro-Climate Modification	Land Use Change
Catch crops etc	+	+	-			
Reduced tillage	+		+			
Residue management	+		+		-	
Extensification						+
Fertilizer application		+				
Fertilizer type		+				
Rotation species	+	+		+		
Adding legumes	+	+		+		
Permanent crops	+	+	-	+		
Agroforestry	+	+			+	
Grass in orchards & vineyards	+	+	-		-	
Optimising grazing intensity			+			
Length and timing of grazing	+					
Grassland renovation				+		
Optimising storage manure						
Application techniques						
Application to cropland vs grassland			+			
Peatland management						+

Given the large range of climates, of agricultural practices and of levels of adaptive capacity in South Africa there is likely to be considerable regional variation in the above barriers, highlighting the need for regional flexibility in designing *policy options* for climate change mitigation in agriculture. To achieve this flexibility, region and / or crop specific packages of best mitigation practices and methods to overcome barriers should be identified. Some policy options for mitigation in agriculture are discussed in **Section 9**.

5.6 Mitigation Options in the Forestry Sector

5.6.1 Themes re. Climate Change Mitigation in the South African Forestry Sector

DAFF (2010) has identified six themes regarding climate change mitigation in South Africa's forestry sector:

- *GHG emission reductions through afforestation (Theme 1)*, with 100 000 ha of land in Eastern Cape and KwaZulu-Natal having been set aside for new afforestation provided there is sufficient water in the catchments.
- *Building on, strengthening and / or scaling up current initiatives (Theme 2)*, which include, but are limited to the following:
 - *Forest rehabilitation*. Here the need is to strengthen the rehabilitation of category B & C plantations. This is a restoration programme that has the potential to strengthen forest productivity, diversity and increase resilience to climate change. The rehabilitation of woodlands, thickets (Subtropical Thicket Restoration Project) and natural forests can also contribute significantly to the mitigation of climate change. It would also achieve the combined aims of improving rural livelihoods, restoring biodiversity, and replenishing natural capital / ecosystem services.
 - *Working for woodlands*. It has been realised that with climate change and other human activities woodlands are increasingly under threat in South Africa. It is therefore vital that appropriate measures be implemented to ensure sustainable woodland management, hence the establishment of the Working for Woodlands programme that implements the Woodland Strategy Framework of 2005.
 - *Subtropical Thicket Ecosystem Project (STEP)*. The STEP project provides a conservation planning framework and implementation strategy for the conservation of subtropical thicket, which can also facilitate in the mitigation of climate change.
- *Implementing the "Business Unusual" Call for Action (Theme 3)*. This is a commitment to low carbon economy through better forest harvesting techniques, reduced transport costs for timber, etc, as well as alignment of policies towards a greener economy. The utilisation and application of bio-energy and other renewable energy technologies in commercial forestry activities is advocated.
- *Preparing for the Future (Theme 4)*. Introducing and promoting carbon friendly technology such as renewable energy, biofuel instead of fossil fuel, improving the transport sector and education and awareness programmes could all present better strategies. The potential for the expansion and opportunities in forest biomass production as a renewable energy should also be further researched.
- *Vulnerability and Adaptation (Theme 5)*. DAFF together with research institutions should continue to identify forestry vulnerabilities to climate change. Conservation efforts should also be further strengthened in attempt to preserve the current carbon sink, through the development of relevant policies, national conservation planning, etc.
- *Alignment, Coordination and Cooperation (Theme 6)*. This theme addresses the role of stakeholders, coordination and cooperatives with other departments and institutions, mainstreaming of policies, integration of climate change into strategic plans all form part of implementation plans for this theme.

5.6.2 On Potential CDM and REDD Activities

Of South Africa's projects registered to date with the CDM, none are forestry related (DAFF, 2010). The forestry sector could consider initiating projects for measuring carbon stocks. This may include calculating existing carbon stocks, observing changes in carbon stocks in the carbon pools and how the processes can be enhanced by considering the six carbon pools applicable to Afforestation / Reforestation CDM activities, viz. above-ground tree biomass, above-ground non-tree biomass, below-ground biomass, litter, dead wood and soil organic matter. South Africa has an opportunity to measure carbon stocks in all these areas considering existing and potential afforestation areas (DAFF, 2010).

The currently available National GHG inventory of South Africa (cf. **Section 5.2**) shows that there is a sink potential in the country's forestry sector that contributes significantly to carbon storage. This should be considered if the country takes up REDD or REDD+ projects. South Africa still needs more accurate measurement of its carbon profile from the different types of forests. From **Table 5.6.1** it can be estimated that an annual increase in eucalypt plantations of 10 000 ha per year, for example, could increase the carbon sinks capacity by ~ 65 700 tC/yr. Forests in South Africa currently remove ~ 13 million tonnes CO₂ from the atmosphere in a year, but this figure varies from year to year very much depending on rainfall as trees grow best when rainfall is high, while in dry years there is much less growth (DAFF, 2010).

Table 5.6.1 Comparison of different types of forests in terms of carbon density uptake (DAFF, 2010)

Type of Vegetation	Carbon Uptake (tC/ha/yr)
Pine Plantations	1.88
Eucalypt plantations	6.57
Natural Forests (e.g. Knysna)	0.46
Savanna (e.g. Nylsvlei)	3.90
Grasslands	1.90

Although it may seem that South Africa's forests consume a considerable amount of CO₂, the figure above is in fact a very small percentage of the total amount of CO₂ that is released from the country's coal fired power stations, factories, vehicles and other sources.

The voluntary participation of the country in REDD+ process is based on concerns regarding environmental integrity, i.e. maintenance of ecosystem services and biodiversity and their associated link with human livelihoods and national economies. It has been widely illustrated that in terms of reducing atmospheric GHG, maintaining ecosystems services and biodiversity, as well as reducing deforestation or afforestation, are considerably more cost efficient and makes more sense than reforestation or afforestation. Forestry recognises that its effective participation in the REDD+ process may contribute toward assisting the region to realise the benefits of the REDD+ mechanism. The country could also benefit from REDD+ because of carbon stock enhancement in large forest areas.

6. IMPLICATIONS OF ADAPTATION AND MITIGATION IN THE AGRICULTURE AND FORESTRY SECTORS

6.1 Social Implications

In addressing climate change, DAFF should rope in other social structures and community organisations to inculcate a culture where society will be climate resilient and knowledgeable about the negative and positive impacts of climate change. These social structures will assist in enhancing effectiveness and communicating climate information to local people and most importantly minimising the greenhouse gases emissions, and reduce the vulnerabilities and risks associated with the negative impacts of climate change.

6.2 Economic Implications

Climate change can have negative impacts on the economy as it affects agricultural production and will ultimately affect food security and exports opportunities. The benefits of strong, early action on climate change outweigh the costs. By adopting early strong adaptation and mitigation strategies and/or measures will assist in reducing the costs of addressing climate change impacts in the future. However, there could be some positive spin-offs out of climate change such as renewable energy production which could create some job opportunities in the agricultural sector. Research is therefore critical in pinpointing the main drivers of climate change and identifying opportunities.

6.3 Financial Implications

Adequate resources will be required to ensure that climate change policies, strategies and plans are implemented successfully and efficiently. Climate change is a cross-cutting issue and affects us all. Given the financial constraints within DAFF, private sector has a specific role to see its “partnership” with government and civil society developing to meet the challenges of putting in place measures to address the impacts of climate change. Opportunities to assist countries to tap into international funding should be explored and optimised. These should include Clean Development Mechanism (CDM) funding for CDM projects and Global Environmental Facilities (GEF) as well as the Adaptation Fund linked to the United Nations Framework Convention on Climate Change (UNFCCC).

6.4 Natural Resources Implications

In addressing the impacts of climate change, DAFF in partnership with the private sector and social structures should ensure that any measures and interventions taken should contribute to the regulation, promotion and co-ordination of the conservation of agricultural land and water resources to ensure sustainable development and environmental integrity. Enforcement of legislative tools such as CARA, NEMA, etc will ensure the protection of natural resources for future use.

7. CHALLENGES AND OPPORTUNITIES

7.1 Identifying Gaps and Constraints

Two key knowledge challenges in regard to climate change have been identified by DST. From an agriculture and forestry perspective they are adapted as follows: The first is that of understanding a changing planet, under which proposed research includes supporting effective observation / monitoring, developing an improved understanding of the links between atmosphere, land and ocean and how they impact on terrestrial climates over South Africa, and reducing uncertainties by improving model projections at different scales, particularly local scales that matter. The second addresses adapting the way we live, with proposed research focusing on preparing for rapid change and extreme events in the agriculture and forestry sectors in order to ensure food, fodder and fibre security in an environment of changing soil, surface and sub-surface water security.

The SNC (2010) also highlighted important gaps and constraints, partially overlapping with those of the DST, which bear relevance to agriculture, including the need for more extensive and improved long term monitoring networks; improved projections of potential climate change at finer spatial resolutions; the development of appropriate impact simulation models; improved forecasting and early warning systems; building capacity through education and training at all levels; and improving awareness through better communication among scientists, the media, policy-makers, and other stakeholders.

From the above and from the CCSPAFF (2013) a number of practical challenges are identified related to climate change and that need to be addressed to ensure effective action to counter effects of climate change on the environmental, social and economic integrity components of the agricultural and forestry sectors. The main challenges are a reduction of negative impact that climate change may have on food, feed, fibre and timber production, on those who produce them and on related export and GDP. Technology related challenges are the focus in the SNC (2010) and these are summarised in **Annexure 4**, while the most important challenges identified by the CCSPAFF (2013), many of which are addressed in **Sections 7.2 to 7.5**, include

- Creating awareness on climate change and climate intelligence;
- Developing an enabling mitigation and adaptation environment;
- Improving knowledge on, and an improved understanding of, climate change;
- Increasing capacity to respond to climate change impacts;
- Identifying relevant research needs; and

- Obtaining / providing sufficient funding of the relevant research projects.

7.2 Creating Awareness on Climate Change

Through the media the threats of climate change have been well publicised. There remains, however, a widespread lack of insight into, acceptance and possible imminence of its reality at all levels of society. This affects readiness for the effects of climate change such as vigilance towards extreme weather events and the need for adaptation and mitigation. These concerns need to be addressed by effective, appropriate and innovative means of communication to include school and tertiary level, all tiers of government, the private sector, NGOs, CBOs, industry and value chains, organised agriculture and forestry, farmers and foresters and their communities, the media and the public at large. Creating awareness in the sector is a priority which involves all the role players and stakeholders within the sector to ensure that climate change is incorporated into their activity plans and is effected by events such as workshops and seminars organised in partnership with all the role players in contact with the sector and notably with provinces and communities to facilitate effective awareness of climate change (CCSPAFF, 2013).

7.3 Identifying Relevant Research Needs to Respond to Climate Change

7.3.1 General

Appropriate, timely and proactive basic and action-oriented research needs to be conducted, based on a participative and coordinated research agenda. This would include regular updates of, and on,

- vulnerability audits as were undertaken in this document of the different sectors in agriculture and forestry;
- the science of climate change, scenario modelling and appropriate downscaling for South Africa, including uncertainty analyses;
- agricultural commodity impacts modelling using state-of-the-art models, including economic components;
- GHG inventory updates with detailed and comprehensive agricultural components;
- adaptation studies per agricultural / forestry sub-sector as well at community level; and
- the relationship between natural disasters and climate change.

Current research effort, consisting largely of an insufficient number of isolated studies which have been conducted by different institutions, needs to be expanded and more holistic and collaborative in nature, comprising of research institutions, government departments, NGOs, SAEON, etc. This initiative also needs long term committed funding to support driving of the process. The institutional arrangements and funding mechanisms articulated in the National Agricultural Research and Development Strategy provides an excellent platform to ensure goal-directed, applied, multi-stakeholder and partnership research, with this Strategy needing to be adapted for the forestry sector.

The DAFF needs to establish and maintain quantified baselines of long term or permanent monitoring datasets. In line with these, there should be space-based technologies for monitoring and assessment. The Department needs to invest in genetic resources, institutional and human capacity, long term funding, international collaboration and support of technologies with basic ground work.

7.3.2 Agriculture Specific

There is a need for the agricultural sector in partnership with relevant role players and stakeholders to:

- Identify opportunities that arise out of climate change and ensure alignment of the sector to effective interventions in order to minimize the negative effects of climate change on South African agriculture, including risk assessment and management.

- Ensure that food security is not compromised in addressing the impacts of climate change.
- Increase international cooperation and investment in research on Greenhouse Gases emissions in order to improve knowledge sharing, develop the science and technology needed to improve the measurement and estimation of greenhouse gas emissions.
- Promote and cooperate in the development, application and diffusion of technologies, practices and processes that control, reduce or prevent anthropogenic emissions of greenhouse gases.

DAFF should therefore vigorously pursue the latent opportunities in becoming part of the existing Global Research Alliances and that the Alliances and new international partnerships should be used as a vehicle to maximise the benefits for the sector to carry out tasks required in meeting climate change obligations under the UNFCCC.

7.3.3 Forestry Specific

For forestry there is a need to have controlled growth and testing facilities that will assist to observe impacts of climate change on trees. There should be encouragement of initiatives such as that of some academic institutions Tree Health Biotechnology, in partnership with the Forestry and Agriculture Biotechnology Institute, in which the focus is on a multidisciplinary approach for the field of tree health by looking at all environmental factors, the nature of trees, organisms with respect to tree health by bringing together the fields of silviculture, agronomy, genetics, plant pathology, microbiology, entomology, molecular genetics, in an integrated manner to ensure healthy forests (Communication by the DAFF team with the DST Centre of Excellence in Tree Health Biotechnology).

7.4 Capacity Building: Improving Knowledge on Climate Change and Increasing Capacity to Respond to Climate Change Impacts

7.4.1 General

Effective insights into climate change and actions on possible impacts at all levels of society require a necessary knowledge. The knowledge gap can be bridged by skills development and by gaining knowledge, including indigenous knowledge, and understanding which will promote the adoption of sustainable best management practices and climate-friendly behavioural changes. In particular the youth at all institutional levels should be targeted, with even more attention paid to climate change in school and tertiary education curricula. The capacity to respond to the climate change challenge is coupled to knowledge and the means to act through appropriate interventions, both pre-emptively as well as post-event, through disaster management support by all tiers of government and other stakeholders concerned.

Interventions will need to be client-, ecosystem- and disaster-specific, as individuals and communities differ vastly in their needs and abilities to take appropriate action. An imperative for access to better information and technology should go hand-in-hand by breaking language and cultural barriers and bureaucracy. Of particular importance are capacitation of communities towards self-reliance, provision of knowledge and measures for both mitigation and adaptation to enable responses to short-term, medium-term and long-term effects of both climate variability and climate change, with these provisions tailor-made per ecosystem. This can be accomplished through participation, at all levels, in the negotiation and implementation of adequate strategies and practical initiatives which increase preparedness for impacts of climate change. Such capacity has to be provided by Government through policy frameworks with clear guidelines for short-, medium- and long-term actions. This implies political buy-in as an essential for better implementation of climate change policies. Collaborative efforts with all role players at all levels are also essential. More resources enabled by infrastructure will have to be provided to communities involved, especially the vulnerable, to increase preparedness and to build disaster resilience (CCSPAFF, 2013).

7.4.2 Within DAFF

DAFF needs to support the development of more climate change courses, refresher courses, workshops, information sharing sessions and dialogues, internship programmes and extension services. In its structural changes the department needs to consider strengthening its climate change unit and personnel who are dedicated to promoting awareness internally and externally, participate in international negotiations, monitor the development and implementation of the forestry sector plan for climate change. The unit should also maintain and strengthen its involvement in the national climate change policy development processes driven by DEA.

7.5 Funding

Insufficient funding, lack of accessibility to funding resources for climate change research projects both nationally and internationally, is a long standing challenge. The funding sources envisaged by the National Agricultural Research and Development Strategy should be accessed for climate change-related research and include forestry research projects. Sourcing the increasing amounts of research funding available internationally is also a priority issue. This has the added advantage of creating wider international networking opportunities

DAFF and other role players need to identify relevant areas that require funding while being conscious of not duplicating functions. There is a need for long term sustainable funding to support capacity building, technology, information archiving, knowledge banks and projects for both mitigation and adaptation in the agriculture and forestry sectors. Possible sources of general funding include, but not limited to, the following: Adaptation Fund (UNFCCC); Global Environmental Facility (GEF); Green Economy Fund; Government funding through DAFF and DST; Water Research Commission

More specifically for the forestry sector would be funding from Working for Water, Woodlands and Fire Programmes; Private sector funding (major timber companies; Forestry SA); Clean Development Mechanisms (CDM) / voluntary carbon markets, including levies on CDM projects; REDD funding; Copenhagen Green Fund; Bilateral trades; the Special Climate Change Fund agreed upon at the CoP16.

8. RESPONSE MEASURES

8.1 Institutional Arrangements

While it remains the responsibility of DAFF to coordinate the implementation of its Climate Change Sector Plan (CCSPAFF) at national, provincial and local levels in collaboration with appropriate stakeholders (which include civil society, NGOs, CBOs, the scientific community and the private sector), this climate change adaptation and mitigation plan for the sector (CCAMP) is seen to support the Sector Plan. Some strategic issues identified in the CCSPAFF (2013) to be considered for action in this CCAMP include the following:

- Support the development and implementation of climate change sector action plans at provincial level linked to information management systems;
- Support the development of systems to share climate change information;
- Support the establishment and maintenance of monitoring systems to adapt, mitigate, prevent and respond to disasters;
- Provide support to establish and improve institutional and organizational capacity with special focus on human and financial resources;
- Support awareness creation within communities concerned by promoting the engagement of the media in order to stimulate a culture of disaster resilience and strong community involvement in sustained public campaigns at all levels.
- Support alignment of DAFF to ensure effective interventions to minimise the negative effects of climate change on South African agriculture and forestry, including risk assessment and management;

- Contribute to the regulation, promotion and co-ordination of the conservation of agricultural and forestry land and water resources to ensure sustainable development and environmental integrity;
- Conduct a research audit in consultation with research and academic institutions to identify new climate change research areas and establish needs and gaps;
- Support research priorities related to vulnerability (audits), socio-economic and environmental implications, mitigation and adaptation to climate change identified through the R & D Strategy; and
- Support incorporation of climate change into departmental programmes.

With this *Climate Change Adaptation and Mitigation Plan for the South African Agricultural and Forestry Sectors* seen as a support document to the CCSPAFF (2013), it therefore also has to be seen to be in support of the documents which are listed in **Annexure D**, some of which might have to be amended in light of climate change:

8.2 Existing Structures

The agriculture and forestry sectors should adequately consult and engage, *inter alia*, the following institutions in decision making and implementation of climate change programmes (DAFF, 2010):

- Traditional leadership,
- Department of Education (DoE), Institutions of Higher Learning,
- Department of Environmental Affairs (DEA),
- Department of Trade and Industry (DTI),
- Department of Water Affairs (DWA),
- Department of Science and Technology (DST),
- Forestry Industry and private sector companies,
- Institute of Commercial Forestry Research (ICFR),
- Industry role players such as Forestry South Africa (FSA), Sawmilling South Africa (SSA), independent consultants and communities
- Non-governmental organisations (NGOs),
- Labour,
- District and Local Municipalities,
- Research, academic and information institutions such as Universities, the ARC and the CSIR.

Furthermore, DAFF should encourage the use of indigenous knowledge while consulting, promote Participatory Forest Management (PFM) and engage in local participatory planning that may influence Integrated Development Plans (IDPs).

8.3 Education, Training, Public Awareness and Research

DAFF will collaborate with all relevant national, provincial and local government departments and agencies to ensure that climate change programmes such as capacity building, awareness and research are developed and implemented in partnership with sector communities including academic and research institutions, organised labour, producers and non-governmental organisations, etc.

8.4 Information Management and Communication

8.4.1 Information Management and Communication in Regard to Mitigation

In regard to mitigation practices in agriculture a number of information tools for sustainable farming could be considered for South Africa. Adapted from Frelih-Larsen *et al.* (2008) these are:

- *Developing and promoting monitoring tools for farm sustainability*, including farm training on climate change mitigation (and adaptation) and the development and strengthening of farm advisory services to enable farmers to take action related to mitigation and adaptation, with these possibly financed under a revised rural development policy;

- *Addressing consumer behaviour through carbon labelling*, with consumption patterns having to change through information and awareness raising campaigns and product labelling to indicate the climate and environmental impacts of products to help enable more climate-friendly consumer choices; and
- *Regular measuring, accounting and monitoring of agricultural greenhouse gas emissions* using state of the art indicators and indicator systems to facilitate comparisons over time and between countries, and supported by soil organic carbon maps to help set better targets for mitigation as well as by remote sensing which can be used for verifying the maintenance of carbon-rich ecosystems such as wetlands.

8.4.2 Information Management and Communication in Regard to Adaptation

In regard to adaptation it is recommended that DAFF effectively becomes a “clearing house” for information management and communication by undertaking continual updates on relevant literature, what the advances the various provinces and sectors within South Africa have made and what advances have been made in research institutions (e.g. Universities, CSIR, ARC etc.) and through funding agencies (e.g. NRF, WRC). This information needs to be synthesised and disseminated to the various role players in South African agriculture and forestry at appropriate levels, through appropriate media and in appropriate languages.

9. STRATEGIC ISSUES TO BE CONSIDERED

9.1 Identifying Possible Priorities for Policy Updates and Action in the Agriculture Sector

Based on the agricultural mitigation practices outlined in **Section 5**, three priorities are identified, *viz.* supporting climate change mitigation as part of a strategic and integrated approach to sustainable agriculture, protecting / preserving existing carbon stocks as a mitigation priority, and increasing resources for rural development to support mitigation, with the assumption throughout being that existing policy instruments are implemented effectively, since many of those already control environmental impacts of agriculture and, usually as a side-effect, influence the emission of greenhouse gases from agriculture.

9.1.1 Supporting Climate Change Mitigation as Part of a Strategic and Integrated Approach to Sustainable Agriculture

Climate change mitigation in agriculture in South Africa should be pursued as part of the “Climate Smart” initiative to promote an integrated approach to sustainable agriculture in order to build synergies and avoid conflicts between climate change mitigation and other policy objectives, and to avoid offsetting mitigation efforts through intensification of production or land use change. Such initiatives would have co-benefits and trade-offs with water, biodiversity and climate change objectives, and integrate mitigation and adaptation concerns, especially if undertaken down to more local levels. As a point of departure, a “climate-proofing” of South Africa’s existing agricultural acts / strategies / programmes / policies outlined in **Annexure D** should be undertaken to assess whether they support or hamper climate change mitigation, and determine how they could be improved.

Reasons why an integrated approach should be pursued are two-fold:

- First, mitigation practices in agriculture can have complex and manifold effects on agro-ecosystems (cf. **Section 5**) since they can generate multiple environmental benefits by contributing to biodiversity conservation, soil protection, water conservation, or improved soil fertility, thereby potentially improving agriculture’s ability to adapt to impacts of climate change by increasing resilience of farming ecosystems.
- Secondly, if mitigation practices are implemented in isolation rather than as part of integrated land use policies, there is a real danger of the overall net mitigation effects to be undermined because of the so-called ‘leakage problem’ (Smith *et al.*, 2007b), whereby carbon savings in one area can be quickly offset by the intensification of arable production or land use changes (e.g. conversion from grassland to arable) elsewhere.

9.1.2 Protecting / Preserving Existing Carbon Stocks as a Mitigation Priority

The protection and preservation of existing carbon stocks needs to be considered as a mitigation priority since the protection of soils rich in organic carbon (i.e. with humic and organic topsoils in the South African soils classification), as well as wetlands and certain grasslands, would bring great benefits for mitigation. Significant emission reduction could be obtained if drained wetlands currently used for agriculture were rewetted / restored and a ban placed on the conversion of grasslands on carbon-rich soils to other agricultural uses. The reason for protecting soils with high carbon content is that it is more efficient than attempting to try to increase carbon in soils with low carbon content as carbon losses from organic soils are far higher than gains in mineral soils under improved management (Smith *et al.*, 2008). It can also create several synergies with biodiversity, water, soil protection and other policy objectives and is, furthermore, also a very cost-efficient measure (UNEP 2008).

A combination of regulation and financial compensation would be needed to ensure effective protection of important carbon stocks in soils. This could include bans on the conversion of intact wetland areas with high soil carbon, and requirements to rewet drained wetlands and use them in a way that minimises carbon loss. Financial compensation can be an option to farmers to offset potential loss of income, and to ensure that individual farms or specific regions with a high proportion of land with such soils are not placed at a disadvantage. A prerequisite for setting up an effective protection scheme for high-carbon soils would be mapping these areas across South Africa using the ARC's Land Type soils database and wetlands inventories, possibly supported by remote sensing techniques.

9.1.3 Increasing Resources for Rural Development in Support of Mitigation

Increased funding is required in order to strengthen rural development instruments to support agricultural practices with multiple environmental benefits, but with the additional objective of GHG mitigation. Such measures could include

- *building awareness, knowledge and capacity for mitigation* through
 - promotion of appropriate agricultural techniques;
 - farm training to address also technical and social barriers to implementation of mitigation measures; and
 - institutional capacity building such as farm advisory services which provide a key information and delivery channel for agricultural policy measures, specifically on the technical and economic aspects of mitigation practices, but more generally on effects of climate change mitigation and adaptation to improve awareness of the challenges and opportunities, and facilitate the integration of climate change with other farm and environmental objectives;
- *climate screening of development measures related to mitigation*, for example, when farms are sold / bought or even in the land reform / redistribution process; and
- *formulating an organic farming policy* and promoting it as a highly sustainable approach to food production in that it
 - seeks to enhance soil fertility and diversity at all levels and make soils less susceptible to erosion,
 - offers a very high mitigation potential in particular regarding N and N₂O due to a highly efficient recycling of manures from livestock and crop residues by composting as well as the use of leguminous crops to deliver additional nitrogen, and
 - achieves high C sequestration in soils through the use of green and animal manure, soil fertility-conserving crop rotations with intercropping and cover cropping, as well as by using composting techniques.

9.2 Economic Implications to Support Climate Change Mitigation in Agriculture

Economic instruments to support climate change mitigation in South African agriculture could include a results-oriented set of approaches to carbon storage and nitrogen surplus, options related to carbon trading, and environmental taxes.

Results-oriented approaches to C storage and N surplus reward farmers for achieving specific mitigation targets. Their effectiveness is difficult to control, however, especially with regard to the maintenance of existing C stocks (e.g. in wetlands, other organic C rich soils and permanent grasslands). An approach could be to remunerate the *results* of farmers actions by making payments conditional on the achievement of environmental benefits rather than on taking certain *actions*. For example, C storage on agricultural land would be remunerated either by subsidies or in the context of project-based carbon offset schemes or cap-and-trade system. Tons of carbon would thus become a product to sell by farmers to society. Farmers could be remunerated by, for example,

- *assessing carbon stocks in soils* through either carbon sequestration by periodic measures of C stocks in soils (although difficult to ascertain accurately over short time periods), or by maintaining the current C-content of particularly rich soils; or through
- *remunerating carbon stocks in wood*, thus allowing present tree stands to be maintained or new areas to be afforested through either isolated trees, agroforestry practices, or even complete plantations to be established, all subject to existing policies on afforestation in South Africa.

Options relating to carbon trading through emissions trading would have to be explored in the South African agricultural context in light of feasibility, benefits and costs.

Consideration of taxes as an element of national integrated strategies for sustainable agriculture could focus on taxes on nitrogen as an instrument to be used in national integrated strategies for sustainable agriculture and exploit their potential to reduce nitrogen losses, with benefits for water protection and N₂O emissions. Examples could include.

- *Tax on mineral fertilizers*, which could be applied at the level of retailers, with price increases passing the incentive to reduce fertiliser use on to the farmers (an option which could work in South Africa); alternatively, the taxes could encourage fertiliser producers to create more climate-friendly products; or
- *Tax on nitrogen surplus or farm-level nitrogen balance*, where the tax could be levied on farm nitrogen surplus calculated as the difference between inputs (e.g. in manure, feed, seed, fertiliser) and outputs (sales at arm gate of plant and animal products); an option which would be difficult to monitor in South Africa.

9.3 Identifying Possible Priorities for Policy Updates and Action in the Forestry Sector

DAFF (2010) has highlighted the following policy directions / messages, which have been updated where necessary:

- Given the contribution of the forestry sector to the achievement of national development strategies, adaptation measures will be important for ensuring that these contributions are not diminished through climate change.
- Greater emphasis should be placed on analysing adaptation needs from a livelihoods perspective and focusing actions which have the greatest effect on poverty alleviation.
- Implementing sustainable forest management and best practices in ecosystem management will increase ecosystem resilience. Applying existing knowledge is a first, immediate step, later supplemented by actions in direct response to climate change.
- Strong institutional and human capacity should be established in forestry to address forest and climate change needs. However, increased financial resources need to be devoted and increased expertise in climate change needs to be built in order to effectively address the new climate-related needs.
- Long-term, well targeted and sustained funding should be committed to support forest and climate change research, technology and activities, subject to regular reviews.
- Climate change should be integrated into existing forest policies, institutions, research programmes, expanding or adjusting programmes as necessary, but with no need to set up parallel policies and structures.
- There is a wealth of data and knowledge available within South Africa. However, research data are often scattered and not easily accessible. Relevant research data

should be audited and harvested, a knowledge management system developed to safeguard institutional memory, and research networks and collaborative research, development and innovation (RDI) programmes should be strengthened.

- Forest monitoring systems need to be upgraded and expanded in order to provide for the collection of needed data for planning and evaluating adaptation and mitigation.
- The definition of forests chosen by South Africa for the purpose of monitoring and reporting to UNFCCC has important implications. There is a need to consider this question, both in light of existing policies, data collection as well as the potential benefits from REDD+, and CDM mechanisms under UNFCCC.
- Public awareness of forests and climate change issues is limited. Communications programmes should be launched to increase awareness and understanding of issues.

10. IMPLEMENTATION PLAN

Although DEA has been designated as the lead agency for climate change response in South Africa, it is recognised that climate change is a cross-cutting issue that has ramifications for diverse activities in other government departments, in this case DAFF. The following are fundamental to the successful implementation of this plan:

- Even more effective coordination amongst the various departments involved in, or impacted by, climate change is required to ensure that any response measures identified through research and other endeavours be properly directed, acceptable to all relevant stakeholders and carried out with a national focus to be aligned to the National Development Plan.
- Numerous policies and pieces of legislation deal with the climate change issue as it is projected to impact on South Africa. DAFF will need to ensure that its policies and sector plans are aligned with national climate change mitigation and adaptation policies and plans.
- In the case of the forestry sector, nationally and internationally determined environmental performance and, in particular, cleaner production technology can represent a significant competitiveness factor for industry.
- Appropriate government / industry partnerships should be encouraged and developed, with industry / business involvement of a substantial nature, including taking on a role through capacity building in government.
- More specifically within the forestry sector, DAFF is involved in the Working for Water / Wetlands / Woodlands / Ecosystems Programmes which, through their significant role in rehabilitation and restoration of degraded landscapes, promote a low carbon economy.
- DAFF is also driving the integration of climate change into National Forest Programmes (NFPs), this including, *inter alia*, the incorporation of climate change aspects in the forestry strategies that are being developed.
- The Department also has to ensure more incisive enforcement and implementation of current strategies, particularly in identified areas of climate change risk.
- The Research and Development (R&D) strategy of DAFF also needs to enhance informed policy compilation and more effective science communication.

In ensuring that this plan is implemented successfully, DAFF in collaboration with relevant government stakeholders and role players including the private sector needs to develop implementation clear guidelines to ensure successful implementation nationally, provincially and locally, with DAFF ensuring that resources be made available and enforcement be effected in partnership with government stakeholders and role players. DAFF will engage identified government stakeholders and role players through-out the consultative processes.

11. MONITORING AND EVALUATION

Many facets of monitoring and evaluation have been listed and highlighted in **Sections 7, 8, 9 and 10** above and are not repeated here. What are seen as practical implementation imperatives, however, to assess whether this plan's objectives are met include

- the establishment of a climate change monitoring unit for the agriculture and forestry sectors in South Africa, preferably in the Directorate of Climate Change and Disaster Management,
- with mandates, *inter alia*,
 - to develop an information management system,
 - to cover advances in climate change science, specifically within a South African context,
 - to evaluate conceptual and technological advances and new insights into adaptation and mitigation options,
 - to monitor progress on the adoption of adaptation and mitigation practices within the various sectors of agriculture and forestry, and
 - to synthesise the above findings in order to report back to role players within the public and private domains through an annual series workshops at national, provincial and sector levels.

12. REVIEWS AND UPDATES OF THE PLAN

This *Climate Change Adaptation and Mitigation Plan for the South African Agricultural and Forestry Sectors* should be viewed as a dynamic document with updating being an ongoing process of refinement and enhancement as and when new information comes to hand (see **Section 11**), but with formal reviews being undertaken as required by the National Climate Change Response White Paper (or its successor) and also in the same cycle that South Africa prepares new National Communications to the UNFCCC, in order for the updated information to be used in such National Communications.

This Adaptation and Mitigation plan must not be seen as an end in itself, but rather as constituting one step in an ongoing process of refinement and enhancement of needing to cope with projected future climates in the South African agricultural and forestry sectors. The approved plan will be reviewed every Five (5) years from the first year of its implementation date. On-going assessment will be conducted to determine its effectiveness and appropriateness if and when deemed necessary.

13. CONCLUSIONS

Handling the vagaries of climatic variation and positioning DAFF to maximise both opportunities and the negative impacts of more frequent severe weather events and climate change will be major challenges of the future. However, an efficient and effective South African climate change response will need the participation and commitment of all spheres of government, business, academia, research, industry and civil society in general. Reducing greenhouse gas emissions in the agricultural sector will be a challenge on the one hand, but implementing alternative strategies for adapting to the negative effects of climate change is possibly even more appropriate within agriculture and forestry, especially for poorer communities and in a vulnerable economy. Climate change can have negative impacts on the economy as it affects not only agricultural production, but ultimately also food security. The benefits of strong, early action on climate change outweigh the costs. Adopting early adaptation and mitigation strategies and / or measures will assist in reducing the costs of addressing climate change impacts in the future (CCSPAFF, 2013).

This adaptation and mitigation plan for the South African agricultural and forestry sectors has outlined a variety of useful mitigation and adaptation options promoting soil, water and nutrient conservation for agricultural production including soil carbon sequestration (enhanced sinks), soil cover and improved crop and grazing management conducive to sustainable agricultural and soil productivity. The latter include improved agronomic practices, water and nutrient use efficiency, conservation agriculture and residue management, restoration of soil organic matter and restoration of degraded lands. The challenge to the agricultural and forestry sectors is to promote the adoption of climate-smart processes. The intricate process involved in the adoption of best practice technologies is of the utmost importance and needs to be encouraged.

Overall, however, because mitigation is largely concerned with innovative ways of reducing emissions and adaptation with ways of dealing with changed or changing conditions, the agricultural and forestry sectors' main focus will be on adaptation, while mitigation practices will be intensified.

IMPORTANT

Information

from Government Printing Works

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Please take note of these guidelines when completing your form.

GPW Business Rules

1. No hand written notices will be accepted for processing, this includes Adobe forms which have been completed by hand.
2. Notices can only be submitted in Adobe electronic form format to the email submission address submit.egazette@gpw.gov.za. This means that any notice submissions not on an Adobe electronic form that are submitted to this mailbox will be **rejected**. National or Provincial gazette notices, where the Z95 or Z95Prov must be an Adobe form but the notice content (body) will be an attachment.
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9. All submissions and re-submissions that miss the cut-off will be rejected to the customer to be submitted with a new publication date.
10. Information on forms will be taken as the primary source of the notice to be published. Any instructions that are on the email body or covering letter that contradicts the notice form content will be ignored.

You are therefore advised that effective from **Monday, 18 May 2015** should you not comply with our new rules of engagement, all notice requests will be rejected by our new system.

Furthermore, the fax number **012- 748 6030** will also be **discontinued** from this date and customers will only be able to submit notice requests through the email address submit.egazette@gpw.gov.za.



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