Vulnerability and Adaptation to Climate Change in the Semi-Arid Regions of Southern Africa

CARIAA
Collaborative Adaptation Research Initiative in Africa and Asia

ASSAR
Adaptation at Scale in Semi-Arid Regions

About ASSAR Working Papers

This series is based on work funded by Canada's International Development Research Centre (IDRC) and the UK's Department for International Development (DFID) through the Collaborative Adaptation Research Initiative in Africa and Asia (CARIAA). CARIAA aims to build the resilience of vulnerable populations and their livelihoods in three climate change hot spots in Africa and Asia. The program supports collaborative research to inform adaptation policy and practice.

Titles in this series are intended to share initial findings and lessons from research and background studies commissioned by the program. Papers are intended to foster exchange and dialogue within science and policy circles concerned with climate change adaptation in vulnerability hotspots. As an interim output of the CARIAA program, they have not undergone an external review process. Opinions stated are those of the author(s) and do not necessarily reflect the policies or opinions of IDRC, DFID, or partners. Feedback is welcomed as a means to strengthen these works: some may later be revised for peer-reviewed publication.

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Vulnerability and Adaptation to Climate Change in Semi-Arid Areas in Southern Africa

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List of Acronyms

ADC	Agriculture Development Centre
ARC	Agriculture Research Council
ASSAR	Adaptation at Scale in Semi-Arid Regions
CARIAA	Collaborative Adaptation Research in Africa and Asia
CORDEX	Coordinated Regional Climate Downscaling Experiment
CAU	National Climate Analysis Unit, Namibia
CCSA	Climate Change Strategy and Action plan
CCU	Namibia's Climate Change Unit
CDKN	Climate Development Knowledge Network
CES	Creative Entrepreneurs Solutions
CGCC	Contact Group on Climate Change
CGS	Council for Geo-sciences
CIA	Central Intelligence Agency
CSIR	Council for Scientific and Industrial Research
CSO	Central Statistics Office, Republic of Botswana
DAPEES	Directorate of Agricultural Production, Extension and Engineering Services
DEA	Department of Environment Affairs, Republic of South Africa
DFID	Department for International Development-
DMS	Department of Meteorological Services
DMU	Disaster Management Unit
DRFN	Desert Research Foundation of Namibia
ENSO	El Niño Southern Oscillation
FAO	Food and Agriculture Organisation of the United Nations
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit, Germany
HDI	Human Development Index
IDRC	International Development Research Centre, Canada
IECN	Integrated Environmental Consultants Namibia
IFAD	The International Fund for Agricultural Development
IGCCC	Intergovernmental Committee on Climate Change
IPCC	Intergovernmental Panel on Climate Change
ISPAAD	Integrated Support Programme for Arable Agricultural
ITCZ	Inter-Tropical Convergence Zone
IUCN	International Union for Conservation of Nature
MAWF	Ministry of Agriculture, Water and Forestry, Republic of Namibia
MET	Ministry of Environment and Tourism, Republic of Namibia
NAPA	UNFCCC National Adaptation Programme of Action
NCCC	National Committee on Climate Change
NCCC	National Climate Change Committee
NCCP	Namibia's National Climate Change Policy
NCCRP	South African National Climate Change Response Policy
NASCO	Namibian Association of CBNRM Support Organisations
NCCC	Namibia Climate Change Committee
NDP3	National Development Plan 3
NGOs	Non-Governmental Organisations
NNF	Namibia Nature Foundation
NPC	National Planning Commission
NVAC	National Vulnerability Assessment Committee
MEWT	Ministry of Environment, Wildlife and Tourism
MTF	Management and Transition Framework
MICOA	Ministry for Environmental Coordination, Republic of Mozambique

OPM	Office of the Prime Ministry
RDS	Regional Diagnostic Study
RCMs	Regional Climate Models
SADC	Southern African Development Community
SAIAB	South African Institute of Aquatic Biodiversity
SARs	Semi-Arid Regions
SASSCAL	The Southern African Science Service Centre for Climate Change and Adaptive Land Use
SESF	Social-Ecological System Framework
SIDA	Swedish International Development Cooperation Agency
SNC	Second National Communication
SREX	Special Report Managing the Risks of Extreme Events
START	System for Analysis Research and Training
UNAM	University of Namibia
UNCCD	the Global Mechanism of United Nations Convention to Combat Desertification
UNDP	United Nations Development Program
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNISDR	United Nations International Strategy for Disaster Reduction

Executive Summary

Context

The semi-arid areas of southern Africa are culturally and ecologically diverse characterised by a high proportion of poor people with limited access to services, high unemployment levels, high levels of inequality, and high levels of HIV and AIDS. In addition to agriculture, the people living in these areas are reliant on a variety of natural resources, employment and remittances for their livelihoods due to the relatively low agricultural productivity of land.

Climate change, trends and projections

Semi-arid areas in southern africa are characterised by seasonal and highly variable rainfall (inter-annually and intra-seasonally), frequent droughts and flash floods. Temperatures are predicted to increase in semi-arid areas in southern Africa by between 1 and 4 degrees Celsius by 2050 and substantial multi-decadal variability in rainfall is predicted to continue into the future, without certainty in the direction of change in rainfall in any area.

Risks, impacts and vulnerability

The main impacts of climate change are expected to include: reduced water availability, increased occurrence of vector and water-borne diseases, reduced crop and livestock productivity and damage to transportation infrastructure and buildings. Vulnerability in the semi-arid areas of southern Africa is a function of the existing environmental and climatic conditions coupled with governance, socio-economic, health, education, culture and human demography issues. Communities in semi-arid regions are characterised by: i) dependence on primary production and natural resources; ii) reliance on rain fed agriculture; iii) a low diversity of livelihoods; iv) dependence on activities that are sensitive to the impacts of climate change; v) limited infrastructure and services; vi) limited institutional capacity; vii) high levels of poverty; and viii) cultural beliefs and superstition. The climatic and socio-economic environment in semi-arid areas in southern Africa makes communities vulnerable to food insecurity and unstable livelihoods as well as leading to unsustainable agro ecological systems. Some of the key vulnerabilities in semi-arid areas include: i) people settling in floodplains, ii) the lack of marketing of livestock driven in part by cultural beliefs, economic factors and lack of institutional support in terms of available markets; iii) the degradation of natural resources; iv) livestock not coping with heat and not having well adapted crop varieties; v) not having information on adaptation options; vi) not having integrated policies and programmes across different ministries; vii) lack of parental care of the youth and lack of opportunities for the youth; viii) lack of institutional capacity at the local scale; and ix) conflicting government programmes and programmes that increase dependence. Women are particularly vulnerable to the impacts of climate change as in many areas they are responsible for the provision of food, water and firewood and these commodities become difficult to obtain during times of drought. In some places there are conflicts between national and customary institutions which impedes the implementation of activities locally.

Adaptation

Numerous coping and adaptation interventions have been implemented and suggested for semi-arid areas in Southern Africa. The main coping mechanisms include relying on social networks for assistance, reducing the size of livestock herds and supplementing livestock with food and water. Adaptation interventions include those related to forecasting, storage of food, water efficiency, water management and water harvesting, environmental improvement interventions such as soil and water conservation, tree planting, wind breaks and conservation agriculture, and the diversification of livelihoods, crops and livestock, spatial and temporal changes e.g. moving livestock, changing planting dates of crops and accessing other land and water. At the national level, adaptation plans and processes are occurring to different degrees across the region. The issue is on the national agenda but not a high priority for most governments.

Barriers to adaptation

There are a number of barriers to adaptation that have been reported in the literature. These include a number of governance related issues including a lack of coordination, technical capacity and availability of resources. At the local level factors such as a lack of access to information, natural and financial resources, technical know-how and incentives play a role.

Key knowledge gaps

Key knowledge gaps identified during the RDS phase include limited information on the impacts of climate change on individual households and community needs during drought, measures of adaptation, appropriate crop varieties and other adaptation options, costing of adaptation measures and socio-economic impacts and the effectiveness of existing policy and practice with regards to the implementation of adaptation measures.

Conclusions

The adaptation measures that are currently being implemented in southern Africa are unlikely to help communities adapt to climate change into the future. Despite the lack of knowledge regarding the effectiveness of current measures in reducing vulnerability and how to measure adaptation, the nature of climate into the future is likely to require transformation and not merely adaptation. Limited mainstreaming of adaptation currently and plethora of barriers that already exist to the implementation of adaptation require that an evidence base is built to influence policy and practice towards enabling widespread and sustained adaptation.

CHAPTER 1

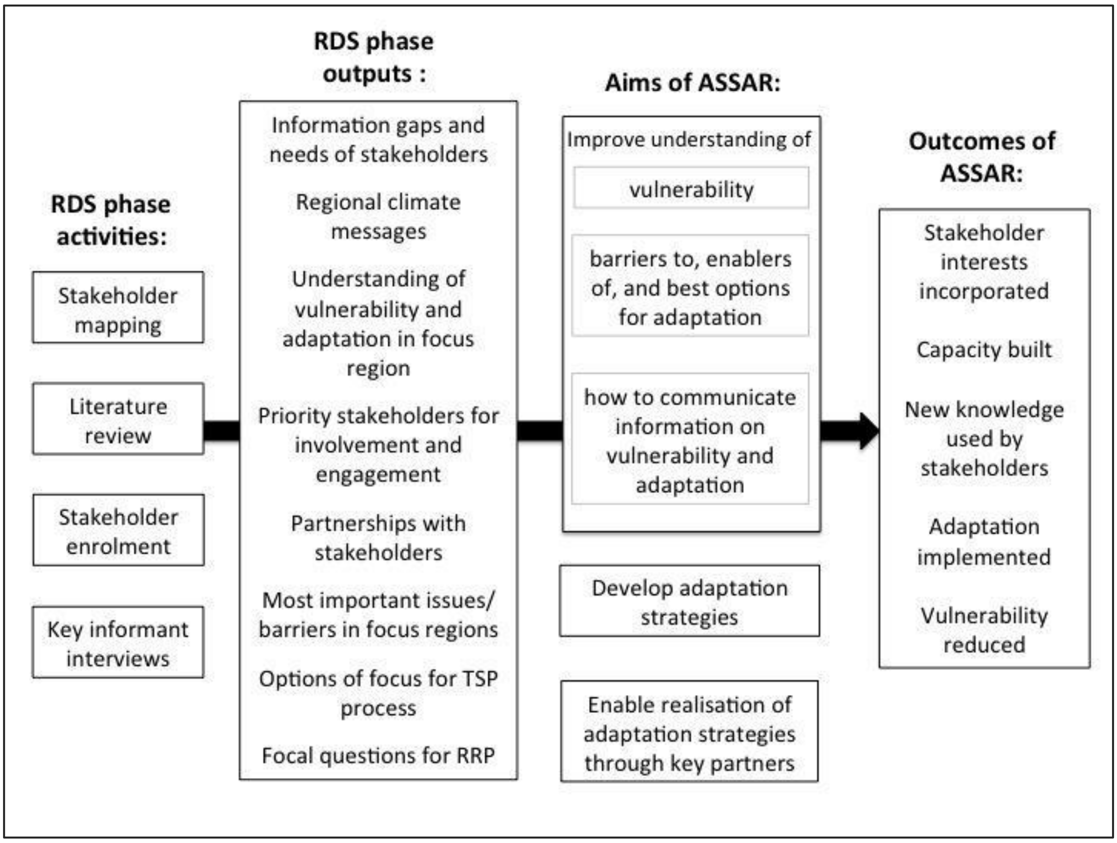
Introducing the Regional Diagnostic Studies Report

Introducing the Regional Diagnostic Study

The main objectives of the RDS phase are to: i) develop a systematic understanding of existing knowledge and perceptions of climate change trends, impacts, vulnerability, adaptation strategies, and barriers and enablers to effective adaptation in SARs; ii) provide a system scale perspective from which ASSAR researchers can undertake research in the Regional Research Programme (RRP); and iii) help inform the more detailed sets of specific research foci for the RRP.

Figure 1

The Role of Regional Diagnostic Studies within the ASSAR project



1.1 Expected outcomes

The RDS phase provides:

- A synthesis and set of information products that capture the current state of affairs from a regional and national perspective in SARs, and allow us to understand common and divergent system-scale climate-change adaptation issues across SARs
- Clarity on gaps in information in the literature, which will shed light on what should be addressed through the RRP
- Input to develop specific, more narrowed down questions that stem from the 7 research questions
- Identification of societal determinants of vulnerability, adaptive capacity, and barriers/ enablers to successful adaptation.
- Inventory of priority stakeholders for engagement.
- Research and knowledge gaps, informing the focus of the next phase of the research.
- Inform the research design and methodology development for RRP.
- Identification of intermediaries/boundary organisations.
- Increased understanding of current risk management and adaptation practices and their effectiveness within the regions. at the regional scale.

1.2 Audience for the report

This report will form the foundation for further work of the ASSAR research project including the synthesis of work across the four ASSAR regions. The primary audience for this report therefore is the ASSAR researchers across all four regions. The second audience for this report is the ASSAR stakeholders including policy makers and practitioners in different national and local government departments and non-governmental organisations. The report provides a status quo on research knowledge on vulnerability, impacts and adaptation in SARs. In particular, the report should be communicated to those stakeholders who have provided information for inclusion in the report as key informants. Summary fact sheets of the report will be developed for some stakeholders e.g. policy makers, government authorities and community members. The relevant summary documents will be translated into the local language where relevant. The RDS report and peer-review papers resulting from it could also be an important contribution to the next IPCC report and other reports, such as national communications and regional strategy documents.

Box 1

Collaborative Adaptation Research in Africa and Asia (CARIAA)

The aims of the CARIAA programme are to understand: i) what makes people in "hotspots" of climate change impact vulnerable to climate change; ii) what works and does not work in adaptation; and iii) what are the barriers to and enablers of adaptation.

The three hotspots of impact to climate change that CARIAA is working in are: i) semi-arid regions, ii) deltas and low-lying coastal areas; and iii) glacier-fed river basins. The ASSAR (Adaptation at Scale in Semi-Arid Regions) project is one of 2 projects working in semi-arid regions and is focused on southern Africa, west Africa, east Africa and India.

Adaptation at Scale in Semi-Arid Regions (ASSAR)

The ASSAR research project aims to examine and understand the barriers and enablers for effective medium-term (up to 2030) adaptation as well as what responses enable more widespread sustained (up to 2050) adaptation. The five objectives outlined in the ASSAR proposal are to: i) undertake high-quality, innovative, transdisciplinary research to generate new stakeholder-driven knowledge on vulnerability and adaptation to climate change in SARs, with a specific focus on understanding what enables effective, long-term and sustainable adaptation; ii) develop and trial relevant and actionable strategies for adaptation that inform and influence key stakeholders within, across and beyond CARIAA SAR hotspots; iii) create innovative communication approaches for effective knowledge sharing on climate change vulnerability and adaptation in SARs; iv) enable systemic capacity strengthening for adaptation in SARs, in research, policy and practice domains, and create a new cadre of Southern adaptation specialists who can take on leadership positions in these domains; and v) ensure that the ASSAR research is used during – and well beyond – CARIAA so as to shape policies and practices that enable, at widespread scales, vulnerable populations or sectors adapt to climate change.

Within ASSAR, researchers are investigating: i) the drivers of vulnerability of different demographic groups in semi-arid regions; ii) the effective communication of useful and relevant information on climate change; iii) the effectiveness of different adaptation strategies at different scales; iv) the availability and utility of climate projections for determining potential impacts of climate change and potential adaptation options; v) the role of social, political, economic and governance factors in driving vulnerability into the future; vi) adaptation planning in the face of biophysical and socio-economic uncertainties; and vii) the barriers and enablers of effective long-term adaptation.

1.3 Approach for the RDS phase

The RDS reports prepared for ASSAR are a follow on from CARIAA's review documents on hotspots:

- Berrang-Ford, L., Pearce, T. & Ford, J.D. 2015. Systematic review approaches for climate change adaptation research. *Regional Environmental Change* DOI: 10.1007/s10113-014-0708-7
- Bizikova, L., Parry, J-E., Karami, J. & Echeverria, D. 2015. Review of key initiatives and approaches to adaptation and planning at the national level in semi-arid areas. *Regional Environmental Change* DOI: 10.1007/s10113-014-0710-0
- Ford, J.D., Berrang-Ford, L., Bunce, A., McKay, C., Irwin, M. & Pearce, T. 2014. The status of climate change adaptation policy and practice in Africa and Asia. *Regional Environmental Change* DOI: 10.1007/s10113-014-0648-2
- Tucker, J., Daoud, M., Oates, N., Few, R., Conway, D., Mitsi, S. & Matheson, S. 2014. Social vulnerability in the high poverty climate change hotspots: what does climate change literature tell us? Regional Environmental Change DOI: 10.1007/s10113-014-0741-6
- Kilroy, G. 2015. A review of the biophysical impacts of climate change in three hotspot regions in Africa and Asia. Regional Environmental Change DOI: 10.1007/s10113-014-0709-6

Where as these reviews took a more general broad scale perspective in their analysis this RDS report provides more specific information.

The RDS includes four main approaches to obtain an understanding of the adaptation landscape. These are: i) a literature review of existing documents including peer-reviewed articles, reports and policy documents; ii) stakeholder mapping including relevant organisations that ASSAR researchers want to influence, collaborate and share information with; iii) key informant interviews with a representative spread of regional, national, and local actors who will contribute insights from different knowledge and political-economic systems; and iv) a new generation of regional climate-change projections arising from the Coordinated Regional Climate Downscaling Experiment (CORDEX) initiative, which will be refined into credible and actionable regional climate messages early in the research phase of the project.

1.3.1 Key informant interviews

The key informant interviews with a combination of national, district and local stakeholders are critical to obtain information on multiple perspectives on threats, opportunities and barriers in the biophysical and political-economic-social domains, and to gauge the range of understanding and capacities of different actors across these systems.

1.3.2 Regional climate messages

The next-generation climate messages will fill a critical gap in climate information with SARs, where there has been very little systematic provision of higher resolution scenarios at relevant space and time scales, and with clear communication of confidence in different aspects of the scenarios.

1.4 Data gathering methods

A literature review was conducted with a focus on climate change vulnerability and adaptation in semi-arid areas (following Kottek *et al.* 2006) in Botswana, Namibia and South Africa for the time period 2005 to 2014. Both grey and peer-reviewed literature was obtained. Searches were conducted using Web of Science, Google Scholar and Google. Key words used for searches included “semi-arid”, “Namibia”, “Botswana”, “South Africa”, “Botswana”, “Mozambique”, “southern Africa”, “adaptation”, “climate change”, “vulnerability”, “dryland” National communications were consulted as a key resources as well as references therein. The team member’s knowledge of the literature was also used in terms of identifying important reports and papers.

The identified documents were reviewed extracting information relevant to ASSAR’s 7 research questions as outlined in the project proposal. Information was entered into a database in excel for use in writing the RDS report.

1.5 Framing of Social-Ecological Systems

In the ASSAR project the importance of vulnerability and particularly well-being is foremost within a broader development context. The focus on well-being takes a broader more holistic view of vulnerability and is used to frame what is considered as effective adaptation i.e. adaptation measures are not considered effective if well-being is reduced. Well-being will be defined for the different communities where research is conducted. The focus of this report is the impact of climate change on people and how people can adapt to the impacts of climate change. Having said that, the importance of ecological systems in providing ecosystem services to people is recognised, as is the importance of intact ecosystems for increasing resilience to the impacts of climate change.

ASSAR researchers are following the framework of Tschakert *et al.* (2013). In line with the proposed framework of Tschakert *et al.* (2013) ASSAR research and the RDS report aims to consider barriers, multiple spatial scales and the linkages between scales and structural sources of vulnerability including issues of governance, gender and development-adaptation linkages. In addition ASSAR’s research is participatory.

Following the characteristics reviewed by Binder *et al.* (2013) the way ASSAR Southern Africa is framing Social-Ecological Systems includes the following: i) All hierarchical levels are being studied and duality between the macro and micro level is being considered i.e. social structure influences individual behaviour and individual behaviour perpetuates or changes social structure) e.g. in the Social-Ecological System Framework (SESF) (Ostrom 2007) social and governance structures affect the way in which actors behave and actors might be part of the governance system and shape it; ii) the ecological system is being defined based on its utility for humans i.e. the ecological system is seen as a provider of services that increase human well-being. There isn’t a focus on analysing the ecological system; iii) Different spatial scales will be studied; iv) Changes to the ecological system that are relevant to the social system will be studied; and v) The reciprocity between the social system and the ecological system is considered, including feedback loops and learning processes in the social system in response to changes in the ecological system. There is more of a focus on how the ecological system influences the social system. Similar to the Management and Transition Framework (MTF) (Pahl-Wostl 2009) the ecological system influences the social system through the provision of ecosystem services and environmental hazards that threaten the social system. The social system influences the ecological system by interventions related to using services and preventing hazards.

Following the above the RDS report focuses on the impacts of climate change on people, their vulnerability, well-being and adaptation responses they have made. It does not focus on the impact of climate change on ecosystems or biodiversity nor how biodiversity is, or ecosystems are vulnerable or adapting.

CHAPTER 2

Regional to sub-national context in southern Africa

The Regional to Sub-national Context

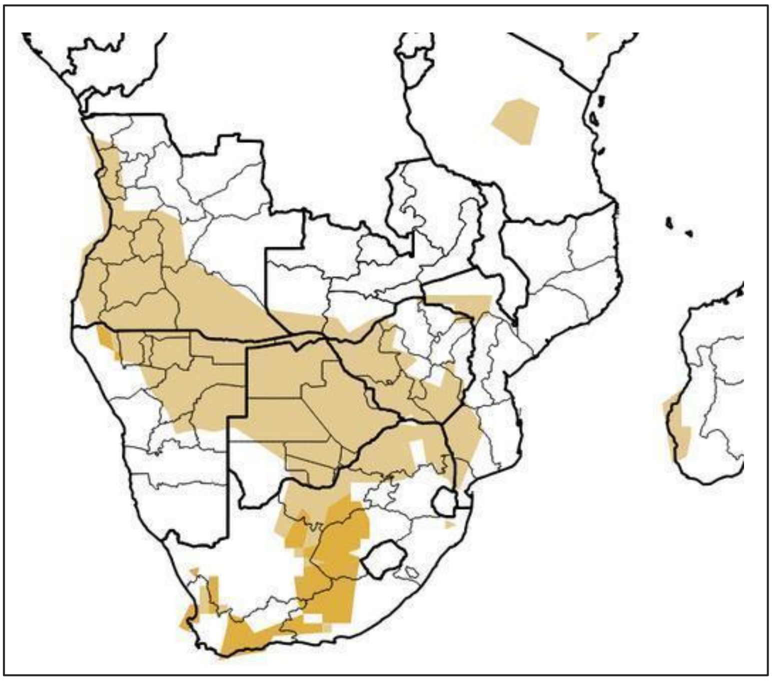
2.1 Geographical location of the semi-arid regions of southern Africa

While the Southern Africa subregion of the UN is restricted to South Africa, Namibia, Botswana, Swaziland and Lesotho, the region is more commonly defined to also include Zimbabwe, Mozambique, Zambia and Angola; further, the Southern African Development Community (SADC) also includes countries as far north as Tanzania and the Democratic republic of Congo. In southern Africa the ASSAR project focusses on semi-arid areas in Botswana, Namibia and South Africa. In Figure 1 the broad coverage of semi-arid climatic zone can be seen. This includes:

- most of Botswana – particularly the north and south east
- the north-central and north-eastern regions of Namibia - specific regions include: i) Oshana, Oshikoto, Kavango, Caprivi and Ohangwena; ii) most of Otjozondjupa (east), Omusati (north), and Omaheke (northeast); and iii) some of Khomas (north-east) and Kunene (north-east and south-east)
- parts of South Africa including: i) most of North West and Limpopo Provinces; ii) about half of the Free State Province (west); and iii) less than half of the Western and Eastern Cape Provinces
- south, west and south-western Angola
- south and west Zimbabwe
- south west Mozambique

Figure 2.2

Semi-Arid regions of Southern Africa following Kottek *et al.* (2006) with primary administrative boundaries. Mapped using the shape file from http://koeppen-geiger.vu-wien.ac.at/present.htm



2.2 Socio-economic context

2.2.1 Poverty

People in semi-arid areas in southern Africa are generally poor with limited access to services. For example in Dr Ruth Segomotsi Mompati district, North West Province, South Africa less than 50% of households had piped water inside their dwelling or yard in 2011 (Lehohla 2011a), in Kavango and Ohangwena regions 25% had piped water inside their dwelling or yard in 2011 (Statistics Namibia 2012) and in rural villages in Botswana 22% of households had piped water in 2011 (Statistics Botswana 2014)). Countries in southern Africa are classified as having medium (Botswana, Namibia, South Africa) and low (Mozambique, Zimbabwe) human development (Table 1, UNDP 2014) and the region includes some of the poorest countries in the world. Mozambique has a very low Human Development Index - HDI (178 out of 187) and Zimbabwe (175 out of 187) has a very low gross national income per capita with most of the population (72% in 2010/2011) living below the income poverty line (Table 6, UNDP 2014). In semi-arid regions in Southern Africa poverty is more pronounced than in other climatic zones. For example in Dr Ruth Segomotsi Mompati district, North West Province average household income was less than R50,000 in 2011 (Lehohla 2011a) compared to a national average of over R103,204 (Statistics South Africa 2012), most households in Bobonong census district were categorised in the poorer wealth categories in 2011 (Statistics Botswana 2014) and Kavango was the poorest region in Namibia with 24% of households being classified as severely poor and 43% of the households being classified as poor (Namibia Statistics Agency 2012).

Poverty rates are often higher or incomes lower for women than men (Namibia Statistics Agency 2012, Statistics South Africa 2012) although in Botswana female headed households are not poorer than male headed households (Statistics Botswana 2014). Despite efforts to reduce poverty and inequality in Namibia and South Africa there is still substantial inequality in income reported for these countries (GINI coefficient of 63,9 and 63,1 respectively: Table 3, UNDP). However, the majority of the richer nationals live in large cities outside of semi-arid regions (Namibia Statistics Agency 2012, Statistics South Africa 2012).

2.2.2 Economies and development

The economies of Botswana, Namibia and South Africa have been based largely on primary sectors including mining, agriculture and tourism. Although South Africa has an abundance of natural resources as well developed financial, legal, transport, energy and communications sectors unsustainable and unreliable electricity supplies restrict development. Economic policies focus on controlling inflation however budget deficits limit the delivery of basic services to low-income areas and the creation of employment opportunities (Central Intelligence Agency - CIA 2014a). Namibia's economy is heavily dependent on the mining sector (CIA 2014a; United Nation Development Programme 2010; United Nations Country Team– Namibia, 2013). The country imports about half of its cereal requirements making food shortages a major problem during drought years. The Namibian economy is closely linked to the South African economy and the Namibian dollar has the same value as the South African rand (CIA 2014a). Botswana had one of the world's highest economic growth rates after independence in 1966 with the economy being fueled largely by diamond mining (CIA 2014b) and the country has been rated as having the best credit risk in Africa. The stability of Botswana's economy is partly the result of four decades of democracy and political stability, significant capital investment and progressive social policies. While the economies of Angola, Botswana, Mozambique, Namibia and South Africa have been growing during the period 2000 to 2008 that of Zimbabwe was in decline (World Bank 2014).

In terms of development in semi-arid areas in Namibia there is ongoing work in water, sanitation, drought relief, road infrastructure, health, education, flood warning & response and agriculture development. Development in the water sector has seen increases in the number of households with access to water and sanitation (Namibia: Namibia Statistics Agency 2013; South Africa: Statistics South Africa 2013b). However, in South Africa there have been reductions in access to electricity in Western Cape which is linked to the high influx of migrants and and creation of informal dwelling (Statistics South Africa 2013b). Household incomes have also increased (Namibia: Namibia Statistics Agency 2013; South Africa: Statistics South Africa 2012). In Namibia this is related to employment in construction related to post flood rehabilitation and through the Targeted Intervention for Employment and Economic Growth initiative. In addition the Community-Based Natural Resource Management Programme has improved livelihoods. The country is also committed to achieving the United Nation's Millenium Development Goals and will be developing new National Development plans every 4 years. Other policies geared towards socio-economic development include the National Land Policy, the National Drought Policy and Strategy, the Agriculture Policy, the Poverty Reduction Strategy and Action Plan of Namibia and a Desertification and Biodiversity Policy.

In Botswana there is ongoing work in poverty reduction, dam construction, road infrastructure, power generation, communication, drought relief, health, food aid, food for work, water transfer, glass manufacturing, health, education, waste management and the Government helps the youth especially those who are unemployed with finances to start up small businesses to try address unemployment. The Farmer's association programme also helps the youth to improve their livelihoods but with the pressure that the natural environment already have, problems like overgrazing might occur.

2.2.3 Unemployment

Unemployment levels are high in semi-arid areas in southern Africa. For example in semi-arid areas unemployment rates in Namibia vary from 30 to 50% (Namibia Statistics Agency 2013a), in Botswana reach 27% (Statistics Botswana 2014), vary between 29 and 52% in Limpopo Province (Lehohla 2011b) and vary between 30 and 36% in North West Province (Lehohla 2011a) of South Africa. Unemployment rates are higher for women than for men (Namibia Statistics Agency 2013b, Statistics South Africa 2013a). For example in South Africa the unemployment rate for women in formal rural employment is 19 % versus 7 % for men (Statistics South Africa 2013a), and in Central Bobonong, Botswana the unemployment rate for women is 29.5 for women versus 22.5% for men (Statistics Botswana 2014). Although women often have higher rates of enrolment in education (Namibia Statistics Agency 2013b, Statistics Botswana 2014) more men with the same level of qualification are employed and they are often paid more (Statistics South Africa 2013). Employment in semi-arid areas in southern Africa is mainly in agriculture with little reliance on subsistence farming for generating income (Namibia Statistics Agency 2013c).

2.2.4 Population dynamics

Populations in semi-arid areas in southern Africa are growing (e.g. 0.6% in Omusati region, Namibia and 0.9% in the Limpopo river basin in Botswana where the population density is about 17 people/km2) this follows trends in southern Africa where a large proportion of children are under the age of five in southern Africa (Table 15, UNDP 2014). Whereas in Namibia a large proportion of the semi-arid population is classified as rural (94%) in Botswana most of the population is classified as urban with only about 38% classified as rural. However, these statistics do not accurately reflect reliance and connections to rural areas. Urbanisation is increasing in semi-arid areas. In Botswana there is a 2% increase in urbanisation per year and villages such as Mahalapye, Palapye, Bobonong are becoming urban centres. In Nambia, Outapi in Omusati Region is an emerging urban centre.

Namibia is the second least densely populated country in the world after Mongolia (World Bank 2014) with the country's population being estimated at 2113077 in the 2011 census with an estimated population density of 2.6 people per km2 (National Statistics Agency 2013c). However, the population is not evenly distributed geographically and much higher population densities are found in the semi-arid areas in Namibia with about 60% of the population living in North Central Namibia where the population density is about double the national mean. In Omusati region the population density is about 9 people/km2. The total population of Botswana was estimated as 2024904 in the 2011 census with a country wide population density of 3.5 people per km2 (Statistics Botswana 2014). Population density varies from 0.4 in the Western Region to 13.8 in the South East, with a population density of 5.4 people per km2 in the Eastern Region of Botswana (Statistics Botswana 2014).

2.2.5 Gender issues

In comparison to other countries globally countries in southern Africa are ranked better for gender development and gender inequality than they are for human development (Tables 4 & 5, UNDP 2014). In semi-arid areas in southern Africa women have historically been responsible for building houses and caring for crops but they didn't have the right to be allocated land (Angula & Menjono 2014, Statistics Botswana 2014). Although in Botswana land started being allocated to women by local authorities towards the end of the twentieth century and a national policy on women in development was adopted in 1996 to promote women in leadership and decision making (Statistics Botswana 2014). However in 2010 the representation of women in parliament in Botswana was only 8% compared to 43% in South Africa (Statistics Botswana 2014). In Namibia women are also underrepresented in policy and decision making organs (United Nations Country Team Namibia 2013) and in South Africa even though women are represented in politics women's issues are not sufficiently represented (Goetz 1998). Likewise some policies and laws adopted in Botswana since independence have been discriminatory against women (Statistics Botswana 2014). At the local level, a high number of households in semi-arid southern Africa are women headed and these households are mostly poorer than other households (Statistics Botswana 2014). For example, 55% of households are women headed in Omusati region in Namibia (Namibia Statistics Agency 2013) and 47.5% of households in Botswana are female headed (Statistics Botswana 2014).

2.2.6 Land tenure

Land tenure is an important issue in semi-arid areas in southern Africa. Land ownership in Namibia and South Africa in general remains skewed in favour of a small number of predominantly white households despite past land redistribution efforts. In South Africa the land claims process continues whereby people that were moved from their land during apartheid can apply for compensation. Although a large proportion of Namibia is still occupied by large commercial white owned farms the semi-arid areas of Namibia are mainly communal areas. In the communal areas in Botswana land is largely under customary tenure without the provision of title deeds. In semi-arid areas in northern Namibia, where the majority of the population is found the availability of productive land is becoming a problem. Issues include: i) the division of plots as families divide properties between family members; ii) the fencing of plots reducing communal access; and iii) the limited availability of productive land both due to the nature of the area and high pressure on resources (Kuvare *et al.* 2008, Newsham & Thomas 2011, Wilhelm 2012, Academics, University of Namibia, November 2014). In both Namibia and Botswana, with increased pressure on land and low productivity in low rainfall years cattle are moved to more productive areas.

2.2.7 Crime

In Botswana, Namibia and South Africa there is a low perception of personal safety compared to other countries globally (Table 16, UNDP 2014). However, this is more of an urban issue.

2.2.8 Government

Namibia, Botswana and South Africa are constitutional democracies that have linked histories. Botswana gained it's independence from British rule in 1966 and along with South Africa is one of the most democratic (The Economic Intelligence Unit 2013) and least corrupt countries in Africa (Transparency International 2014). Where as Zimbabwe is one of the least democratic and most corrupt countries in the world. Namibia became independent and democratic in 1990 and South Africa in 1994 after both of these countries were previously ruled under the apartheid regime after being colonised previously. Although governments in Southern Africa have made efforts towards decentralization (Namibia: Decentralization Policy, 1997 (Ministry of Regional Local Government and Housing 1997); Botswana: Ministry of Local Government and Rural Development 2014) decentralisation has not been particularly effective as yet (Botswana: Dipholo & Mothusi 2005; Namibia: Larsen 2003, Sibolile 2005; South Africa: Koelble & Siddle 2013, Stanton 2009) particularly for some some key ministries. This restricts the capacity at the local scale to implement adaptation.

2.2.9 Environment

With low levels of employment and high levels of poverty there is high reliance on natural resources. Semi-arid areas in southern africa are characterised by very seasonal and highly variable rainfall (inter-annually and intra-seasonally), frequent droughts and flash floods (South Africa: Vetter 2009). In addition, Namibia is considered as one of the driest countries south of the Sahara (Ministry of Environment and Tourism 2011; Turpie *et al.* 2010). In Namibia, the mean annual rainfall ranges from just above 700 mm in the northeast (semi-arid) to less than 25 mm in the southwest and west (hyperarid) of the country. Characteristic of Namibia's climate is therefore the scarcity and unpredictability of its rainfall (Kuvare et. al. 2008). Due to the prevalent climatic conditions in these semi-arid areas there is a reliance on groundwater.

Semi-arid areas in southern Africa support high biological diversity and biodiversity hotspots are recognised in South Africa (Rossa & Willert 1999), Namibia and Botswana. These countries support a variety of ecosystems and are home to high numbers of endemic species. Protection of the environment is also a high priority in these countries e.g. in Namibia the environment is included in the country's constitution and 14% of the land area of the country is protected (CIA 2014a).

Semi-arid areas in southern Africa are water deficient as would be expected and increasing population sizes place increased pressure on water resources. In addition limited water availability limits development (Namibia: United Nations Country Team - Namibia 2013).

2.2.10 Culture

Southern Africa is culturally diverse. The largest ethnic group in Namibia is the Ovambo tribe which comprises about half of the total population (CIA 2014a, Ministry of Environment and Tourism, 2011) and the majority of the people in this group live in the north central and semi-arid regions of the country, specifically in Oshana, Ohangwena, Omusati and Oshikoto region. Other ethnic groups in Namibia include: the Kavangos (9%), Damara (7%), Herero (7%), Nama (5%), Caprivian (incl. Lozi, Subiya, Yei, Mafwe, Mbukushu) (4%), Bushmen/San (3%), Baster (2%), Tswana (0.5%), mixed race (6.5%) and citizens of European descent (6%) with Afrikaans, English and/or German as their mother tongue (CIA 2014a). Of these groups the Herero and Kavango also live in semi-arid areas of Namibia and the san are a marginalised group in semi-arid areas. In Botswana the dominant ethnic group is the Batswana (79%), Kalanga (11%), Basarwa (3%) and other groups including Kgalagadi and white (CIA 2014b). In South Africa the ethnic groups reported are black african (79.2%), white (8.9%), Indian/Asian (2.5%) and other 0.5% (CIA 2014c) . Languages spoken include isiZulu, isiXhosa, Afrikaans, English, Sepedi, Setswana, Sesotho, Xitsonga, siSwati, Tshivenda and isiNdebele (CIA 2014c).

2.2.11 Health

HIV and Aids are an important factor in semi-arid areas in southern Africa. The prevalence of AIDS in Botswana is second highest in the world. In Botswana Foot and mouth disease is a threat to livestock and the transportation of livestock. Access to healthcare in semi-arid areas in Southern Africa is limited. There were 0.336 physicians and 2,844 nurses and midwives per 1000 people in 2010 in Botswana, 0,758 physicians in 2011 and 4,902 nurses and midwives per 1000 people in 2012 in South Africa and 0,374 physicians and 2,775 nurses and midwives per 1000 people in 2010 in Namibia compared to global averages of 1,5 physicians and 3.3 nurses and midwives per 1000 people (The World Bank Group 2015). Likewise life expectancy is lower than global averages - in 2012 it was 47 years for Botswana, 63 years in Namibia, 56 years in South Africa compared to a global average of 70 years (The World Bank Group 2015).

2.3 Socio-ecological systems and livelihoods

Livelihoods in semi-arid regions in Southern Africa need to be varied as conditions for crop production are marginal. For example in Namibia livelihoods include agriculture, livestock, employment, remittances and the use of natural resources (Ashley 2000) and in semi-arid areas in Botswana sources of income include formal employment, pension, government support, household activities such as traditional beer and agricultural activities such as crop farming, mopane worms, melons, sweet reeds, firewood, poultry, sorghum, millet, goats, sheep and cattle (Statistics Botswana 2014).

For the people living in communal areas of north-central Namibia (Oshikoto, Ohangwena, Omusati and Oshana region), subsistence agriculture remains the main means of livelihood. However, the irregular rainfall and the unsuitable terrain pose serious threats to food security and to livelihoods (Wilhelm, 2012). In Omusati region, the trade and service sectors in the urban areas provide employment outside the agricultural sector while manufacturing also occurs on a small scale (Omusati Regional Council 2010). Werner (2012) reported that subsistence farming is main source of income for between 41.3% of households in Oshikoto and 59.6% in Omusati regions. The north central part of Namibia mainly covering north eastern Omusati, Northern Oshana, North West Oshikoto and Western Ohangwena regions mainly grow crops such as millet (mahangu) and sorghum. Many households in the area own cattle and small stock such as goats. Due to the high population density, livelihoods have been diversified particularly into non-farm income sources, such as trading, self-employment activities (crafts and sell of labour) (Kiaka *et al.* 2012). Another source of livelihoods is from remittances (Namibia: Eriksen *et al.* 2008; Oshana and Erongo, Namibia: Angula 2010; Kalahari, Botswana: Twyman *et al.* 2004).

CHAPTER 3

Climate Change trends and projections

Climate change, trends and projections in Southern Africa

3.1 Observed Variability and Trends

The climate across southern Africa varies from arid conditions in the west to humid subtropical conditions in the north and east, while much of the central part of southern Africa is classified as semi-arid. The primary factors affecting the climates experienced in southern Africa include altitude, the warm Indian and cool South Atlantic Oceans, the migration of the Inter-Tropical Convergence Zone (ITCZ) and the location of dominant atmospheric high and low pressure systems. The semi arid regions extend over southern African belt, centred on the greater Kalahari region, extending from northern Namibia through Botswana, into parts of South Africa, Zimbabwe and Mozambique.

Most of the region, with the exception of southwest South Africa, receives the majority of its rainfall in the summer months, between November and March. However, there is a large difference in the amount of rainfall experienced in the eastern and western parts of southern Africa, primarily due to the influence of the ocean on the atmosphere and the direction of prevailing winds. The warm Agulhas Current in the Indian Ocean provides a source of additional moisture, which leads to higher rainfall in eastern parts of the region, while the cool waters of the Benguela Current in the South Atlantic Ocean corresponds to much lower rainfall in the west.

The highest temperatures are experienced in the Kalahari Desert which spans southwest Botswana, southeast Namibia and northwest South Africa. Here the diurnal cycle can be large (>20°C), with extremely high daytime maximum temperatures (>40°C) and much lower temperatures at night. In addition, some of the highest average temperatures are experienced in coastal regions, such as Mozambique where the warm Indian Ocean maintains warm temperatures at night. The lowest temperatures are found in the high altitude regions of Lesotho, South Africa and Zimbabwe.

Throughout the year, the timing and magnitude of the summer rains is largely dictated by the seasonal migration of the ITCZ and the related Congo Air Boundary (Tyson & Preston-Whyte 2000) This large-scale atmospheric feature represents an area of intense convective activity associated with low pressure. The ITCZ is found near the equator during late March and late September (the equinoxes) but moves south during the southern hemisphere summer bringing rains to much of the region. However, each year the amount of summer rainfall experienced varies as the ITCZ interacts with other dominant global and regional atmospheric patterns.

The best studied and arguably most important of these patterns is the El Niño Southern Oscillation (ENSO) – a cyclical variation in the surface temperature of the tropical eastern Pacific Ocean. When the ocean surface in this region is warmer than average an El Niño event occurs and when the ocean surface is cooler than average a La Niña event occurs (Zaroug *et al.* 2014a). The timing (Zaroug *et al.* 2014b) between ENSO events varies but typically an El Niño or La Niña occurs once every few years. El Niño is associated with drier and warmer than normal conditions in Southern Africa from December to February while La Niña is associated with wetter and cooler conditions. However, these associations vary at finer scales and they are not always apparent. The mechanisms that link ENSO and the southern African climate are still not fully understood.

Year-to-year variability in the weather is a result of variability in these large scale processes and variability in regional and local scale processes, such as the location of storm tracks (particularly relevant for rainfall associated with tropical cyclones in the east of the region) and feedbacks between the atmosphere and land surface.

Figure 3

Summer (December to February) mean, maximum and minimum temperatures at each grid cell over the period 1963 to 2010; data taken from the CRU TS3.22 and UDEL dataset.

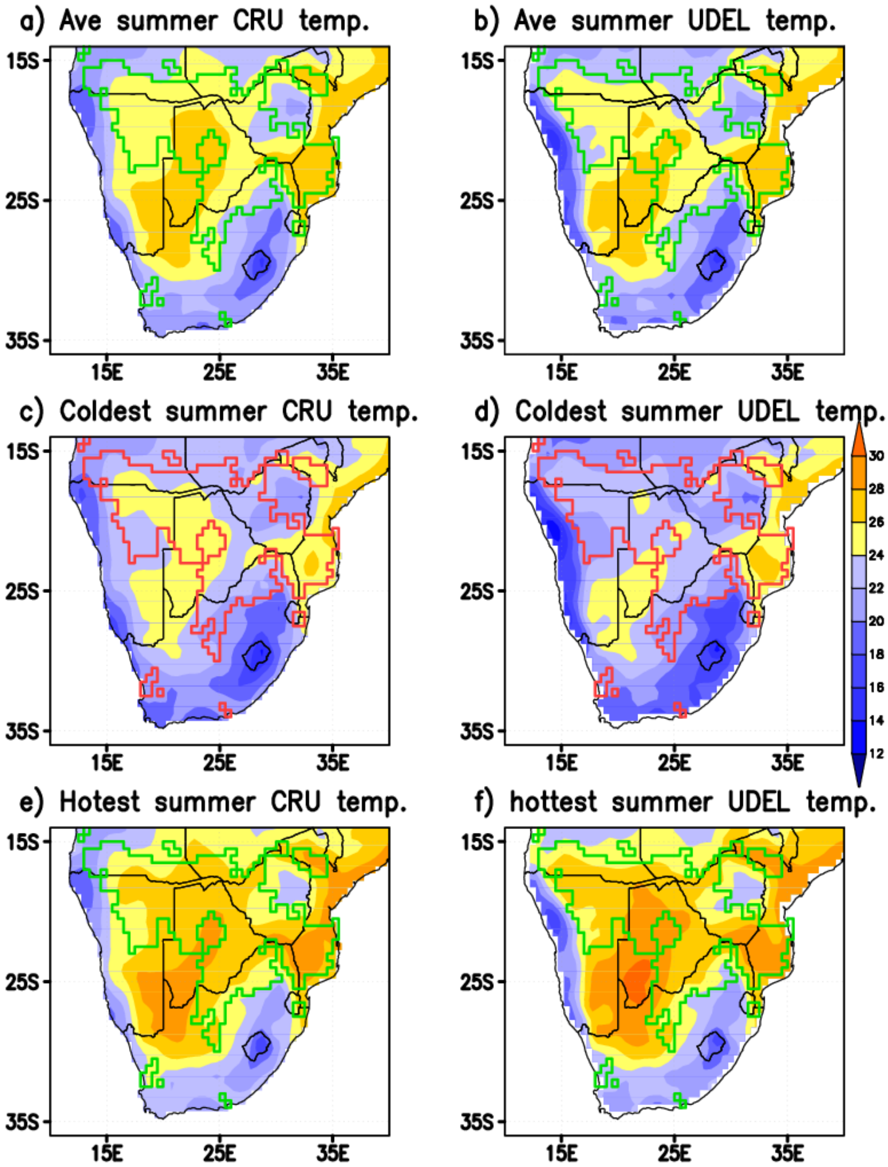


Figure 4

Winter (June to August) mean, maximum and minimum temperatures at each grid cell over the period 1963 to 2010; data taken from the CRU TS3.22 and UDEL dataset.

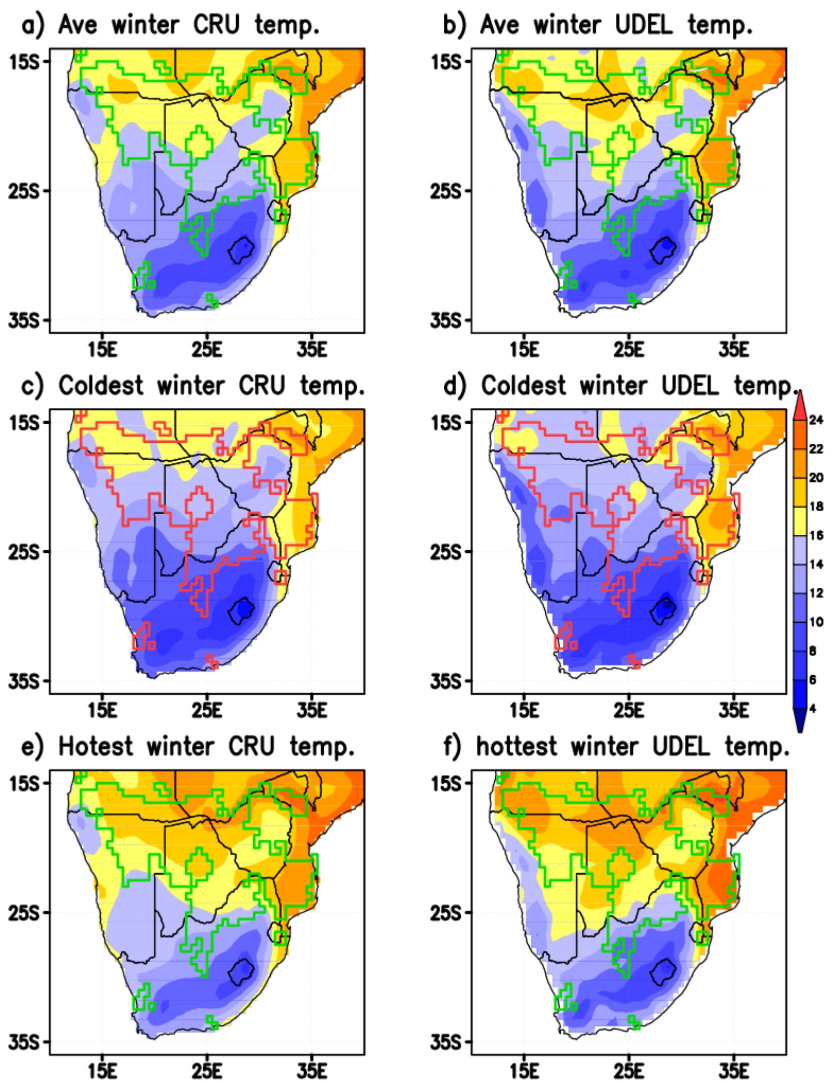


Figure 3 shows the average summer and Figure 4 shows winter temperatures across the region (upper panel), as well as the warmest (lower panel) and coolest (middle panel) years over the 48 year period from 1963 to 2010 for a particular location; the year of the warmest summer in one grid cell may differ for an adjacent grid cell. The figure shows that the oceans moderate temperatures along much of the coastline, except in Mozambique where the warm waters of the Mozambique Channel maintain high temperatures throughout the year. High summer temperatures are experienced in Mozambique as well as in the Kalahari and throughout Botswana. The coldest winter temperatures occur in the interior regions of South Africa, and especially in the high altitude regions of Lesotho. The greatest differences between the average summer and winter temperatures in the warmest and coolest years are also found in the interior of the region.

Rainfall is more variable than temperature, both in space and time. Figure 5 shows the average summer and winter (Figure 6) in the upper panel along with the wettest in the middle panel and driest years in the lowest panel at each grid cell. In summer there is a clear east-to-west gradient, with very dry conditions experienced on the Namibian coast and western parts of South Africa while there is much higher rainfall in the north and east. The difference between the wettest and driest summers is substantial in many locations. In the semi-arid regions of northern Botswana the summer rainfall varies from less than 2 mm/day to more than 10 mm/day between the driest and wettest year. In winter, a northwest-to-southeast gradient is observed with Namibia and Botswana typically receiving little to no rainfall. The coast of South Africa and Mozambique receives some winter rainfall, particularly in the winter rainfall region of southwest South Africa. There is also a very large difference between the wettest and driest winters. Some regions experience no rainfall in the driest year and received 4 mm/day of rainfall in the wettest year.

Figure 5

Summer (December to February) mean, maximum and minimum rainfall at each grid cell over the period 1963 to 2010; data taken from the CRU TS3.1, GPCC, and UDEL dataset.

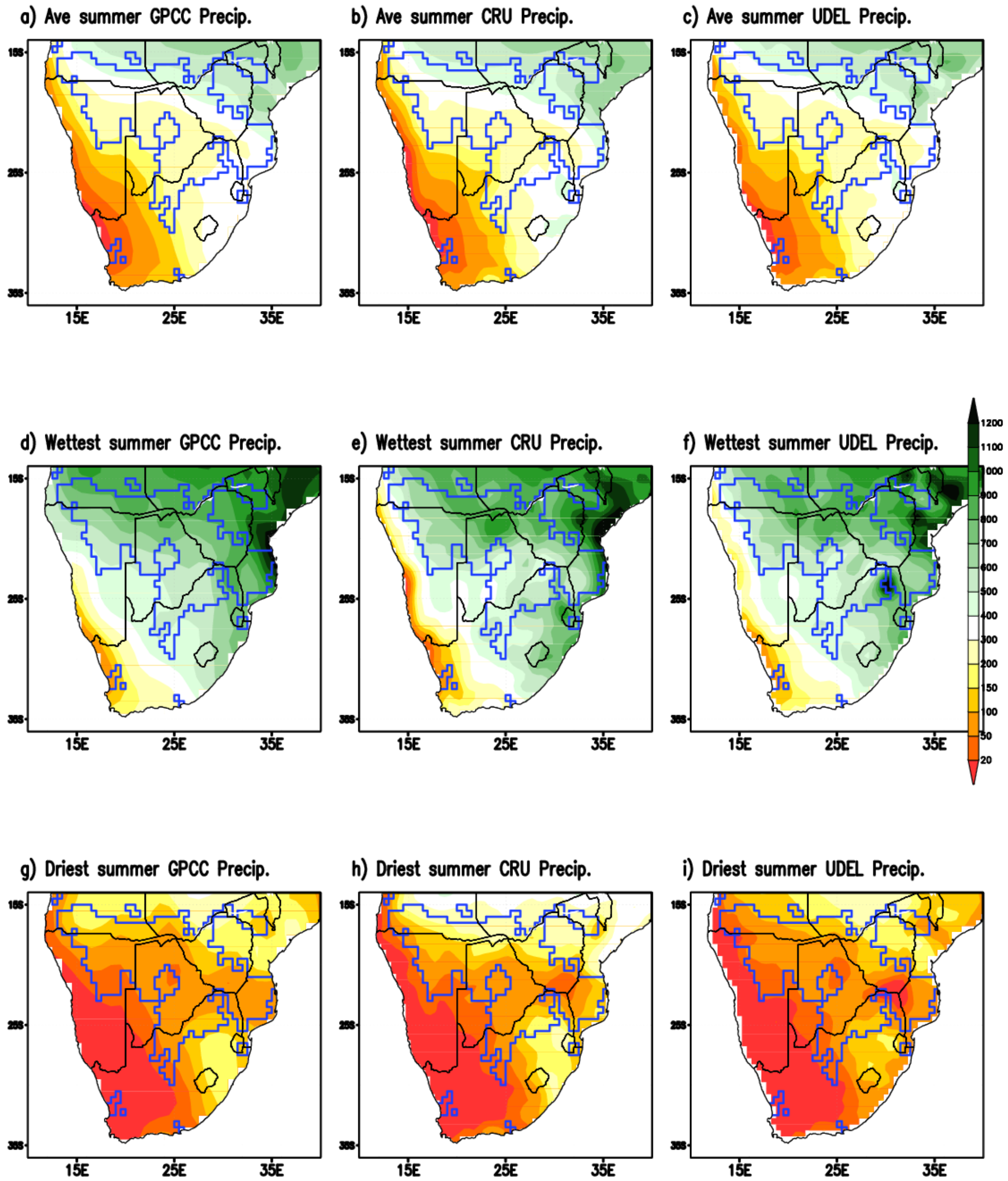


Figure 6

Summer (December to February) mean, maximum and minimum rainfall at each grid cell over the period 1963 to 2011; data taken from the CRU TS3.1, GPCC, and UDEL dataset.

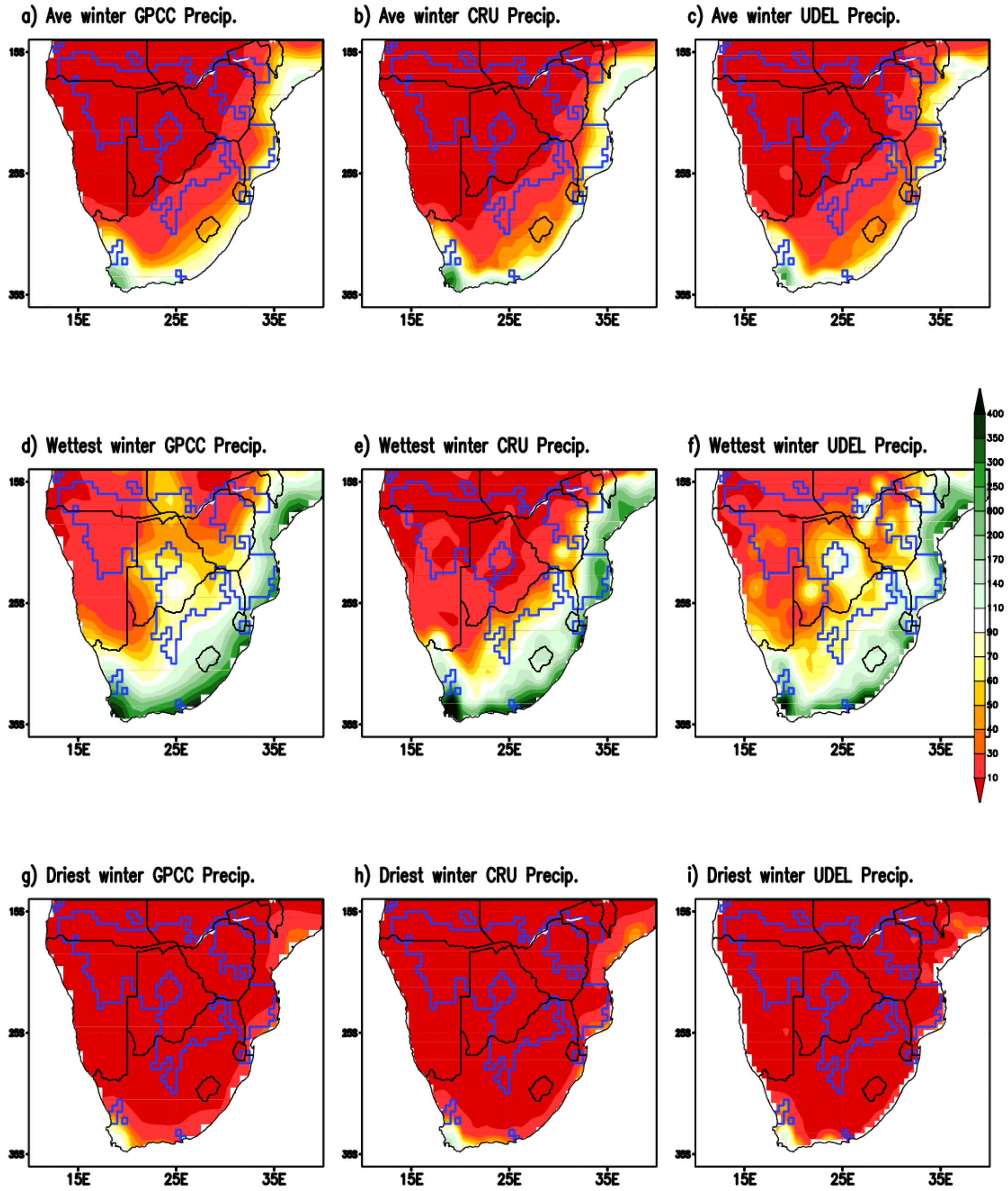


Figure 7 shows the difference between the mean decadal (ten year) temperature and the mean temperature over the 1963 to 2010 period at each grid cell. We can clearly detect a warming signal as all locations in southern Africa were warmer, on average, in the 2000s than in the 1970s. However, it is also apparent that in some locations, more recent decades are cooler than preceding decades; for example, the northeast of Namibia was warmer in the 1990s than the 2000s, and the southern coast of South Africa was warmer in the 1980s than in the 1990s.

Figure 7

Difference between decadal mean temperatures and 1963 to 2010 mean temperatures at each grid cell. Data taken from the CRU TS3.22 and UDEL dataset

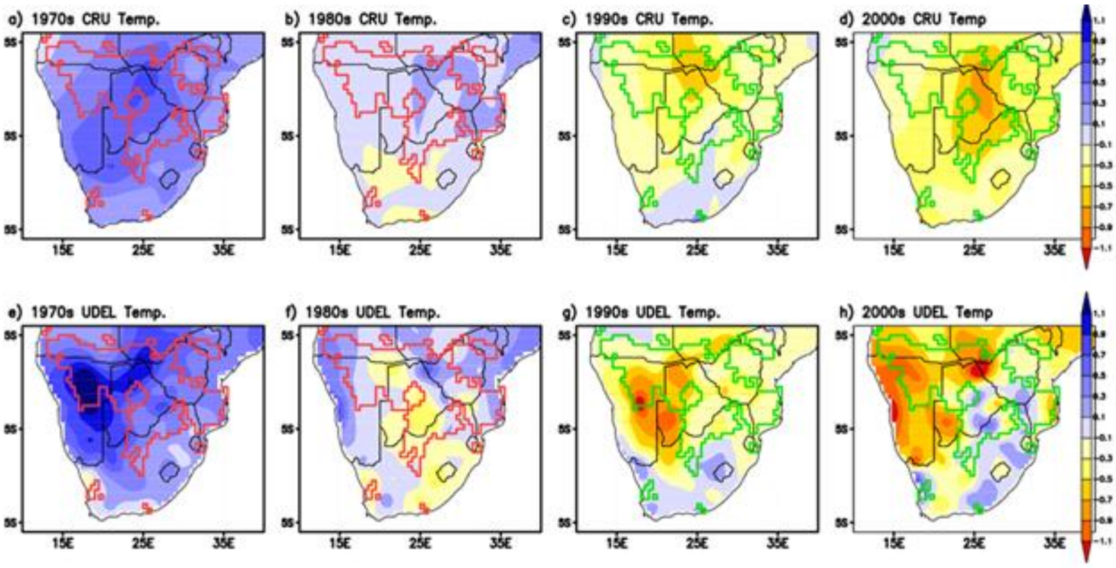
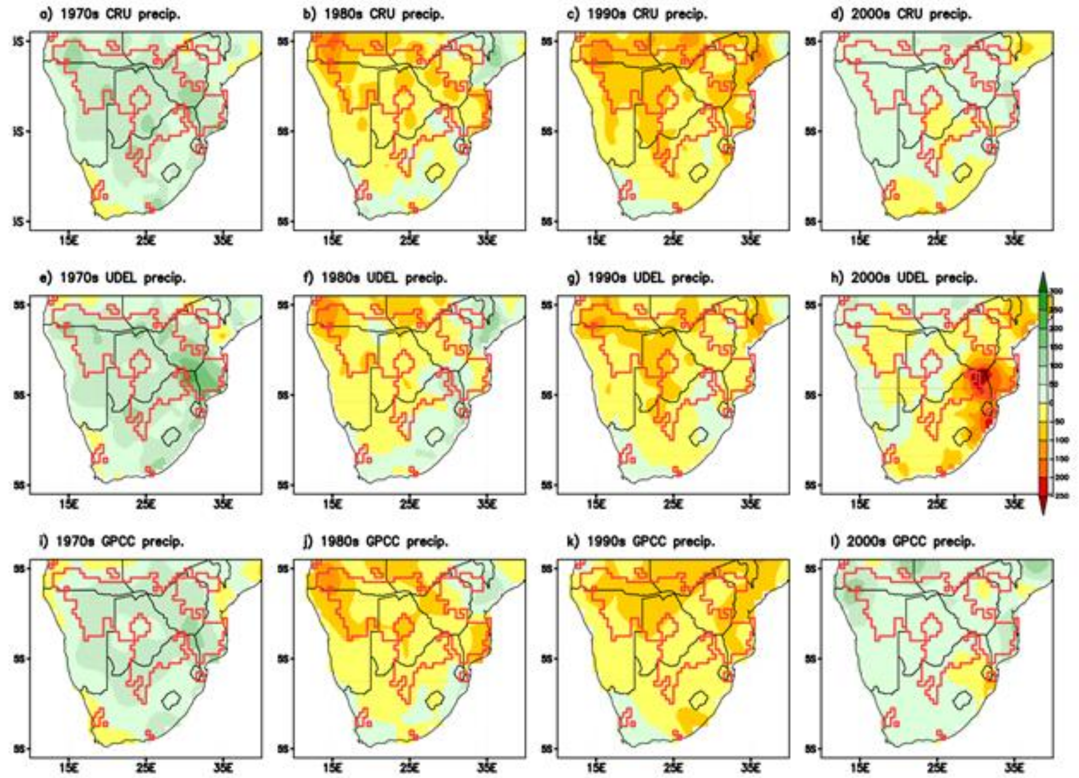


Figure 8 shows the difference between the mean annual rainfall total for each decade and the mean annual rainfall total over the 1963 to 2010 period at each grid cell, illustrating considerable variability in rainfall on multi-decadal time scales. The 1970s were, in most locations across southern Africa, much wetter than average, while the 1990s were much drier. The CRU rainfall data is consistent with a number of related recent studies, such as the Mmopelwa (2011) study that identifies a significant difference between the wet 1970s and the dry 1990s in the Okavango and Boteti basins in Botswana.

Figure 8

Difference between decadal mean annual rainfall totals and 1963 to 2010 mean annual rainfall totals for each grid cell. Data taken from the CRU TS3.22, UDEL and GPCC dataset.



On much longer time scales, the climate can vary dramatically due to external influences on the climate system. Over time scales of thousands of years, it is well established that the glacial-interglacial cycle is primarily driven by variations in the orbit, tilt and precession of the Earth and the resultant impact on incoming solar radiation.

To determine whether or not, and by how much, the climate has changed in the recent past, trends in temperature and rainfall are calculated from the available observed data. Figures 5 and 6 show the seasonally averaged spatial and temporal changes in temperature over southern Africa during the period 1963 to 2012. Despite annual and decadal variability, across all seasons and locations temperatures have increased over this period; the region west of Lesotho in summer is an exception. Temperature increases were generally higher (approximately 1.6 to 2°C) in the interior regions, particularly in northeastern and central parts of Botswana, and lower (approximately 0.4 to 1.4°C) along the coasts and parts of central and southern South Africa. Whilst there has been an increase in temperatures in all seasons, the lowest increases are found in the summer months, with the exception of southwest South Africa. This implies that, in general, temperature increases have been more pronounced in the dry season. In addition, the IPCC AR5 reports “it is likely that the number of cold days and nights has decreased and the number of warm days and nights has increased in southern Africa (high confidence)” (also see MacKellar *et al.* 2014).

Figure 9

The change in temperature between 1963 and 2012 at each grid cell, according to a linear trend, for the four seasons: Summer (DJF), Autumn (MAM), Winter (JJA) and Spring (SON). Data taken from the CRU TS3.22 dataset – see technical reference document.

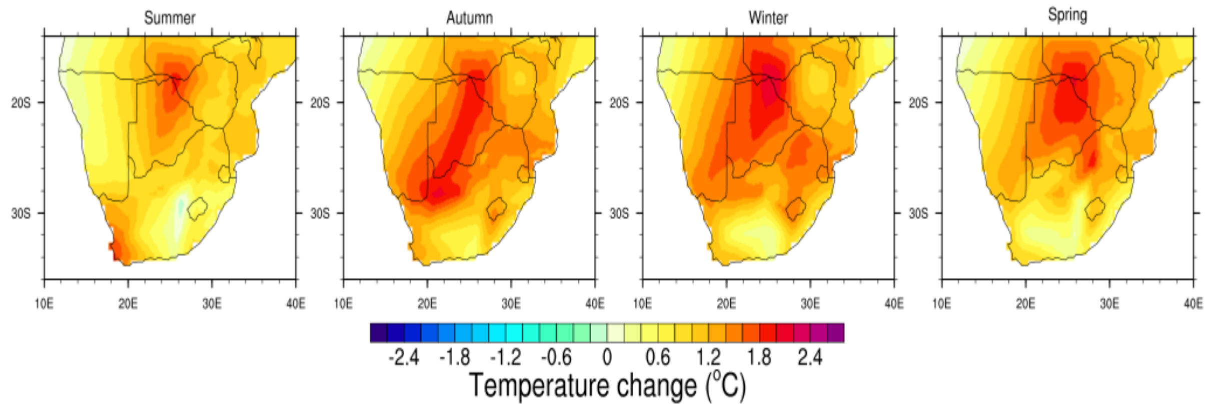


Figure 10

Time series of the land area averaged seasonal temperature changes between 1963 and 2012, corresponding to figure 5. Data taken from the CRU TS3.22 dataset – see technical reference document.

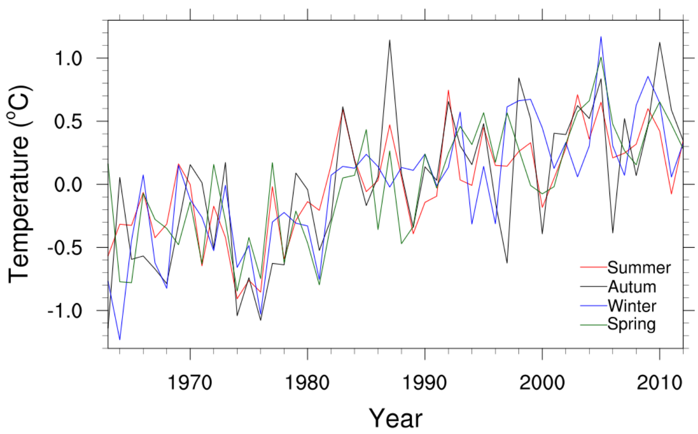
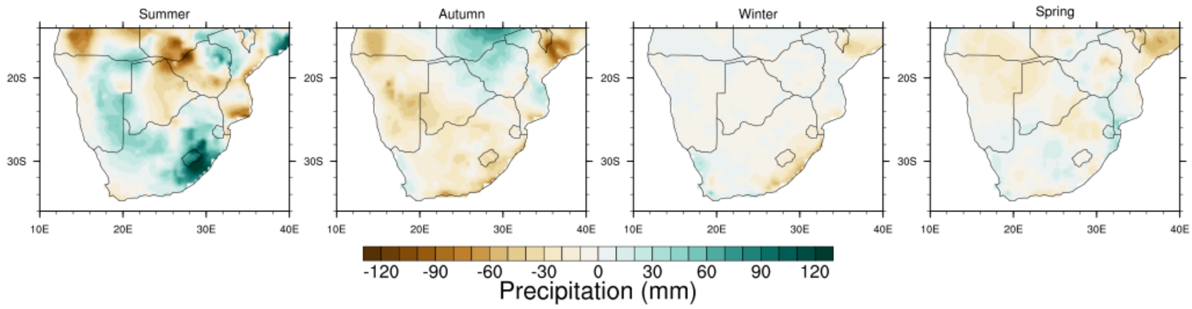


Figure 11 shows how the total rainfall has changed for each season from 1963 to 2012. In winter and spring the observed trends over much of the region are close to zero across the region, meaning that there has not been any substantial drying or wetting over this period. In the summer and autumn, however, we observe larger magnitude trends. In autumn, there has been a decrease in rainfall (in the order of tens of millimeters) across much of the region, with the exception of southwest South Africa (small increase, < 20 mm) and in northern central regions where rainfall has increased by up to 60 or 70 mm. The changes in summer are more dramatic, which might be expected given that the region receives most of its rainfall in the summer months. The spatial pattern of change is almost the exact opposite of the pattern observed in autumn. Much of South Africa and Namibia has become wetter, especially in the region near Lesotho, while elsewhere we observe decreases in summer rainfall, particularly in the border between Botswana, Namibia, Zimbabwe and Zambia, corresponding to part of the upper Zambezi river catchment. The increase in summer rainfall may be linked to an intensification of rainfall associated with the seasonally migrating ITCZ. However, the patterns of change are not consistent everywhere and rainfall in southern Africa, as described in prior sections, is highly variable so any signals of systematic change are weak.

Figure 11

The change in rainfall between 1963 and 2012 at each grid cell, according to a linear trend, for the four seasons: Summer (DJF), Autumn (MAM), Winter (JJA) and Spring (SON). Data taken from the CRU TS3.22 dataset – see technical reference document



In relating any observed climate trend to underlying changes in the climate, we must first account for the different time scales of climatic variability. In southern Africa, and particularly across the central regions of Botswana, Namibia and northern South Africa, the climate is subject to decadal and longer term climate variability. Moreover, even if we detect a significant trend, that we are confident is not merely a result of long time scale variability, we must first rule out other external drivers before we can attribute such changes to increasing GHG concentrations.

3.1.1 Trends in extreme rainfall and temperature

To better understand the impacts of historical climate variability and future climate change on communities and ecosystems, it is often more relevant to focus on the less frequent but more severe weather and climate events that influence exposure and vulnerability.

A report by Climate Development Knowledge Network (CDKN 2012) summarizes the findings of the Intergovernmental Panel on Climate Change (IPCC) Special Report on Managing Extreme Events - SREX (IPCC 2012). Changes to temperature and precipitation extremes in southern Africa observed since the 1950s, with the period 1961-1990 used as a baseline, are reported:

- Increase in warm days (decrease in cold days) – *medium confidence*
- Increase in warm nights (decrease in cold nights) – *medium confidence*
- Increase in warm spell duration – *medium confidence*
- No spatially coherent patterns of trends in precipitation extremes – *low confidence*
- General increase in dryness – *medium confidence*

Because of sparse observations in some parts of southern Africa, and given statistical issues associated with deriving trends in extremes for short sampling periods, none of the findings are stated with high confidence. However, there is medium confidence in the observed trends associated with temperature extremes. The low confidence associated with any trends in extreme precipitation is consistent with the findings for mean annual rainfall where the variability over the last 50 years confounds any trends.

An earlier study by New *et al.* (2006) analyzed daily temperature (maximum and minimum) and precipitation data from 14 south and west African countries over the period 1961–2000. The findings of the study are largely consistent with the SREX results but the study also showed evidence of increase in dry spell durations and rainfall intensity. However, the observed trends in temperature extremes were more apparent than for precipitation. Furthermore, the authors provided evidence that the frequency of hot extreme events had been increasing at a faster rate than the decrease in cold extreme events, resulting in the conclusion:

"Hot extremes generally have trends of greater magnitude than their cold counterparts, suggesting that the warm tails of the daily temperature distributions are changing faster than the cold tails." (New *et al.* 2006).

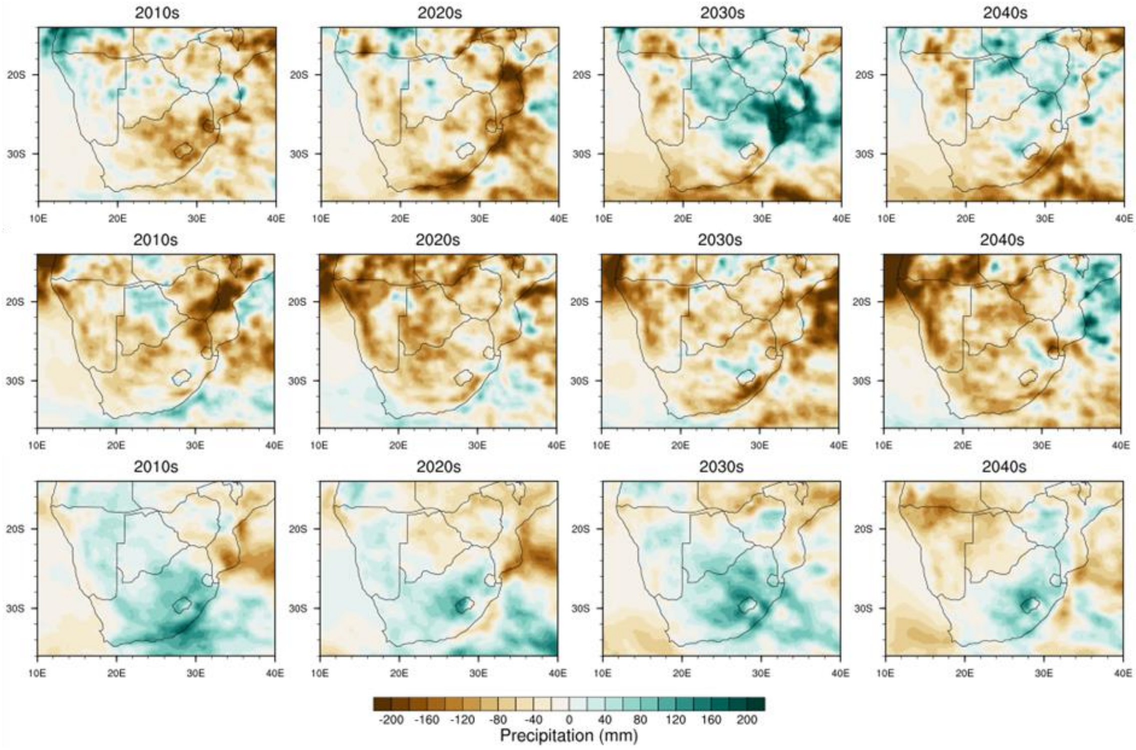
3.2 Future climate projections

The Coordinated Regional Downscaling Experiment (CORDEX) uses the latest generation of Regional Climate Models (RCMs) to provide 50 km resolution projections of climate change up to the year 2100 for regions across the world. The models are driven by GCMs used in the IPCC AR5 report. Here, some example CORDEX model projections are presented showing possible future regional climate change scenarios for southern Africa. It should be noted that all projections shown are for the same GHG forcing scenario, RCP8.5; this scenario is often categorized as "business as usual" with respect to GHG emissions.

Regional climate projections are subject to significant uncertainties (Hawkins and Sutton 2009). The output of a single model simulation should be treated with caution and even an ensemble of regional model projections cannot be expected to provide reliable quantitative "predictions" (Daron *et al.* 2014). Rather, the projections show possible scenarios of future change. Further explanation of the issues in projecting the future climate at regional scales is provided in the supporting technical documentation.

Figure 12

Difference between decadal mean annual rainfall totals and the 1950 to 2000 mean annual rainfall totals, at each grid cell, for three CORDEX models under the RCP8.5scenario: A = HadGem2-CCLM4; B = ICHEC-CCLM4; and C = ICHEC-KNMI.



The model projections shown in Figure 12 are taken from combinations of two GCMs (HadGem2 and ICHEC) and two RCMs (KNMI and CCLM4), all driven by the RCP8.5 scenario. A more rigorous exploration of future climate scenarios would involve analyzing many more GCM-RCM combinations that are being made available in the CORDEX project. However, for demonstrative purposes it is useful to look at some of the available data to examine the nature of future climate output. Figure 3.4 shows model projections of future rainfall change for four decades. The average annual rainfall change for a particular decade is calculated by subtracting the decadal average from the average annual rainfall over the period 1950 to 2000 in the model.

In general, all projections show that for most of the domain substantial multi-decadal variability in rainfall patterns will continue with most locations experiencing dry decades and wet decades in the future. However, there are some large differences between the model projections. Model A shows a broad pattern of drying in the 2010s and 2020s with wetter conditions for some regions (e.g. east South Africa) in later decades. Model B also shows a general pattern of drying with a particularly strong drying signal in northwest Namibia and southern Angola. The changes projected by model C are much lower in magnitude but there is a general pattern of wetting across South Africa and a variable signal further north. Both model B and model C are driven by the same GCM so the large differences in magnitude clearly demonstrate that selecting a different RCM can result in qualitatively different estimates of future climate change.

Whilst there is no consensus on the direction of change in rainfall for the future, even amongst a small selection of three model simulations, there is much better agreement that temperatures are likely to increase. Figure 13 shows decadal changes in temperature for the same set of GCM-RCM combinations under the RCP8.5 scenario. In all model simulations, temperatures across the region are projected to rise. Model A projects the greatest magnitude increase by the 2040s with some regions (e.g. central Namibia) expected to have an increase in average annual temperatures of up to 4°C. The changes are less dramatic in model B and C; all regions are expected to warm by less than 3°C by the 2040s in model C. In general, there is less warming in coastal regions, which corroborates with the CMIP5 GCM projections and the observed warming experienced in the last 50 years.

Figure 13

Difference between decadal mean temperatures and the 1950 to 2000 mean temperatures, at each grid cell, for three CORDEX models under the RCP8.5 scenario: A = HadGem2-CCLM4; B = ICHEC-CCLM4; and C = ICHEC-KNMI

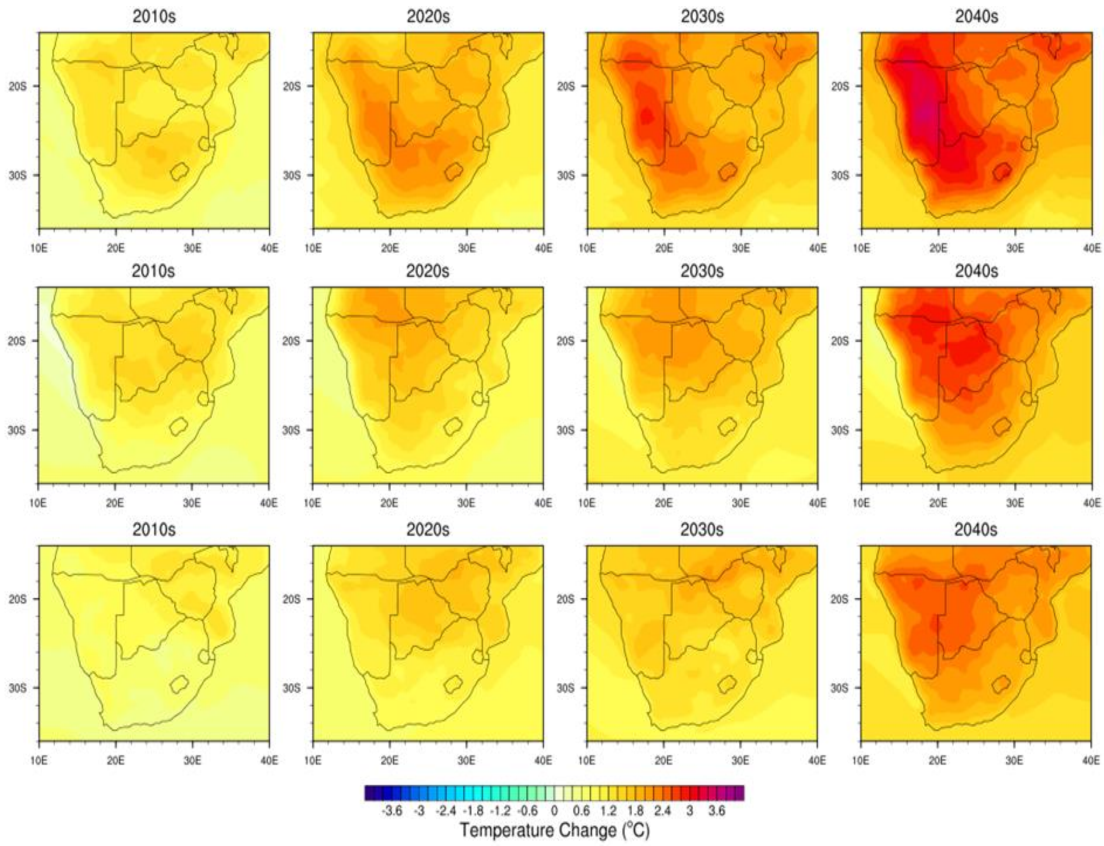
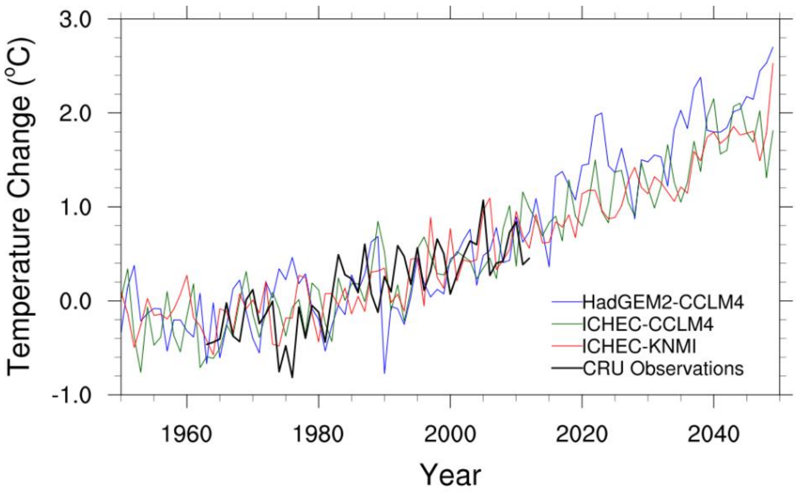


Figure 14

Time series of the change in southern Africa annual average temperatures from the three CORDEX models analysed (see key). The model changes are relative to the average of the models in the respective domains from 1963 to 2000, while the CRU TS3.22 observational data (from 1963 to 2012) are relative to the observed 1963 to 2000 average.



Unlike rainfall, changes to temperature on the decadal time scale appear to be dominated by a systematic warming signal as opposed to multi-decadal variability. This can also be seen clearly when aggregating temperature changes over the region and analysing the time series' of model projections. Figure 14 shows the change in annual average temperature for the three model simulations, as well as the observed changes from the CRU dataset. All model simulations appear to capture the emergence of a warming trend over the past 50 years and this trend is projected to continue into the future. By 2050, there is some uncertainty in the projected temperature change – even from a very small sample of simulations all driven with the same GHG forcing scenario – with the three simulations projecting a 1.9°C to 2.6°C warming by 2050. The divergence of models would likely be much larger if additional simulations and forcing scenarios were included.

CHAPTER 4

Risks, Vulnerability and Impacts

Risks, Impacts and Vulnerability

The working definition of vulnerability that is being used by ASSAR is "the degree to which people, sectors, assets or systems are susceptible to the impact of hazards". Vulnerability in the semi-arid areas of southern Africa is a function of the existing environmental and climatic conditions coupled with governance, socio-economic, health, education, culture and human demography issues. Communities in semi-arid regions are characterised by: i) dependence on primary production and natural resources (SA: Akpalu 2005; Botswana: Sallu *et al.* 2009); ii) reliance on rainfed agriculture (Namibia: Capoco 2012; Newsham & Thomas 2011; Zeidler *et al.* 2010; SA: Gbetibouo 2009, Kori *et al.* 2012; Botswana: Sallu *et al.* 2009); iii) a low diversity of livelihoods (South Africa: Archer *et al.* 2008, Archer *et al.* 2009, Thomas *et al.* 2007; Botswana and South Africa: Twyman *et al.* 2004; Namibia: Dirkx *et al.* 2008) ; iv) dependence on activities that are sensitive to the impacts of climate change (South Africa: Gbetibouo 2009; Namibia: Newsham & Thomas 2009, Zeidler *et al.* 2010; Botswana: Sallu *et al.* 2009); v) limited infrastructure and services (SA: Akpalu 2005, Archer *et al.* 2009; Namibia: Amadhila *et al.* 2013); vi) limited institutional capacity (South Africa: Bourne *et al.* 2012, Koch *et al.* 2007, Pasquini *et al.* 2013; Namibia: Kandjinga *et al.* 2013; Capoco 2013; David *et al.* 2012); and vii) high levels of poverty (SA: Akpalu (2005); Thomas *et al.* 2007; Bourne *et al.* 2012; Archer *et al.* 2009; Botswana: Twyman *et al.* 2004; Dougill *et al.* 2010). The climatic and socio-economic environment in semi-arid areas in southern Africa makes communities vulnerable to food insecurity and unstable livelihoods as well as leading to unsustainable agroecological systems (South Africa: Gbetibouo 2009; Namibia: Newsham & Thomas 2009; Zeidler *et al.* 2010; Botswana: Sallu *et al.* 2009).

Semi-arid areas in southern Africa are characterised by high rainfall variability, frequent droughts, low soil moisture and extreme events such as flash floods (Namibia: Midgley *et al.* 2005, Mozambique: National Adaptation Programme of Action, Ministry for Environmental Coordination - MICOA, 2007). These conditions provide the foundation of vulnerability in semi-arid areas. On top of these environmental conditions poverty (SA: Akpalu 2005, Thomas *et al.* 2007, Bourne *et al.* 2012, Archer *et al.* 2009; Botswana: Twyman *et al.* 2004, Dougill *et al.* 2010), the lack of access to services (SA: Akpalu 2005; Archer *et al.* 2009), high population densities (Namibia: Capoco 2012, Newsham & Thomas 2011) a reliance on natural resources (SA: Akpalu (2005); Botswana: Sallu *et al.* 2009), limited resource governance (SA: Bourne *et al.* 2012) and limited livelihood options (South Africa: Archer *et al.* 2008; Archer *et al.* 2009; Thomas *et al.* 2007; Botswana and South Africa: Twyman *et al.* 2004, Namibia: Dirkx *et al.* 2008) leads to the degradation of resources. In addition access to resources confounds progress e.g. in Botswana water from dams is diverted to the capital city. Drivers of vulnerability in semi-arid areas in southern Africa are further outlined below.

4.1 Drivers of vulnerability

4.1.1 Limited institutional support

The lack of service provision in semi-arid areas in southern Africa make people in these areas susceptible to the impacts of climate change. In particular there is a lack of agricultural extension services (SA: Akpalu 2005, Archer *et al.* 2009, Moeletsi *et al.* 2013, Mpandeli & Maponya 2013). At a higher level there is a lack of appropriate and integrated policy (South

Africa: Koch *et al.* 2007, Pasquini *et al.* 2010). Another problem in semi-arid areas in Southern Africa is that government ministries operate centrally restricting the capacity and effectiveness of implementation of activities at the local level. An additional form of institutional support that makes communities vulnerable is a lack of markets to provide opportunities for the sale of products in an attempt to diversify livelihoods.

4.1.2 Reactive versus anticipatory planning

The reactive, short term planning approach that is generally applied in semi-arid regions in southern Africa keeps communities vulnerable in the face of climatic variability and change.

4.1.3 Poverty

Semi-arid areas are often the poorest areas in a country e.g. in South Africa, average household income is the lowest in the Eastern Cape and Limpopo Provinces (Statistics South Africa 2012) and poverty is often most pronounced in female-headed households, based in rural areas (Namibia: Central Bureau of Statistics 2008). Such poverty makes communities in SARs in Southern Africa particularly vulnerable (Twyman *et al.* 2004, Akpalu 2005, Dougill *et al.* 2010, David *et al.* 2013). Poor households have a low capacity to develop and sustain economic activities (Ministry of Environment and Tourism 2011), are more reliant on natural resources and the provision of ecosystem services (Reid *et al.* 2007, Brown 2009) and have few resources to cope with and recover from man-made and natural shocks and diseases. It follows that poverty prevents communities from exploiting opportunities for adaptation such as the introduction of new varieties of crops (Newsham & Thomas 2009). Living conditions for the poor are often characterised by health problems (e.g. no access to healthcare), fairly low levels of education (e.g. limited access to schools), and high levels of unemployment (e.g. low levels of formal education), which are other stressors for vulnerability (see below). In addition, the living conditions are prone to the development of detrimental behaviours such as violence and alcohol abuses (Seely *et al.* 2008, Angula 2010). Poverty is also often closely linked to food insecurity which is exacerbated by the impacts of climate change (Kuvare *et al.* 2011).

4.1.4 Unemployment

In rural areas of semi-arid southern Africa there are limited employment opportunities (South Africa: Akpalu 2005, Thomas *et al.* 2007, Archer *et al.* 2008, Archer *et al.* 2009, Bourne *et al.* 2012; Botswana: Twyman *et al.* 2014; Namibia: Dirkx *et al.* 2008) and off-farm jobs are scarce, especially for unskilled workers. This concerns a large part of the workforce as education and literacy levels remain fairly low (Archer *et al.* 2008). In this context, employment on semi- or commercial farms is critical on a seasonal basis as a complementary source of income to subsistence agriculture (Archer *et al.* 2008). Yet, employment on commercial farms mainly depends on sufficient agricultural productivity, which relies on a number of components including soil fertility, weather patterns and rainfall quantity and periodicity. In the North West Province of South Africa and in some parts of the Limpopo Basin, mining activities also employ a large part of the population. However, decline of employment in the mining sector is observed across the country, currently contributing to raising unemployment level.

Unemployment rates could also be increased due to climate change impacts on agriculture. Reports have indicated that farming production could decline substantially as a result of the effects of climate change (IPCC 2014a; Zeidler *et al.* n.d.), thus activities on subsistence agriculture and seasonal work in commercial farms are both threatened. For instance, commercial farms will need to employ less seasonal workers as yield decreases. As a result, people may turn to off-farm work, a necessary pathway to provide other subsistence mean, yet such jobs are scarce especially in rural areas for unskilled workers. Labour forces that come from the agricultural sector may face difficulties to find new employment opportunities outside of agriculture, thus risks of heightened unemployment rate and increased poverty are prevailing for the next decade (North-central Namibia: Newsham & Thomas 2009).

A possible future result of lack of employment opportunities is a higher reliance on natural resources for many individuals and households rural areas, thus more pressure on land and water resources can be expected. Yet, water and land quality are both increasingly affected by the impacts of climate change. Without implementing vulnerability reduction measures (e.g. creation of paid job in other sectors), or applying relevant adaptation strategies, increased poverty, food insecurity and famine could be expected in rural areas for the next decades, whereas migration towards the cities, which is already a stressor for vulnerability, could be accentuated (see later section).

4.1.5 Limited access to loans and to farmers' insurance

Limited access to loans and to farmers' insurance contributes to vulnerability among farmers' households (Etosha basin, Namibia: Zeidler *et al.* 2010; Caprivi region, Namibia: Nyambe & Belete 2013, Giorgis 2011). Loans and insurance help coping with facing and recovering from more frequent climate disruptions, such as more frequent and intense droughts and floods as a consequence of climate change. Loans can also facilitate the implementation of adaptation strategies by facilitating access to agricultural equipment and input (e.g. short-cycle varieties of crop) that contribute to improve farm yields in the context of a changing climate (Bryan *et al.* 2009, Zeidler *et al.* 2010, Oyekale 2012, Nyambe & Belete 2013). The fact that access to loans and insurance is seriously limited for farmers in SARs of Southern Africa will contribute to a degradation of livelihood conditions over the next decades, as yields decrease. However, there are some existing support mechanisms. For example in Botswana the government run Integrated Support Programme for Arable Agricultural Development (ISPAAD) provides some access to credit, as does Agribank in Namibia.

4.1.6 Low level of education and literacy

In South Africa, Limpopo has the highest proportion of people over 20 years old with no schooling (17,3%), followed by Mpumalanga and North West province (14,1% and 11,8% respectively) (Statistics South Africa 2012). In the Kunene region of Namibia, literacy rate reaches 65% of the 15+ years whereas 37% of the population never attended school; in Omusati, literacy rate for the same group is 8% whereas only 13% of the population never attended school. It should be noted that, in both regions, level of literacy and education are slowly improving as observed throughout the last decade (Republic of Namibia 2011 a&b).

Educational attainment is critical in addressing skills shortage and in being able to access paid jobs in the Southern African SARs. Thus, the observed weaknesses in educational levels significantly hinders people's capacity to access paid jobs, as noted in South Africa for instance (Archer *et al.* 2008) and in semi-arid Namibia (Reid *et al.* 2007, Giorgis 2011). In fact, paid jobs are scarce in rural areas especially for unskilled workers who, thus, have to find income from other activities, e.g. labour on commercial farms or in the informal sector.

4.1.7 Population growth

Population growth rates driving changes in human settlement can also be a stressor for vulnerability, especially in regions where people are highly reliant on natural resources (e.g. rural areas) or in regions with high population densities (e.g. cities). However, population growth rates across SARs are decreasing: for instance, in Omusati region of Namibia, population growth rate has declined from 1,5% to 0,6% between 2001 and 2011 (Republic of Namibia 2011 a&b). In the rural context, increased densities mean more pressure on land and ecosystems, and increased demands for shared resources such as water, already available in limited quantity. Such competitive demands and uses of natural resources are already observed in multiple arid and semi-arid regions of Namibia, such as Kunene, Ohangwena, Omaheke, Omusati, and Oshana: this is due to the effects of migration and high population densities (Kuvare *et al.* 2008). Higher human densities on agricultural lands, coupled with land management policies (see last section), have also contributed to shifts in land distribution, and to the allocation of smaller fields to farmers e.g. shift from communal to individual grazing land in Botswana land (Dube & Pickup 2001). A consequence is a reduced capacity to diversify crops and to increase yields, whereas crop diversification is a strategy to avoid yield loss in the context of pest spread or climate hazards. In north central Namibia increased population density, has led to competition over land use between settlement, cropping on the one hand, and grazing on the other (Newsham & Thomas 2009). Higher food production is also necessary to respond to the demands of a growing population, whereas heightened human pressures on land affect soil quality, contributing to land degradation, fertility loss, and reduced harvests (Kuvare *et al.* 2008).

4.1.8 Migration

In South Africa, people tend to move from the rural province of Eastern Cape and Limpopo to the most industrial provinces of Gauteng and Western Cape (Statistics South Africa 2012). Migration from rural to urban areas and the mining centres is also increasing in Namibia (Kuvare *et al.* 2008, MET 2011b) in the hope to improve their livelihood options. Population densities tend to increase in areas where either economic activities and/or natural resources (arable land, water and grazing) offer improved livelihood options thereby increasing pressure on natural resources and increasing vulnerability to the adverse effects of climate change (Kuvare *et al.* 2008). Depending on whether the economy creates employment, the impact of population growth, migration and increases in population densities can be associated with rising levels of unemployment, increasing dimensions of problems with youth, and the potential degradation of the ecological environment. Climate change intertwines with these social stressors and puts increased stress on the government which is already struggling to provide sufficient public services.

Migration is a driver for vulnerability in rural and urban areas. As a result of increased migration flows, cities are under pressure whereas their capacities to absorb new flows of population may reach limits. For instance, development trends in population growth and urbanisation levels have resulted in dangerous settlement location in the cities, e.g. people are settling down in flood-prone areas where building are not properly conceived to welcome a high number of inhabitants (South Africa: DEA 2011).

While temporary migrations towards the cities are part of the rural livelihood strategies, e.g. seasonal migrations in search of better pasture are common for Ovahimba cattle farmers in the arid Kunene environment of Namibia (Integrated Environmental Consultants of Namibia 2011), permanent moves toward urban regions are on the rise due to increased poverty, land degradation and declining livelihood conditions in the countryside, which impair the capacities of farmers' households to support livelihood expenses such as school, healthcare and food (Botswana: Dougill *et al.* 2010; Namibia: Reid *et al.* 2007). Rural exodus, is a burden to rural development and a driver for urban poverty. Not only does it deprive farms from a necessary young workforce, but it also contributes to wage decreases and high unemployment rates in the cities (Dirkx *et al.* 2008, Newsham & Thomas 2009).

Migration to the cities, already growing for a number of reasons, could be amplified by the impacts of climate change as living conditions in the countryside are deteriorating. As rural inhabitants may look for other sources of income, movement towards the cities may increase. The resulting situation may be an accentuated difficulty for urban areas to absorb new population flows, especially due to the current lack of adequate infrastructure (see related section). Pressures on the poor urban inhabitants are expected to rise, as their access to food and income decrease, and their sensitivity to climate extremes such as floods increase.

4.1.9 Health

Households with disabilities constitute 4% in the Kunene region and 6,3% in the Omusati region of Namibia (Republic of Namibia 2011a&b). Sick or handicapped people have a reduced capacity to work in the field or to perform paid labour. Thus, households with disabled or sick people tend to access less income, and rely more on their direct environment for survival (DEA 2011). When the general health of farm workers is affected, their ability to care for their families is significantly reduced, which can result in withdrawing children from schools due to loss of income and general loss of labour. Such behaviours have been observed in semi-arid regions of Namibia, such as Kunene, Ohangwena, Omaheke, Omusati, and Oshana (Kuvare *et al.* 2008).

The adult (population aged 15-49) prevalence rate of HIV/AIDS in Southern Africa is high (Namibia: 13%, South Africa: 18% and Botswana: 23%; CIA 2014). In Namibia 7% of all people living with HIV/AIDS are under the age of 15, and 60% are women. In Namibia Orphans and other vulnerable children make up 28% of all children. Of the children who have lost one or both parents, nearly 50% were estimated due to HIV/AIDS. The very high incidence of tuberculosis in Namibia is also fuelled by the HIV/AIDS pandemic (MET 2011b).

In Namibia AIDS-related illness and mortality are thought to impact the environmental sector and have an impact on the management of natural resources (MET 2011b). For example the CBNRM support organizations, conservancies and parks reported that they are losing personnel, knowledge and skills through HIV/AIDS related sickness and death and that absenteeism and psychological stress affect productivity on the work floor.

HIV/AIDS already threatens human capacity in Namibia, furthermore a complex interaction of socio-economic stressors in subsistence farming households exists (poor health, inequitable access to land, gender inequality, population growth, and increasing competition for shared resources), and climate change induced impacts will only add to this situation. Wilhelm (2012) stated in the north central Namibia (Oshikoto, Oshana, Omusati and Ohangwena) the precarious situation of village life is exacerbated by the impact of the high levels of HIV infection. The North Eastern Caprivi region has the highest HIV prevalence in Namibia and Southern Africa. HIV/AIDS is impacting the ability of subsistence farmers to grow enough food for themselves in North Central Namibia and Caprivi.

Other major infectious diseases include waterborne diseases such as bacterial diarrhea, hepatitis A, and typhoid fever and vector borne diseases such as malaria and bilharzia.

4.1.10 Low livelihood diversification

There are limited opportunities in semi-arid areas in southern Africa for diversifying livelihoods. This is in part due to the limited availability of natural resources and limited availability of markets. However, in some cases there is a lack of initiative and know how in terms of exploiting possible opportunities.

4.1.11 Reliance on subsistence agriculture

Most of SARs' inhabitants are located in rural areas (e.g. in Kunene (73,6%) and Omusati (94%) in Namibia) where agriculture (commercial and subsistence) is one of the main economic activities. In Omusati, households with farming activities as a main source of income constitute 32% of the population, whereas they constitute 41% of Kunene's inhabitants (Republic of Namibia 2011a&b).

According to the IPCC (2014), the livelihood activity most at risk from climate change impacts in the SARs of Africa is agriculture. Dependence on rain-fed agriculture increases vulnerability of livelihoods to climate-related hazards such as droughts and floods (Paavola 2004, Conway *et al.* 2005).

Across SARs, subsistence farming is a feature of semi-arid regions of Namibia and Botswana (UNDP n.d.). Activities generally include a combination of crop cultivation and small livestock rearing, as observed in Omusati region of Namibia (Kuvare *et al.* 2008) and in semi-arid regions of Southern Africa more generally (Eriksen *et al.* 2008). Crop cultivation, at a subsistence level, is characterised with low-input rainfed agricultural varieties. Because of its low productivity, subsistence farming is often complemented with small scale mining, wildlife conservation (for tourism) or seasonal labour, often on neighbouring commercial farms (South Africa: Archer *et al.* 2008, Eriksen *et al.* 2008). These activities are critical as complementary sources of income. As access to paid employment in rural areas is scarce (South Africa: Thomas *et al.* 2007), people are especially relying on agriculture as main source of income and main subsistence activity. As agricultural output is extremely sensitive to climate conditions and to the quality and quantity of natural resources like rangeland and water, those depending on it for their livelihoods are extremely sensitive to natural hazards, shifts in climate patterns, and land degradation.

It is very likely that issues of food insecurity and limited income from agriculture will be amplified due to climate change impacts on water and agriculture; this accentuation is, actually, already observed in some regions of North-central Namibia, for instance (Newsham & Thomas 2009). Rainfed agriculture, dominant among smallholders, is extremely sensitive to shifts and changes in temperature, seasonal rainfall patterns, humidity and rainfall quantity. These effects of climate change are expected to affect regions such as Omusati in Namibia and the Limpopo basin in South Africa, where they will increase the likeliness of crop failure (Gbetibouo 2009, Newsham & Thomas 2009, Zeidler *et al.* 2010, Sallu *et al.* 2009). These factors (changes in seasonal onset, reduced amount of precipitations) will continue to affect agriculture within the next decades, thus accentuating risks of increased poverty and food insecurity especially among the poorest households (Archer *et al.* 2008).

4.1.12 Reliance on livestock rearing

Pastoralism as a main occupation is predominant in the Kunene region of Namibia (Kuvare *et al.* 2008). Cattle are sensitive to endemic diseases, which implies a risk to lose a major source of income as a consequence of disease spread. In addition, practices for livestock husbandry have already caused significant losses in the grass biomass. For instance, the Omusati region in Namibia has witnessed shifts and changes in the soil fauna and forage species due to overgrazing practices (UNDP n.d.). The disappearance of plants and wildlife due to similar reasons was also observed in the Limpopo River Basin (Dube *et al.* 2007, Dube & Sekhwela n.d.). As a result of land degradation, yields from both commercial and subsistence farming are in decline, whereas food insecurity is increasing. It should be noted that malnutrition already concerns between 21% and 31% of the overall population located in South Africa, Namibia, Botswana and Zimbabwe (see NVAC 2014).

Reliance on livestock rearing will also emphasise vulnerability in the context of climate change. Livestock are highly sensitive to heat stresses and endemic diseases, which are both expected to increase in SARs (IPCC 2014a). In addition the productivity of rangelands is affected by climate change. Dramatic consequences can be expected as heat rises, and as pests or diseases spread, adding up to other challenges such as the depletion of pasture quantity and quality (Dougill *et al.* 2010, Unganai & Murwira 2010, DEA 2011, Oyekale 2012). For instance, drier and hotter conditions will make it more difficult to fight desertification and land degradation processes in Omusati region of Namibia (Kandjingaa *et al.* 2010), thus emphasise the depletion of natural resources and fertility losses. These consequences impair agricultural yields as well as cattle productivity: grazing areas, for instance, will become smaller and vegetation will deteriorate. As a result, livestock productivity will be negatively affected in semi-arid regions of Namibia among others (Kandjingaa *et al.* 2010); pastoralists may lose their main source of income as well as their traditional identity.

It should be noted that farmers in north central Namibia, for instance, are already looking for off-farm and/ or informal job as a result of more frequent crop and livestock failures, partly related to current climate change impacts in SARs (Newsham & Thomas 2009). However, limited paid jobs are available particularly in rural areas and for unskilled workers. Thus, it is likely that climate change will create new challenges to survive in rural areas of SARs, especially for the poorest households that rely on natural resources. For instance, there is a risk to see more frequent temporary or longer-term food shortage, malnutrition and increase dependency on external aid in regions dominated by pastors such as the Cuvelai Etosha Basin (Zeidler *et al.* 2010).

In Namibia, concern was expressed over the limited marketing and selling of livestock (*pers. comm.* respondent from Directorate of Agricultural Production, Extension and Engineering Services (DAPEES) Oshana region, November 2014). People resist selling their livestock and then during droughts they lose some of their herd.

4.1.13 Erosion of traditional knowledge and networks

Over the past decades, governmental land management regulations have initiated changes in local practices. In the Kalahari rangelands of Botswana, for instance, land management policies were implemented at the local level without integrating existing local practices, which now threaten to disappear (Dube & Sekhwela n.d.). Rural migration towards the cities also accentuate local knowledge erosion, as observed for instance in the North Central provinces of rural Namibia (Newsham & Thomas 2009). Poverty and a lack of access to land as a productive resource not only affect cultural identities (e.g. farmers must find new subsistence activities in North Central Namibia for instance; Newsham & Thomas 2009); it also affects existing social networks. For instance, safety nets such as economic support of farmer groups, are tested and challenged in a context of poverty, because it becomes more difficult to maintain social reciprocity with increasingly limited resources (Namibia: Midgley *et al.* 2005).

4.1.14 Cultural beliefs and superstition

Cultural beliefs and superstition make communities vulnerable to the effects of climate change as they constrain the uptake of adaptation measures. Rural communities in southern Africa attribute climatic changes to a number of factors related to their belief systems, superstitions and limited understanding of information they have at hand. For example in Bobonong some people believe that observed climate anomalies are the result of their people displeasing god whereas others believe extreme droughts are a consequence of their people displeasing their ancestors. Rural communities have a strong preference for traditional crop varieties and approaches and they are reluctant to adopt new measures that are unknown to them, they may not use a measure without proof of its effectiveness and may stop using measures for superstition e.g. not using a new variety again after it is eaten by quelea the first time it is planted. Another instance where cultural systems increase vulnerability is the reluctance to sell cattle in north central Namibia. Because of the cultural value of having cattle for their symbolism of wealth people hold on to their cattle without wanting to sell them until they are old when the price is low. This places people at risk of losing animals when there is a drought.

4.1.15 Government programmes that engender dependence and funder driven measures

The provisions of government programmes that create dependency and stop people from pursuing other productive more sustainable initiatives make communities vulnerable by reducing their adaptive capacity. For example the uptake of an effective and sustainable beekeeping project in Botswana has been constrained by a relief provision programme - Ipelegeng. Likewise in Namibia the provision of drought relief in Namibia stops communities from putting their own measures in place to help themselves. Another potential source of vulnerability is the implementation of initiatives that are driven by funders and not based on community needs.

4.1.16 Low productivity of land

Low productivity of land makes people vulnerable in semi-arid areas in southern Africa. In Namibia, for example, loss of productivity of the land is one of the major problems. Land that formerly supported many people, e.g. crops and pastures for livestock has become more difficult to farm and less able to provide necessary pasture for animals. This has lead to a reduction in food security.

4.1.17 Limited crop diversification

Limited crop diversification is another driver for vulnerability in the context of climate change. For instance, the reliance upon a single main production of Rooibos in the Karoo Plateau of Northern Cape increase the likeliness of crop failures as climate change induces seasonal variability, shifts in pests distribution and more frequent dryspells (Archer *et al.* 2008, Oyekale 2012).

4.1.18 Limited irrigation capacity

Developing irrigation capacities and implementing sound irrigation systems are necessary pathways, suggested in the Karoo Biome, the central Savannah Biome and the north eastern Woodland Biome (Namibia: Barnes *et al.* 2012), to cope with changing rainfall patterns and reduced precipitation, two observed impacts of climate change. In fact, improving opportunities for irrigation and implementing water conservation strategies will be required to maintain agriculture in most regions of Southern African SARs (MICOA 2007, IPCC 2014a). Yet, challenges to develop such strategies are significant as water scarcity is a common feature of SARs, whereas declines in the resource are expected as a result of climate change. The potential result of reduced irrigation capacities due to climate change impacts is the impossibility to maintain agricultural activities on drylands, a threat already affecting Namibia for instance (Midgley *et al.* 2005).

4.1.19 Lack of access to information and relevant technologies

Lack of access to relevant technologies also contributes to vulnerability in the context of climate change. For instance, shifts in rainfall patterns require adjustments in the agricultural calendars (e.g. changes in tillage timing), with the risk of crop failure being more and more present (Namibia: Angula *et al.* 2012; Zimbabwe: Unganai & Murwira 2010; Kalahari in Botswana: Mogotsi *et al.* 2011). Resorting to new agricultural technologies like short-cycle varieties of crops is a proposed pathway to adjust agriculture to climate change impacts in Omusati and Caprivi regions of Namibia, for instance (Zeidler *et al.* 2010, Nyambe & Belete 2013). However, these technologies are not easily accessible, especially to smallholders, because of their cost and because of a lack of access on the markets, as noted by Nyambe and Belete (2013) in the region of Caprivi. As a result, farmers remain vulnerable to shifts in seasonal patterns and reduced precipitation quantities, which continue to amplify due to climate change.

Not only is limited access to technology a source of vulnerability but so is limited access to information on adaptation options.

4.1.20 Unsustainable use of natural resources

In most Southern African SARs, agriculture is critical for economic development and for the subsistence of households. Thus, the way natural resources are managed is critical to maintain or improve livelihood conditions in these regions. Further, in the absence of financial security communities are reliant on natural resources for their livelihoods e.g. fuel wood is obtained as a source of energy.

Intensive land use related to high population densities is a common problem and a driver of vulnerability in SARs (MET 2011b). It leads to land degradation (Zeidler *et al.* 2010), which in turn amplifies agricultural productivity losses. For instance in the semi-arid northern Sandveld and the Limpopo River Basin of South Africa, farmers are seeking immediate benefits from land production through input intensive farming, despite the proven benefits of sustainable soil management (Archer *et al.* 2009; Oyekale 2012).

Overgrazing, a practice observed in many semi-arid regions of Southern Africa including Oshana and Omusati regions of Namibia (Klintenberga *et al.* 2007, UNDP n.d.), and the Limpopo basin and Namakwa district of South Africa (Gbetibouo 2009; Bourne *et al.* 2012), contributes to cause important land degradation. In return, livestock and crop production is reduced, which intensifies farmers' vulnerability to food insecurity and poverty (Dougill *et al.* 2010; Bourne *et al.* 2012).

Over-abstraction of ground and underground water resources, either for agriculture or mining activities, is another key problem in SARs; it is also a significant driver for vulnerability among rural populations in North central Namibia, in the semi-arid western region of South Africa and in the Limpopo river Basin (Klintenberga *et al.* 2007; DEA 2011; Zhu & Ringer 2012; Bourne *et al.* 2012). Water scarcity is already a problem in SARs, which induces among other consequences degradation of health and sanitation services, and limited irrigation opportunities (Kandjingaa *et al.* 2010; Archer *et al.* 2008; Bourne *et al.* 2012).

Impacts of over-use of water resources, which is already a stressor for vulnerability in SARs, are likely to be accentuated in the context of climate change due to changes in rainfall patterns and ecosystem services. Less water availability and degraded quality could affect health, reduce access to drinking water and the development of sanitation services, as well as diminish current opportunities for irrigation.

Unsustainable behaviours, such as uncontrolled bush fire, felling of trees for charcoal or building materials, constitute another threat for natural resources, and another stressor for vulnerability. These individual detrimental behaviours also contribute to the process of land degradation, in terms resulting in decreased livelihood conditions in the rural areas (MICOA 2007; Archer *et al.* 2009).

Large areas of land in northern Namibia are severely degraded due to deforestation, overgrazing, overstocking, high population pressure and unsustainable farming practices (Nangolo *et al.* 2006 in Newsham and Thomas 2011). Klintenberga *et al.* (2007) stated that in the face of natural cause of environmental change, many factors are worsening the already burning issue. Examples include, putting up fences to claim common lands is making large parts of the common land unavailable for grazing and forcing cattle to pass in narrow corridors between fences, causing increased pressure on the land. This is happening in the north central regions of Namibia.

Gremlowski (2010) established that the situation in the north-central region is intensified by an increase in environmental degradation that is determined by human activities. This degradation is likely to increase the frequency and intensity of natural hazards such as floods, droughts and climate change impacts. A number of human induced activities in that region have a negative influence on land, water resources and wetlands. This includes stream bank cultivation, overgrazing, land clearance, logging and fires which all lead to an increase in soil erosion. This contributes to sedimentation and loss of biodiversity.

Intensive land uses and overgrazing are drivers for vulnerability, which effects are also intensified by climate change impacts. For instance, intensive commercial farming practices implemented in the semi-arid northern Sandveld, South Africa (Archer *et al.* 2009) or overgrazing observed in some parts of rural Namibia (Dahlberg & Wingqvist 2008), coupled with expected climate change impacts on biodiversity, temperatures and precipitations, will further deteriorate soil quality and productivity, and therefore increase farmers' vulnerability as their source of food and income is degraded. In addition, natural capital such as timber, plants and land, upon which rural population rely as a major source for energy, construction material, or medical care, are diminished due to the combination of unsustainable practices and current and future climate change impacts on biodiversity.

4.1.21 Urbanisation

Urbanisation at a fast pace is another common feature of SARs. Urbanization will substantively change the main characteristics of livelihood conditions in Southern Africa, within the next decades. According to projections, by 2030, half of Africa's population will be living in urban areas. In fact, in South Africa, 60% of the population is already urban. Moreover, rural-urban migration flows are increasing, for instance in the Limpopo province where people are leaving the countryside in favour of larger cities (Statistics South Africa 2012). Impacts in terms of infrastructure needs and development of road systems are already observed, e.g. in Botswana. Challenges are also emerging, for instance regarding waste management, supply of safe water and sanitation issues. Living conditions in the cities for the peri-urban poor are often precarious due to the inadequacy of infrastructure and sanitation systems (DEA 2011) .

According to MET (2011b), Namibia is still mainly rural despite rapid urbanisation. The rate of urbanisation is expected to increase due to the fact that land degradation and constrained access to productive resources will force people to look for greener pastures. This will bring immense challenges for the few Namibian urban centres.

Fuller and Prummer (2000) stated that Khomas region including the capital Windhoek is faced with increased in-migration. The fast and unplanned migration puts pressure on the scarce natural resources in the receiving area, especially the safe water supply. The socio-economic determinants are therefore different. This region has the lowest fertility rate, the highest level of education, and the highest standard of living. It is therefore the centre of attraction in the country. On the contrary the north central regions (Oshana, Omusati, Ohangwena, and Oshikoto) are regarded as poor, with fewer opportunities for work and development and low level of education, so people migrate out to look for a better life. With an increase in human and division of plots for family members less land is available per farmer particularly in the north central Namibia where more than 50% of the total population are concentrated.

4.1.22 Inadequate infrastructure

Building of inadequate infrastructure in risk-prone areas (e.g. areas prone to floods) is another driver for vulnerability which can significantly affect people's livelihood conditions as well as have knock on effects to the national economy by having impacts on different sectors including transport (damage to infrastructure such as bridges), water, agriculture (damage to irrigation infrastructure) and health (spread of disease through contaminated water). Studies in South Africa (DEA 2011) and in Namibia (Omusati and Oshana regions; Amadhila *et al.* 2013) have highlighted the presence of poor infrastructure in flood-prone areas, whereas construction plans did not take into account the related risks. Significant damages to roads and building, with heavy repair costs were already observed, for instance during recent flood events (2008 and 2009) in Omusati and Oshana; additional impacts of flooding events include damages to personal belongings; reduced access to public and private services such as hospitals and schools (IECN 2011); and, sometime, loss of life.

Poor storm water drainage systems in human settlement also have a detrimental impact on health, exposure to contaminated water is increased in the event of a flood: this is the case, for instance, in some urban areas in Ondangwa, Outapi, Helao Nafidi and Katima Mulilo in Namibia (Tamayo *et al.* 2011). Contaminated water also provides breeding habitat for mosquitoes and parasite leading to increase incidence of some diseases (Republic of Namibia 2011).

Finally, in rural areas, there is a lack of good-quality roads and, during flood events, this often results in reduced access to critical facilities such as water boreholes, transportation means, schools or health care services, for instance affecting inhabitants of Omusati and Oshana regions of Namibia (Amadhila *et al.* 2013). Due to a lack of good-quality roads, isolated inhabitants are forced to travel long distance often on foot to find water or to access public services. This situation especially concerns the poorest households, often located in marginal plots or remote areas, characterised by a lack of adequate service delivery such as health care, of sanitation infrastructures, e.g. observed in rural regions such as Omusati in Namibia (Wilhelm 2012).

Building of poor infrastructure in flood-prone area is already a source for economic losses, increased health risks and loss or damages to personal belongings (IECN 2011). For instance, severe floods in 2008 and 2009 in the Cuvelai Etosha Basin of Oshana, Namibia, have demonstrated the extreme vulnerability of infrastructures to flooding (Zeidler *et al.* 2010). With climate change's expected impacts in regard with floods, it is likely that economic losses and health issues will be emphasized, whereas life and personal belongings may be increasingly put at risk, for instance in the Limpopo river Basin (South Africa: Oyekale 2012).

In the Caprivi region and in the Cuvelai Etosha Basin of Oshana, Namibia, farmers have settled down in floodplains or wetland because these local ecosystems support agricultural and fishery activities, and provide services such as water purification, water retention and flood attenuation (David *et al.* 2013). Yet, climate change impacts are increasingly affecting ecosystem services and performances, which, in return, reduce ecosystems' capacities to provide services such as water filtration and retention, thus increasing floodplain inhabitants' vulnerability to flooding events, among other risks (Dirkx *et al.* 2008, David *et al.* 2013).

In the context of climate change, a lack of good-quality roads, which characterises rural areas in SARs, will further emphasise people's remoteness and isolation from critical public services during climate extremes such as floods. Thus, people's vulnerability in rural areas of SARs could be significantly emphasised within the next decade (Kandjingaa *et al.* 2010, Capôco 2012; Bourne *et al.* 2012). Floods isolate people from relief aid in time when they need it the most. With an increased occurrence and intensity, roads could become unusable more often and remote communities more frequently isolated from critical services. Vulnerability to problems such as diseases, limited access to safe water and sanitation or food insecurity is expected to rise in Omusati region of Namibia (Wilhelm 2012).

4.1.23 Summary of key vulnerabilities

According to stakeholders in Namibia some of the key vulnerabilities in semi-arid areas include: i) people settling in floodplains in Oshana, ii) the lack of marketing of livestock driven in part by cultural beliefs, economic factors and lack of institutional support in terms of available markets; iii) the degradation of natural resources; iv) livestock not coping with heat and not having well adapted crop varieties; v) not having information on adaptation options; and vi) not having integrated policies and programmes across different ministries. In Botswana some of the key vulnerabilities in semi-arid areas include: i) lack of parental care of the youth and lack of opportunities for the youth; ii) lack of markets to sell products; iii) lack of institutional capacity at the local scale; iv) conflicting government programmes and programmes that increase dependence; v) reduced availability of natural resources e.g. mopane worms and rivers being dammed for domestic and industrial use in Gaborone.

A number of factors in semi-arid southern Africa constrain the adaptive capacity of rural communities. These include: i) being reactive versus planning ahead; ii) cultural beliefs; iii) lack of institutional support in the provision of information, technical support and infrastructural support in the form of market places; iv) access to capital; v) the provision of aid relief and implementation of initiatives that make people dependent; vi) limited access to natural resources; v) funder driven initiatives; vi) limited opportunities for youth who don't want to follow traditional livelihoods; and vii) limited exposure to adaptation options including alternative livelihoods.

4.2 Biophysical impacts of climate change

The common driving climate features in SARs in Southern Africa are the highly seasonal rainfall and the high variability of rainfall both inter-annually and intra-seasonally. This region is already water stressed (Midgley *et al.* 2005), as droughts and dry spells occur frequently. Furthermore, parts of the SARs in Southern Africa are prone to severe flooding, including flash floods, and to extremes such as cyclones: this is the case of the Gaza Province of Mozambique for example (MICOA 2007). Climate variability and climate extremes cause severe impacts to both human and natural systems, in rural and urban regions of SARs; these features are expected to increase in frequency and intensity in the context of climate change.

It is very likely that climate change will further accentuate current vulnerability among SAR communities: its impacts are increasingly affecting key sectors, critical for livelihood subsistence and wellbeing in rural and urban areas of Southern African SARs (IPCC 2014a, Midgley *et al.* 2005). The likely effects of 1-4 degree increases in temperature, increased frequency and intensity of flash floods and droughts on different sectors are presented in Table 1 below.

As shown in Table 1 climatic changes are expected to have a number of impacts in semi-arid regions in Southern Africa. One of the most pronounced impacts of climate change in semi-arid areas in Southern Africa is the reduction of agricultural yields. In Botswana reduced yields of 36% in maize and 31% sorghum in Sandveldt soils (West and Central) and 10% for both in more fertile Hardveldt soils (Eastern Botswana) are predicted in Botswana with the growing season reduced by 5 days for maize and 8 days for sorghum in sandveldt and 3 days for maize and 4 days for sorghum in hardveldt (Chipanshi et. al. 2004). Climate change impacts will seriously affect livelihood conditions and wellbeing in SARs. A decrease in water availability will not only impair economic development and food security issues, but also create health and sanitation problems. For instance, outbreaks of waterborne diseases such as cholera have already been observed in the Cuvelai Etosha Basin in Namibia, due to the more frequent occurrence of floods (Zeidler *et al.* 2010). Yet, the delivery of public services such as health care in flooded rural areas will be seriously hindered due to road damages in a context of heightened risks of flooding (Zeidler *et al.* 2010). Thus, in flood-prone areas such as Omusati region in Namibia, increased flood frequency and intensity will contribute to disconnecting villages from public services, reducing access to schools, heightening risks of diseases and food insecurity, and increasing damages to personal belongings (IECN 2011).

Table 4.1. Impacts of climate change per sector, in the short- to mid-term (2020-2050)[1]

Sectors	Impacts across Southern African SARs
Water	• Reduced water quantity due to higher temperature, changes in precipitations and rainfall amounts (South Africa: Lumsden et. al. 2009; Namibia: Kandjingaa *et al.* 2010; Botswana: Hambira *et al.* 2012) • All models project reduced groundwater recharge under climate change (Archer *et al.*, 2009). • Reduced water quality due to shifts in, or depletion of, ecosystem services such as water filtration and purification (South Africa: Lumsden et. al. 2009; Namibia: Kandjingaa *et al.* 2010; Botswana: Hambira *et al.* 2012)
Health	• Increased occurrence of vector borne diseases (e.g. malaria) because of change in temperature, humidity and precipitations (South Africa: DEA 2013; Namibia: Hove *et al.* 2011; Botswana: Urguhart &Lotz-Sisitka 2014) • Increased occurrence of waterborne and foodborne diseases due to more frequent floods (Zeidler *et al.* 2010) • Increased sanitation problems due to diminished water quality and access across SARs
Agriculture	• Reduced yields of maize and sorghum of between 10 and 35% in Botswana (Chipanshi et. al. 2004) • Loss of soil fertility due to changes in precipitation, temperature, vegetation and moisture levels (Namibia: Kandjingaa *et al.* 2010; UNDP 2012; David *et al.* 2013; South Africa: DEA 2011; Botswana: Mohammed *et al.* 2013; Urguhart & Lotz-Sisitka 2014) • Accentuated soil erosion due to increased occurrence and/ or intensity of floods and droughts (Namibia: Kandjingaa *et al.* 2010; UNDP 2012; David *et al.* 2013) • Risks of crop failures due to changes in seasonal onset and length of winter seasons, precipitations, temperature, and humidity (Benhin 2006; Newsham & Thomas 2009) • Risks of failure in livestock production due to more frequent heat stresses, less water available, diseases spread and the degradation of soils and pasture (UNDP n.d.; Zeidler *et al.* 2010; Turpie *et al.* 2010))
Infrastructure	• Increased damages to infrastructures (building, roads) due to more frequent and intensive floods (Tamayo *et al.* 2011; Bourne *et al.* 2012)
Biodiversity	• Shifts in species suitability for specific areas due to changes in temperature, moisture and humidity (DEA 2011) • Risk of extinction for endemic species due to changes in temperature, moisture and humidity (DEA 2011) • Loss of ecosystem services such as water purification and filtration, provision of medicinal plants and of biomass energy because of changes in the vegetation, temperature and humidity levels (Dube *et al.* 2007; David *et al.* 2013)
Tourism	• Decline in nature-based tourism due to ecosystems' degradation, changes in weather patterns, and shifts in wildlife localization (UNDP n.d.)
Energy	• Decline in hydro-power production due to reduced rainfall and water flow in main rivers (Namibia: Zeidler *et al.* n.d; Eriksen *et al.* 2008)

[1] References are provided as concrete example in South Africa, Botswana and Namibia. Overall, all impacts are also presented in IPCC 2013 report.

Water is a critical resource in semi-arid regions, fundamental to sustain economic activities such as agriculture (Benhin 2006). Thus, shifts and changes in precipitations and seasonal onset will have severe impacts on farming activities, and especially on rainfed subsistence agriculture (Archer *et al.* 2008; Eriksen *et al.* 2008), whereas commercial farming activities will also be impaired: for instance, less water will be available for irrigation on commercial semi-arid lands (South Africa: Blignaut *et al.* 2009). If the climate scenarios are correct for the west coast and adjacent interior, of Southern Africa decreases in river flows and an increase in flow variability are expected as well as increased storm events as changes in precipitation are amplified in the hydrological cycle (Lumsden et. al. 2009).

Growing uncertainties regarding the implementation of rural subsistence activities, e.g. animal rearing and crop production, are already observed as a result of climate change impacts (e.g. in arid western South Africa: Archer *et al.* 2008). For instance, in the Cuvelai Etosha Basin of Namibia and in the Nzhelele Valley, South Africa, the timing of agricultural activities is affected by changes in the onset and length of the rainy seasons and abrupt stops of the rainfalls (Zeidler *et al.* 2010; Kori *et al.* 2012). Thus, changes in rainfalls induce fluctuation in tillage periods, making it harder for farmers to plan ahead.

Moreover, ecosystem performances (e.g. services such as water filtration and provision of medicinal plants) will be reduced, further affecting people's wellbeing, for instance in Omusati region (IECN 2008), and upsetting agricultural output: according to Midgley *et al.* (2005), grassy savannah in Namibia will lose their spatial dominance to desert and arid vegetation types which will have impacts on the capacities to develop economic activities such as agriculture.

Thus, one of the possible consequences of climate change on human systems is that farming activities might not be a viable option anymore in some parts of semi-arid Southern Africa: this could, for instance, be the case in Namibia where agricultural output for the country has been predicted to decrease by 40 to 80% within the next 50 years (Zeidler *et al.* n.d.). People depending on agriculture will, thus, become more vulnerable to stresses such as poverty and food insecurity, while the impossibility to rely on subsistence farming for a living could lead to a loss of cultural identities (e.g. if communities of pastoralists have to develop another subsistence activity).

Another key economic sector that will be seriously affected by climate change impacts is tourism. Changes in temperature, vegetation, water and the location of wildlife will, for instance, hinder wildlife safaris, water sport and backpacking activities in Namibia and in the Kgalagadi south east district of Botswana, for instance (Barnes *et al.* 2012, UNDP n.d., Hambira *et al.* 2012). Thus, dramatic impacts are expected on a country's GDP and on individuals relying on tourism as main source of income.

4.3 The vulnerability of different groups to climate change in SARs

This section focuses on groups that are vulnerable to climate change, with a goal to report on existing differential vulnerabilities in Southern African SARs: who is more affected by the impacts of climate change, why and how? Driven by these questions, the section attempts to shed light on gender and other differentiated dimensions of vulnerability that contribute to climate vulnerability in SARs.

Vulnerable groups are determined by their access to natural and financial resources, their engagement into social and economic activities, or their role in society. In the context of climate change, these features determine how different groups of people are affected by impacts such as higher temperature and reduced water availability. It is important to note that these different groups are not vulnerable to climate change because of their own individual or inherent features (e.g. because they are male or female), but because of specific configurations and governance systems that characterise livelihood conditions and affect wellbeing in SARs, e.g. generating unequal access to critical resources among various groups (Tschakert *et al.* 2013).

Due to the fact that financial capital is one of the most important indicators of adaptive capacity, population groups that have little access to financial capital, i.e. are considered income poor, are most vulnerable to climate change (Nyong et al, 2007). The level of poverty is often also increased by population pressures (caused by migration and urbanization) within metropolitan areas. There is therefore increased vulnerability that occurs in two scenarios; on the one hand near cities and towns with overcrowding in slum areas and informal dwelling, as well as in far removed remote rural areas, often cut off from economic activity (South African Risk and Vulnerability Atlas). Populations in areas of high economic activity (and poor populations especially) also experience more socio-economic vulnerability, due to that fact that they are highly dependent on often uncertain economic activity. There is also a higher incidence of unemployment and skills shortage in these areas, further exacerbating vulnerability of the population (South African Risk and Vulnerability Atlas). Increased vulnerability in one area often leads to an increase in another area; for example, in areas of high socio-economic vulnerability coupled with high levels of poverty, unemployment and a growing population, there is also vulnerability to water and food scarcity (South African Risk and Vulnerability Atlas)

Emerging, small-scale and resource-poor farmers are especially vulnerable to the effects of climate change. They often have no expertise of financial means to adapt to changing weather and climatic patterns, nor do the have the ability to recover from extreme events such as droughts or flooding (South African Risk and Vulnerability Atlas). According to the South African Risk and Vulnerability Atlas, “Land-use and land-cover changes determine,in part, the vulnerability of places and people to climatic, economic or socio-political” - thus people in heavily built up (such as landscape near coastal zones) or degraded landscapes are more vulnerable to the effects of climate change.

4.3.1 Smallholders

As mentioned in the introduction, the literature on climate change vulnerability and adaptation in Southern African SARs tends to focus on rural areas. In fact, the majority of southern Africa’s farmers are smallholders who engage in low-input farming, in addition to other livelihood activities (Eriksen *et al.* 2008). Thus, one of the prominent vulnerable groups, highlighted by the literature, is smallholder farmers. Smallholders farmers are also known as subsistence farmers, who self provision a livelihood strategy through agricultural produce (Morton, 2007). Usually, the land size of farms is often small and held under traditional or informal tenure. Farm lands may also be geographically marginalised and in risk-prone environments (Morton, 2007). This group is highly reliant on natural resources (e.g. land and water), which access, availability and quality is constantly upset by land management practices, human activities and development trends such as population growth rates (Kandjingaa *et al.* 2010; Zeidler *et al.* 2010; Barnes *et al.* 2012; David *et al.* 2013).

Smallholders rely on subsistence agriculture, have a limited access to natural resources (land, water) and limited economic asset (Namibia: Zeidler *et al.* 2010). These features make them extremely vulnerable to climate change impacts (see previous sections on non-climatic vulnerability stressors). For instance, the small size of field reduces opportunities to exploit diverse agricultural strategies, e.g. combine various types of crop on the land in North central Namibia (Newsham & Thomas 2009), a potentially critical adaptation option in the context of climate change. Furthermore, as mentioned previously, access to paid jobs, which provide a critical source of income, is limited in rural areas especially for unskilled workers like smallholders. Other employments' opportunities, like labour on commercial farms, are also challenged because of climate change impacts on agricultural production (Archer *et al.* 2008). Thus, smallholders' economic asset could be further reduced in the next decades, which could increase their dependency on natural resources that are challenged and reduced in quantity and quality by the effects of climate change, as well as unsustainable human activities (Zimbabwe: Dube *et al.* 2007).

Another stressor for vulnerability among smallholders is a lack of awareness and understanding of climate change and adaptation strategies (David *et al.* 2013). On this matter, a study from Muller & Shackleton (2014) in the semi-arid Eastern Cape in South Africa indicates that smallholders receive less information on, and have a limited understanding of, climate change compared to commercial farmers. It should be noted that the latter also possess more economic and physical assets to respond to fluctuation in rain patterns and other climatic features.

4.3.2 Women

In line with the focus on rural areas, the literature review indicates a differential vulnerability for women whose livelihood is based on subsistence agriculture. Thus, this group is a sub-category of the smallholder group, with specific vulnerabilities that are detailed here. A large number of households in rural semi-arid southern Africa are female-headed households e.g. in Kunene (40%) and Omusati Regions (55%) of Namibia (Republic of Namibia 2011 a&b). In Botswana, the Central Statistics Office (CSO) noted that the number of female-headed households is increasing (CSO 2011).

Table 2: Gender differentiated decision-making in climate change at local and household level (from Angula 2014)

Men	Women	Causes of vulnerability
• Decisions and interests regarding allocation of resources required for responding to climate change risks. • Decisions regarding severe risks posed by drought, floods, pest outbreaks and other related climate change disasters. • Men are making overall decisions at household level.	• Immediate decisions and interests regarding coping that would ensure food security. • Women are making decisions on a daily basis regarding household maintenance, food security and parenting.	• A lack of women's voice reduces a gender balanced decision-making process in community-based climate change adaptation programmes. • Unequal access to information and knowledge limit the potential of majority of women and marginalised men in the Namibian society to participate in local level decision making. • The majority of women are affected by social exclusion in Namibia. This has contributed significantly to inferiority complex and lack of motivation among Namibian women to take up leadership roles in their communities or households.

Angula and Menjono (2014) also concludes that the differentiated relationship of women and men to the environment indicate that women are impacted differently and their perceptions of the impacts are different. Climate risks impacts on livelihood, health and other social aspects mainly affect rural communal areas in Namibia (Republic of Namibia 2011). Table 3 below illustrates gender differentiated impacts and vulnerability to climate change in Namibia.

Table 3. Climate change impacts and gender dimension profile for Namibia (from Angula and Menjono 2014)

Climate change impacts	Gender differentiated impacts and vulnerability to climate change
Water Increased water shortages associated with low rainfall events or flooding associated with above normal rainfall.	• Women and girls travel long distances to fetch water. • Water scarcity limits development of small-scale projects. Majority of women and youth participate in local developmental projects. • Men migrate with livestock to areas less affected by climate change.
Agriculture Agricultural productivity decline (crop and livestock); pests outbreak destroying crops; disease and parasites affecting livestock.	• Women are the main subsistence producers of maize and wheat in Namibia. Productivity of maize and wheat production drops significantly during drought or flooding years in Namibia. • Crop and livestock production changes could affect the gendered division of labour. The changes also affect men and women's income from crop and livestock production. • Men migrate in search for better grazing opportunities or employment opportunities.
Environment and Forestry Loss of biodiversity, shift in dominant vegetation types from grassy to arid and semi-arid shrubland, changes in forest cover (coupled with deforestation)	• Shortage of fuelwood during floods affects cooking and heating in households - traditionally a woman's responsibility. • Women are expected to contribute unpaid labour to soil conservation and reforestation efforts.
Fisheries Access to inland fisheries resources compromised during floods in north-east Namibia; more fish resources in the cuvelai system during floods; closure of fishing industries due to environmental variability in the Benguela Current Large Marine Ecosystem; increased fish prices due to declining fish stocks.	• Opportunities for women to engage in subsistence fishing during floods. • Reduced fish species used by women for domestic consumption. • Majority of women losing jobs in fishing processing industry.
Health Increased water-borne diseases during floods; poor sanitation during floods; increased malaria cases due to increased temperatures; heat stress causing meningitis and other high temperature related illnesses.	• Increase in women's workload due to their role as primary care givers. • Increased vulnerability of maternal and infant deaths due to malaria and other water-borne diseases. • Stress levels and related diseases may increase for both women and men. Men in particular experience and express stress in different, more devastating ways than women due to expectations around providing for the family.

As a consequence of traditional customary law, discriminative labour division and a lack of equality in gender status and gender access to services and resources in Southern Africa, women constitute a marginalized group (Chikulo 2014). Traditionally, the majority of men play leadership roles in societies and hold decision-making positions both at national and local levels. Generally women in Namibia and Botswana are ascribed with lower positions in any given setting. The responsibilities of women are typically separate from men in smallholder households e.g. ensuring that household needs are met (e.g. food, energy and water) and as a result there are differential impacts from climate change (Angula and Menjono 2014). The men traditionally owns the land and tends the crops. The women help tending crops, but her tasks also include securing food, water and household energy, plus taking care of the children (Zimbabwe: Huisman 2005; Limpopo province in South Africa: Vincent *et al.* 2010; Namibia: Zeidler *et al.* 2010). In this context, women's vulnerability is related to the vulnerability of smallholders as they rely on natural resources, have a limited access to land and to income. However, they are also responsible for more tasks than man, a situation which increases pressures on them. The responsibility of women in obtaining resources such as water and firewood makes them vulnerable to the impacts of climate change. Climate change makes these tasks more difficult and time consuming as the availability of these resources is reduced. Women are additionally pressured when they are unable to provide food to the household.

Female-headed households are even more vulnerable. Due to discriminatory land entitlement laws that characterise many countries in Southern African SARs, female-headed households are often entitled to smaller fields or marginal plots compared to men, while their access to equipment such as tractors is reduced. For instance, in North central Namibia, widows are disposed of their valuable assets, such as cattle, claimed by their husband's family following his death (Newsham & Thomas 2011). Moreover, workload in the field increases without a husband to help (Capoco 2012; Caprivi, Karas and Hardap regions of Namibia: Dirkx *et al.* 2008), whereas women have more physical constraints than men, a limited access to agricultural equipment and are often left with few cattle (Zimbabwe: Huisman 2005; Botswana: Dougill *et al.* 2010; Northern Namibia: David *et al.* 2013). In Botswana although men and women have equal opportunity to apply for land, the inheritance of land is from father to son. In some areas in Zimbabwe, women are also excluded from attending meetings with extension officers, therefore receiving less training on agricultural practices (Huisman 2005).

Difficult access to loans for women (Zimbabwe: Huisman 2005), is another driver for vulnerability among this group. The fact that their property is often not registered under their name impairs women's capacity to provide sufficient proof for credit. Furthermore, fewer women than men find jobs outside of agriculture, as they usually have a lower level of education. As a result, women are essentially represented in the agricultural and informal sectors, which are more sensitive to climate variability and change; this is, for instance, the case in Zimbabwe (Huisman 2005). In regard with social networks, a study of Vincent *et al.* (2010) conducted in the Limpopo province indicates that, although women invest and gain more from reciprocity networks, they also have less financial capital, preventing them from being able to pay fees to farmers' groups for instance. Such groups are often critical to receive agricultural training as well as an easier access to input (e.g. fertilizer) and equipment (e.g. tractor), which are bought or rented using the membership fees.

Thus, women as smallholders are more reliant on natural resources than men, whereas their responsibilities to provide for the family are greater. In the context of climate change, female-headed households are especially vulnerable as agricultural output is challenged.

4.3.3 Marginalised groups

The San community in Omaheke and Otjozondjupa regions of Namibia constitute about 80 percent of the very poor households in these regions. Their traditional livelihood strategies such as hunting and gathering are not sustainble. San in Namibia today generally survive through pensions, food aid and casual work and piecework (Kiaka *et al.* 2012).

4.3.4 Other vulnerable groups

Other vulnerable groups include the youth and child-headed households, the elderly and the sick. The literature indicates a differential vulnerability for child-headed households. The number of child-headed household has increased in some semi-arid areas. Child-headed households are depicted as very vulnerable to climate change impacts due to their limited physical capacity to work (Amadhila *et al.* 2013).

Households comprising sick people are among the most vulnerable groups (Capoco *et al.* 2007). They tend to rely more on their direct environment for survival due to limited capacities to perform labours; thus, impacts of climate change in terms of depletion of natural resources will significantly impair their capacities to provide food and income, thus respond to their basic needs (DEA 2011). Diseases also contribute to enhanced poverty, unemployment and inequality and, therefore, further aggravate pressures on natural resources as the direct environment is critical for livelihood subsistence (Zeidler *et al.* 2010). In the rural areas, sickness affects farmers' labour capacities and abilities to respond to their family's need, sometime resulting in withdrawing children from schools to work in the fields (Kuvare *et al.* 2008).

Finally, it is worth to look into the specific vulnerability of the poor peri-urban inhabitants; with urbanisation growing at a fast pace in the South African SARs, this category of the population is likely to increase in size, and their livelihood conditions put under increasing pressures (e.g. poverty, lack of employment opportunities, lack of sanitation). However, the literature about this particular vulnerable group is not well furnished.

4.4 The key governance dimensions of climate change vulnerability

This section sheds light on the drivers for climate change vulnerability that are related to the institutional configurations and governance systems in Southern African SARs. To achieve a better understanding of why individuals and groups are vulnerable to climate change impacts, the local drivers for climate change vulnerability need to be analysed in light of the broader governance system and institutional configurations that shape and influence households' behaviours, activities, and accesses to economic and physical assets or information (Elrick-Barr *et al.* 2014). In line with this objective, this section reports on key policies and structures, across scales, that shape local livelihood conditions in SARs. These configurations, in return, influence vulnerability to climate risks on the ground. Uncovering global policies, institutional configurations and decision-making processes that affect people's access to resources, goods and information - including information about climate change – offers an increased understanding of the reasons why households are vulnerable, in general and, more specifically, are affected by the impacts of climate change (Tschakert *et al.* 2014). At the same time, an understanding of governance provides critical information to implement potential vulnerability reduction measures across Southern African SARs.

The section focuses on two key dimensions of the governance systems that affect people's vulnerability to climate change impacts in SARs: 1) the institutional configurations, especially the decentralisation process and the interaction between the national and local levels; and 2) the understanding of, and communication about, climate change across scales.

4.4.1 Institutional configurations

Research that investigates institutional development in SARs agrees on a lack of coordination and an implementation gap between the national and local levels in Southern Africa, especially seen in rural areas (Limpopo Basin, Botswana: Dube and Sekhwela (n.d.); Kalahari, Botswana: Twyman *et al.* 2004, Dougill *et al.* 2010; Omusati region of Namibia: Kandjingaa *et al.* 2010; South Africa: Koch *et al.* 2007). This implementation gap is reflected through a limited institutional outreach and support at the local level. As a result, individuals and family often face alone stresses such as poverty, natural disasters and the impacts of climate change.

In the rural context, there is often a lack of effective agricultural extension services and support for farmers: this is the case for instance in the Limpopo Province of South Africa (Moeletsi *et al.* 2013, Mpandeli & Maponya 2013, Ziervogel *et al.* 2006). Extension officers are not only critical for providing agricultural advice; they can also play a role in building adaptive capacity, thus contributing to reduce climate change vulnerability. For instance, in Omusati and Oshana regions of Namibia, support and training from local officers were deemed critical to help communities facing and recovering from the impacts of floods, which frequency and intensity is increasing. Yet, this support is missing in many places due to a lack of financial and human capacities at the local level (Amadhila *et al.* 2013).

Poor quality of infrastructure (e.g. roads) and weak service delivery in rural areas, observed for instance in semi-arid regions of North-Central Namibia (Newsham & Thomas 2011) and in the Limpopo river basin (Archer *et al.* 2008, Dougill *et al.* 2010, Oyekale 2012), is also a result of the limited human and financial capacities of local institutions (Omusati, Namibia: Kandjingaa *et al.* 2010, David *et al.* 2013; Namakwa District Municipality: Bourne *et al.* 2012; South Africa: Koch *et al.* 2007; Western Cape: Pasquini *et al.* 2013). In a context where local organisations do not have enough resources to implement rural development plans, climate change vulnerability can be exacerbated: isolated households are very sensitive to climate extremes such as floods because of limited support such as agricultural advice on seasonal onset and length (because of a limited number of extension officers), or emergency supply to recover from floods. These issues currently affect livelihood conditions in the Limpopo basin part of Botswana and South Africa (Dube & Sekhwela 2007); in Omusati region of Namibia (Kandjingaa *et al.* 2010); and in the Northern Cape, South Africa (Bourne *et al.* 2012), for instance.

Few resources allocated to local and decentralised entities by national authorities can explain why local authorities are unable to provide adequate development support on the ground. For instance, the South African Department of Agriculture does not allocate sufficient resources to local agricultural structures in the Limpopo Province and in the Western Cape, thus limiting the scope of extension officers' activities (Akpalu 2005, Archer *et al.* 2008 & 2009, Mpandeli & Maponya 2013, Moeletsi *et al.* 2013). In Namibia the government has tried to bring extension services closer to the farmers, but this is often challenging due to the fact that extension offices in many remote areas are situated far away from the nearest Agriculture Development Centre (ADC). It is reported that the capacity of both farmers and extension officials to travel extensively in the regions is limited by unreliability or unavailability of transport (Thomas 2012). According to Ministry of Agriculture, Water and Forestry (2003) the ratio of government Agricultural Extension Technicians (AETs) to farmers on average in northern central communal areas is estimated at 1: 1500 depending on the remoteness of the villages. This suggests that not all farmers are provided with extension services in northern central communal areas.

The lack of communication and coordination between the national and local scales in SARs is also a barrier to the implementation of relevant land management and natural resource conservation plans. Land degradation due to overgrazing, input-intense farming or overuse of the water resources, has been previously pointed out as a significant driver of households' climate change vulnerability (Botswana: Dougill *et al.* 2010). Thus, it is critical to develop and implement environmental protection laws and resource conservation policies to reduce current vulnerabilities, improve livelihood conditions among rural households, and limit the impacts of climate change on well-being.

Some countries like South Africa possess strong environmental laws that could contribute to better preserve the natural resources and the environment at the local scale (Bourne *et al.* 2012, Pasquini *et al.* 2013). Unfortunately, these regulations are not implemented sufficiently for a number of reasons related to the gap between the national and local scales in Southern African SARs. Among these reasons, the limited institutional capacities are a significant barrier to implement environmental regulations over a given territory: this is, for instance, the case in the Northern Cape, South Africa, where it seriously comprises the implementation of existing regulations and laws to protect the environment (Bourne *et al.* 2012).

Conflicts among regulations across scales can also seriously hinder the implementation of environmental conservation laws. For instance, in the Kalahari part of Botswana, a complex institutional framework surrounds environmental regulations (Dougill *et al.* 2010). Conflicts among national land regulation and local customary law are pointed out in the literature, and have resulted in tensions between state authorities and the local population that affect the implementation of national plans (Twyman *et al.* 2004). In fact, when issues such as land management and resource allocation, which shape livelihood conditions, are addressed by national governmental authorities in isolation, it is likely that there might be potential consequence such as a refusal from the local communities to respect national regulations, as was observed in the Kalahari in Botswana (Dougill *et al.* 2010).

It is important, in this context, to recognize the necessity, as well as the challenges, in connecting national regulations with local practices, a connection also advised by Dube and Sekhwela (2007) in the Limpopo river basin, for instance. Attempts to promote cross-scale policy integration have been observed for instance in South Africa, through the conception of the Integrated Development Plans (DEA 2011). Yet, many barriers for cross-scale collaboration are present and need to be overcome in order to develop and implement relevant environmental policies that contribute to reducing climate change vulnerability.

A lack of trust among the communities and the state representatives can impair the implementation of environmental laws. Mistrust can be the consequence of a lack of integration of the local practices into national development plans; it can influence local behaviours into not respecting laws and land management policies, imposed by distant authorities. This was observed in North-central Namibia, (Newsham & Thomas 2011) where rural development plans are conceived and applied regardless of existing land management practices or land unit frameworks. Yet, these frameworks are critical to understand the local decision-making process for agricultural activities. As a result, research indicates that extension officers are not aware of customary land management practices and, therefore, are unable to provide relevant support and advice to the communities (Newsham & Thomas 2011). Farmers, in return, are reluctant to respect land regulations that do not reflect their own management systems and values.

Rural development policies and programs developed and implemented by national governments can also have detrimental impacts on the natural resources. For instance, in many semi-arid regions of Southern Africa, governmental regulations have promoted the development of commercial and semi-commercial agriculture, which, in return, contributed to extreme land-use intensity; this was the case in the semi-arid northern Sandveld of South Africa (Archer *et al.* 2009). Moreover, land management plans which have resulted in land redistribution have initiated a shift from using communal lands to growing crops on smaller individual fields, for instance in grazing land of Botswana (Dube & Pickup, 2001). Shifts in the land distribution have affected population density on fertile soils, reduced the field size, and limited the opportunities for crop diversification and yield improvement, critical to face climate change impacts (Dube & Pickup 2001).

Local development plans can also foster the adoption of unsustainable practices at the local scale that contribute to the depletion of natural resources. For instance, in Northern Namibia, water pipelines were built to facilitate irrigated agriculture in the dryland. An unexpected side effect was that the presence of water sources encouraged many farmers to bring their cattle along the pipelines; overgrazing is now being observed in the region, which affects the quality of the land (Klintenberga *et al.* 2007). This example indicates the importance of conducting environmental impact studies while conceiving rural development plans to take into account all potential side effects. Furthermore, communication with the local actors is critical to ensure that detrimental behaviours for the environment do not appear.

4.4.2 Knowledge and sharing of information on climate change

Finally, it is important to assess how climate change issues are understood and shared, and then, translated into concrete policies, across scales and across sectors in the South African SARs. An effective mainstreaming of an understanding of climate change impacts into national to local policies on key vulnerable sectors (e.g. agriculture) is critical to reduce climate change vulnerability on the ground.

At the national level climate change is considered as a national and an international concern in countries such as South Africa (Koch *et al.* 2007, Pasquini *et al.* 2013, Ziervogel *et* *al.* 2014) where the matter is essentially in the hands of the Department of Environment. Often there is lack of urgency as climate change tends to be perceived as a future environmental threat and not related to current socio-economic concerns (Zeidler *et al.* 2010, Pasquini *et al.* 2013, Ziervogel and Parnell 2014). Consequently, there is little mainstreaming of climate change-related risks across sectors and across scales (e.g. in rural programs and local agricultural policy).

In South Africa, a case study conducted by Pasquini *et al.* 2013 in the Western Cape suggests a possible lack of interest in climate change from policy-makers and stakeholders. There tends to be a lack of clarity regarding which authority is responsible for developing and implementing climate change adaptation strategies on the ground because there isn't a clear governmental body appointed for this task: this was noted in the Namakwa District, Northern Cape (Bourne *et al.* 2012) and in a number of South African cities (Ziervogel & Parnell 2014). Overall, there seem to be a lack of understanding of climate change issues at the national level, limited dissemination of relevant information across scales and, thus, a reduced knowledge of these issues among the local authorities in Southern African SARs (Koch *et al.* 2007, Pasquini *et al.* 2013).

A lack of locally-relevant data on climate change impacts, noted in the regions of Caprivi, Karas, and Hardap in Namibia for instance, would also impair a comprehensive understanding of climate change impacts on key sectors, and the mainstreaming of these potential or current risks into relevant policies (Dirkx *et al.* 2008, David *et al.* 2013).

Yet, the main issue is a critical communication gap between local communities, stakeholders, and scientists, which is a concern given information is a key part of vulnerability reduction intervention. For instance, in the Limpopo province of South Africa (Mpandeli & Maponya 2013), information on climate change does not reach local communities. Limited access to climate and weather-related information is also observed in Omusati region of Namibia (Kandjingaa *et al.* 2010); and in Etosha Basin (Zeidler *et al.* 2010) due to underdeveloped communication infrastructures and dissemination networks (Capoco 2012).

Limited communication on climate change is reflected in the lack of awareness and understanding of this topics at the local scale, especially observed among smallholders, whereas local extension officers are unable to provide support on adaptation strategies, for instance in the Limpopo Province of South Africa (Mpandeli & Maponya 2013, David *et al.* 2013). This communication gaps across scales seriously hinders the enhancement of adaptive capacities at the local level, thus is a stressor for climate change vulnerability.

CHAPTER 5

The Adaptation Development Spectrum

The Adaptation-Development Spectrum

5.1 Introduction

As already mentioned, communities in semi-arid areas are particularly vulnerable to the impacts of climate change. Many adaptation options exist to build the resilience of these communities to the impacts of climate change. However, these are not widely implemented. This section reviews the state of knowledge on existing and planned coping and adaptation mechanisms to reduce the vulnerability of communities to climate change in semi-arid areas in southern Africa. In so doing the following issues are explored: what adaptation measures have been implemented and are planned, how effective have these measures been in reducing vulnerability of communities to climate impacts, the governance dimensions of adaptation, the institutions within which adaptation is implemented and the barriers and enablers to adaptation in semi-arid areas in southern Africa.

As we report on coping as well as adaptation measures our first distinction here is between these two types of measures (see Table 4).

Table 4. Characteristics of coping and adaptation (Vincent *et al.* 2013, Eriksen *et al.* 2005; Brown 2011, weADAPT 2011[2], Smit *et al.* 1999, Gilbert and Vellinga 1990)

COPING STRATEGIES	ADAPTATION STRATEGIES
Short-term and immediate	Long-term Practices and results are sustained Strategic
Oriented towards survival	Oriented towards longer-term livelihood security
Not continuous	A continuous process
Motivated by crisis; reactive	Involves planning
Often degrades the resource base	Uses resources efficiently and sustainably
Prompted by lack of alternative	Focused on finding alternatives
	Combines old and new strategies and knowledge

Coping measures are short-term mechanisms (e.g. over one season) to ensure survival but are not adaptive in that communities will be sensitive to exposure to the same climate event in the future (see Vincent *et al.* 2013, Eriksen *et al.* 2005). Generally, coping tends to occur when communities are not resilient enough to prevent the damage and losses that result from climate change. Coping strategies tend to be reactive and often result in trade-offs regarding the use of resources that can compromise the ability to deal with future shocks. Whereas adaptation measures prepare for both experienced and expected climate change to secure livelihoods in the long term e.g. over a decade or more. They tend to be proactive, are often opportunistic and involve longer-term shifts in behaviour and practices which will reduce underlying vulnerability (Vincent *et al.* 2013). Some adaptation activities, e.g.

[2] Weadapt adaptation versus coping

diversification of livelihoods, have development benefits in the absence of climate change (Mc Graygh *et al.* 2007).

5.2 Coping with a changing climate in the SARs

5.2.1 Selling livestock

One of the most common strategies of farmers for coping with drought in semi-arid areas is selling livestock (South Africa: Thomas *et al.* 2007; western South Africa: Archer *et al.* 2008; North Central Namibia: Newsham & Thomas 2011; proposed for Namibia (Nhuleipo *et al.* 2011). However, this practice is not readily applied across the board. In north central Namibia there is often resistance to sell livestock in part due to the cultural importance of owning livestock (*pers. comm.* respondent from Outapi Town Council, February 2015; *pers. comm.* respondent from Traditional Authority at Uukolonkadhi, February 2015). Resistance to sell livestock is also due to low price of animals particularly among the communal animal keepers who sell their livestock at an old age. Apart from this, the costs necessary to transfer cattle to auction areas can be an additional constraint. As such there have been initiatives in Namibia to encourage the sale of livestock through the provision of compensation by government. On the other hand, in Botswana there are issues of Foot and Mouth disease that limit the movement and sale of animals and in cases where compensation is paid the amounts are not sufficient.

5.2.2 Supplemental feeding and watering or accessing alternative water and land resources

Another coping mechanism is supplemental feeding including the use of ground maize stalks or cut fodder/wild plants (proposed for Omusati region, Namibia: Kandjinga *et al.*, 2010; western South Africa: Archer *et al.* 2008; Limpopo river basin: Gbetibouo 2009; South Africa: Thomas *et al.* 2007). In Botswana, during times of emergency, farmers receive fodder for animals at a subsidized price from the government. Similarly people are advised to: grow grasses "lablab" for fodder; use stock feed and molasses for their cattle; and use chicken waste mixed with grass and salt as feed during harsh dry season (Botswana: *pers. comm.* Headman Bobirwa subdistrict, January 2015). Similarly, water provision is applied during the dry season (western South Africa: Archer *et al.* 2008). Alternatively, temporary relocation is practiced. In South Africa for example, farmers take livestock to the river or another village, to gain access to land beyond village or access alternative water resources (Thomas *et al.* 2007). Although ground maize stalks could provide supplemental feeding for animals, the challenge of providing supplementary feeding depends on the extent to which crop bi-products such as maize stalks are used for mulching as part of conservation agriculture (Namibia: *pers. comm.* respondent from Ministry of Agriculture, Water and Forestry (MAWF), Directorate of Engineering and Extension Services (DEES), March 2015).

5.2.3 Use of networks for assistance

Networks of friends and family are also relied on to cope with droughts semi-arid areas. Two types of social networks were identified. Informal networks of dependence developed to facilitate daily activities and support (e.g. kinship relations and close neighbours), and external networks that generate new networks and opportunities for assistance. In

Okashana region Namibia for example, informal networks are used to facilitate support such as sharing food with neighbours (Newsham & Thomas 2011). In South Africa, informal groups are used by individuals to buy seeds in bulk (Reid & Vogel 2006; Thomas *et al.* 2007). Similarly, remittances from members living in urban areas is an important coping strategy in southern Africa (Namibia: Eriksen *et al.* 2008; Oshana and Erongo, Namibia: Angula 2010; Kalahari, Botswana: Twyman *et al.* 2004).

5.3 Adaptation in semi-arid areas in southern Africa

Adaptation to climate change continues to rise on the agenda of researchers, practitioners and decision makers driven by growing evidence that climate change threatens to undermine development (IPCC 2014a, Mc Gray *et al.* 2007). The working definition of adaptation that is being used in the ASSAR project reflects the IPCC definition: initiatives, measures and processes undertaken in response to actual and anticipated impacts of climate variability and change and/or interacting non-climatic changes (IPCC 2014a). Such actions targeted at vulnerable systems are intended to exploit opportunities and reduce impacts from climate change (McCarthy *et al.* 2001, United Nations International Strategy for Disaster Reduction - UNISDR 2009, Biagini *et al.* 2014).

Adaptation actions have been categorised in many different ways. For example: i) as structural (e.g. engineering, technology, ecosystem-based, services), social (e.g. education, information, behaviour) or institutional (economic, laws & regulations, government policies and programs) activities (IPCC 2014a); ii) enabling (capacity building, policy reform, planning and management) or technical activities (information & communication technology, early warning systems and improved infrastructure) (Biagini *et al.* 2014); and iii) addressing social vulnerability, enhancing system resilience, targeting a specific climate risk (McGray *et al.* 2007; Eakin *et al.* 2009). The characteristics of adaptation actions that have been reported as being important include timing (anticipatory, concurrent, reactive) (Smit & Pilifosova 2003, Smit & Wandel 2006), intent (autonomous, planned) (Smit & Pilifosova 2003), spatial scope (local, regional, national), form (technological, behaviour, financial, institutional) and degree of necessary change (incremental, transformational) (Smit *et al.* 1999), unit of study (individual, household, community), study system or sector (biological, economic, social) (Smit & Wandel 2006), driver of action (extreme event, climate variability, climate change) and temporal scale e.g. short or long term (Smit *et al.* 2000; Cutter *et al.* 2008).

Many of the adaption measures are not new. Communities in southern Africa have been coping with climate variation by implementing measures based on traditional knowledge accumulated through past experience (O'Farrell *et al.* 2009; Khandlhela and May 2006). However, climate change poses new risks and uncertainties for communities and past experience alone can no longer provide a reliable guide to dealing with future conditions (Armitage and Plummer 2010). This realisation has led to the need to implement adaptation approaches that are suited to present conditions and will be beneficial in the face of future conditions.

5.3.1 Changing planting and harvesting times

In response to changes in rainfall patterns farmers in semi-arid areas in southern Africa adjust the timing of agricultural activities such as the planting and harvesting of crops. This can include delaying the start of the planting season or starting land preparation early to be ready for early rains (Caprivi, Karas & Hardap in Namibia: Dirkx *et al.* 2008; Oyekale in Limpopo River Basin, South Africa: Bryan *et al.* 2009; South Africa: Benhin 2006; Mozambique: Milgroom & Giller 2013). Because all other activities depend on planting dates, farmers also moved the dates of other activities such as harvesting and ground preparation, see South Africa: Benhin 2006; western South Africa: Archer *et al.* 2008; north central Namibia Gremlowski 2010). Another strategy that is employed is ploughing and planting multiple times within a season after rainfall events (north central Namibia: Gremlowski 2010; Mozambique: Milgroom & Giller 2013; Bobirwa Sub-District, Botswana: personal communication with the Headman of Arbitration Kololo Ward, January 2015). How effective these approaches are will depend on the extent to which climate change information is communicated to the end users (e.g. farmers). Language barriers (e.g. use of English vs local language) and the use of technical words which are not clear to express variability in climate (e.g. above or below normal rainfall) was identified to have a critical impacts on effective use of of climate change information for adaptation e.g. changing planting season (Meteorology Services, Namibia, March 2015). Similarly, timing in the delivery of weather forecasting as well as access to update information was identified to be critical factors affecting decision making to farmers. This was linked with the erratic patterns of rainfall prediction and associated changes that happens before the information is updated.

5.3.2 Soil and water conservation activities

Soil and water conservation activities such as tree planting (Limpopo river basin, South Africa Bryan *et al.* 2009), laying stone bunds to combat soil erosion (Thomas *et al.* 2007), removal of alien vegetation, wind erosion prevention and in situ conservation to promote biodiversity are employed in semi-arid areas in southern Africa (South Africa: Archer *et al.* 2008). Conservation agriculture practices that are being used include crop rotation and intercropping, conservation tillage and the maintenance of soil fertility through the application of manure (South Africa: Benhin 2006, Archer *et al.* 2008; Namibia: MET 2011a, David *et al.* 2013).

Similarly water conservation activities (Archer *et al.* 2008, O'Farrell *et al.* 2009) such as rainwater harvesting (northern regions, Namibia: Kuvare *et al.* 2008, David *et al.* 2013; Kalahari, Botswana: Twyman *et al.* 2004; South Africa: Benhin 2006), in-field rainwater harvesting (South Africa: Benhin 2006) using furrows (Zimbabwe: Unganai & Murwira 2010) and zai pits (Mozambique: Ncube *et al.* 2008), shared water resource management (Namibia: Kuvare *et al.* 2008), and drip irrigation (South Africa: Benhin 2006; Limpopo River Basin, South Africa: Bryan *et al.* 2009; Namibia: Country Pilot Partnership 2011) are undertaken to make effective use of the available water. The construction of earth dams has been suggested for Omusati (Kandjinga *et al.* 2010) and Oshana and Ohangwena (Kaundjua *et al.* 2012) regions. The positive response in reducing the vulnerability of farmers has been observed in dry-lands crop farming e.g. conservation agriculture, improved seeds and drip irrigation system in boosting yield in dryland production (Namibia: Country Pilot Partnership, Namibia 2011). The report by UNCCD - Namibia (2010) indicates the potentiality of a ripper furrower to increase agricultural productivity of Mahangu fields: the use of furrow was estimated to brought average yields up to six times the national average from 300kg/h to 2000kg/ha versus.

Beyond these approaches there is recognition that policy reform is required (Namibia: Turpie *et al.* 2010). Similarly insufficient access to resources (e.g. funds to buy petrol to run the tractors or pay labourers to prepare the land) limits both the effectiveness and implementation of these approaches (South Africa: Archer *et al.* 2008). Effective use of these approaches depends on the type of information and the timing in the delivery of the information/engagement. For example, the use of ripper ploughing was identified to be effective if the field is prepared in September before the rain come to keep water, but should not be as late as January (*pers. comm.* respondent from the Traditional Authority at Uukolonkadhi, Namibia, February 2015).

5.3.3 Diversification of livelihoods

Livelihood diversification is an important mode of poverty reduction (Ellis 2000). It provides an opportunity to earn additional income and compensate for income losses from crop failures (Angula 2010). In semi arid southern Africa livelihoods are diversified as a way to cope with poor soil quality and uncertain rainfall regimes (see Wilhelm 2012). Livelihood diversification in the SARs in southern Africa includes wildlife and game farming (Tjiramba & Odendaal 2005, Barnes *et al.* 2012, Nhuleipo *et al.* 2011, IECN 2011) basketry, forest products, vegetable production, ecotourism initiatives, food or cash for work, and marula nut processing in Namibia (Dirkx., *et al.* 2008; Newsham & Thomas 2009; Newsham & Thomas 2011; Angula 2010; Turpie *et al.* 2010; Wilhelm 2012), ecotourism, collection of indigenous plants and seeds, engagement in business, finding work, selling livestock and vegetables and shifting from crop cultivation to livestock keeping in South Africa (Archer *et al.* 2008; Benhin 2006; Reid & Vogel 2006; O'Farrell *et al.* 2009), harvesting mopane worms, morula fruits, money from commercial hunting and photographic safaris and basketry in Botswana. Establishment of Conservancies and other tourist-related activities in Namibia was identified to play an important role in creating employment opportunities, enhance levels of awareness and positive attitudes towards conservation as well as reduce poaching activities and promote the number of wildlife animals (Namibian Association of CBNRM Support Organisation n.d). Similarly, rangeland management was identified to reduce emissions from the livestock sector as they improve animal nutrition (Schneider 2010).

Although livelihood diversification is most likely a necessity for adapting to climate change, it is challenging in SARs. There are limited existing opportunities and the livelihood diversification options used depend on natural resources which are impacted by the effects of climate change for example material for making baskets has become more difficult to find in Botswana.

5.3.4 Diversification of crops and livestock including the use of new varieties and breeds

The diversification of crops and livestock is an adaptation approach that is being used in SARs of southern Africa (Namibia: Kuvare *et al.* 2008, David *et al.* 2013; Botswana: Twyman *et al.* 2004; Limpopo, South Africa: Bryan *et al.* 2009, Gbetibuou 2009, Moeletsi *et al.* 2013; Mpandeli & Maponya 2013). In particular, drought resistant crop varieties and livestock breeds are adopted (Namibia: Kuvare *et al.* 2008, Dirkx *et al.* 2008, Shigwedha 2012; South Africa: Benhin 2006; Botswana: Totolo *et al.* 2004) and proposed (Namibia: Kandjinga *et al.*, 2010; Turpie *et al.* 2010; Zeidler *et al.* 2010; Botswana: Twyman *et al.* 2004). Crop varieties that are introduced include early maturing crop varieties (Namibia: Kandjinga *et al.* 2010, MET 2011, Newsham & Thomas 2011; South Africa: Benhin 2006).

Crop diversification reduces climate risk and increases adaptive capacity in a number of ways. For example, unlike the traditional crop varieties which needs more rain and longtime to grow, the improved varieties such as the Okashana mahangu (millet) mature faster and can be ready for harvest in only three months (Shigwedha 2012). Similarly it produces bigger grains than that of the traditional one contributing to better results in terms of harvest. However, effective crop diversification is constrained by the high costs of implementing diversification such as high price of drought-resistant crops and lack of transport to buy seeds and poor communication between extension officers and the farmer (South Africa: Masters & Duff 2011). In Northern Namibia, farmers awareness and perceptions on the improved crop varieties is likely to affect decision making: for example, investment in improved Mahangu varieties which is too shorter compared to the local 'Oshivambo' Mahangu is perceived to be risky when the fields are flooded (*pers. comm.* respondent from Onesi Constituency Office, February 2015; *pers. comm.* respondent from Traditional Authority at Uukolonkadhi, February 2015).

5.3.5 Grain and fodder storage

Grain storage is another adaptation option adopted in southern Africa. In north central Namibia grain is stored in eshisa (traditional grain storage baskets) to compensate for poor harvest (IECN 2008, Newsham & Thomas 2009). Being able to store grain is dependant on having surplus and planning sufficiently. Fodder for livestock is also stored for future use.

5.3.6 Early warning and seasonal climate forecasting

Early warning systems are being used in some places in southern africa (Namibia: Davis 2012, Kuvare *et al.* 2008, Chishwakwe 2010; South Africa: DEA 2011). Early warning systems allow for preparation for upcoming climatic events and some of these early warning systems include advice for farmers. For example forecasts are useful to determine crop varieties to be planted and improve day to day decisions e.g avoid the use of costly inputs when there is little chance of success (Moeletsi *et al.* 2013). However, unreliability of weather forecasts and lack of simple language to communicate climate information e.g. words to express variability and changes in rainfall constrain effective use of modern information and few people continue to use traditional precipitation indicators to make informed decisions on farm management like clearing farms (Botswana: Mogotsi *et al.* 2011b, Simelton 2013). Similarly, timing in the delivery of forecast information (South Africa: Masters & Duff 2011) and weak capacity to deliver short-term alerts and long-term warnings (Namibia: Giorgis 2011, Mufita 2012, *pers. comm.* respondent from Meteorological Services Agency Office, March 2015) was identified to be the key issue affecting effective use of climate information for adaptation.

In the absence of formal early warning systems farmers have traditional approaches to weather forecasting including observing birds, insects, plants, clouds and stars (South Africa: Mpandeli & Maponya 2013, Moeletsi *et al.* 2013; Botswana: personal communication Bobirwa chiefs 2015). However, in the face of climate change with weather patterns being experienced that haven't been experienced before traditional forecasting methods are not as reliable as in the past.

Mpandeli & Maponya (2013b) identified the need to develop strategies to integrate local knowledge in climate change adaptation through research to test local indicators (behaviour of birds, winds, cloud formation) to validate its use in forecasting. As mentioned above effective application of weather forecasting at the local level depends on factors such as amount of details provided to the end users and the terminology used as well as accuracy and timely delivery of the expected changes in weather conditions (Namibia: *pers. comm.* respondent from Outamanzi Constituency Office, February 2015, *pers. comm.* respondent from Namibia Meteorological Services, March 2015).

5.3.7 Moving livestock

In semi-arid areas in Southern Africa rangelands are often degraded and grazing becomes further limited during dry periods. During these times pastoralists often move their livestock to alternative grazing areas, also known as "cattle posts", where there are more grazing resources available (north central Namibia: Klintenberg *et al.* 2007, Eriksen *et al.* 2008, IECN 2008, Newsham & Thomas 2009; Kalahari, Botswana: Mogotsi *et al.* 2011b; and South Africa: Archer *et al.* 2008, O'Farrell *et al.* 2009).

5.4 Governance of adaptation in SARs of southern Africa

Southern Africa like any other developing region face difficulties in integrating climate change into national policy due to lack of resources and institutional capacities (United Nations Framework Convention on Climate Change - UNFCCC 2005). At the national scale the implementation of adaptation is further confounded by the sectoral nature of governance. The lack of integration and coordination between the policies, plans and implementation of different ministries leads to the implementation of maladaptive or conflicting measures. In addition, there is a disconnect between national and local government in SARs in southern Africa (Twyman *et al.* 2004, Koch *et al.* 2007, Dougill *et al.* 2010, Kandjingaa *et al.* 2010). The implementation of national policies, plans and thereby adaptation interventions is thereby limited by a lack of information, limited technical capacity and financial resources at the level of local government in semi-arid areas in southern Africa (Namibia: Amadhila *et al.* 2013; South Africa: Akpalu 2005, Archer *et al.* 2008 & 2009, Mpandeli & Maponya 2013, Moeletsi *et al.* 2013). This is manifested by a lack of extension services (Moeletsi *et al.* 2013, Mpandeli & Maponya 2013, Ziervogel *et al.* 2006). While traditional knowledge can be used at a local level to implement adaptation measures, synergy with government and other local interventions is crucial for effective adaptation (UNFCCC 2005).

The governments of Botswana, Namibia and South Africa are all party to both the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol. As such, these countries are committed to these international agreements and have submitted their First and Second National Communications and are now working on their Third National Communications. National Adaptation Programmes of Action have not been produced for these countries.

5.5 Institutional structures and policies for climate change adaptation in Namibia

As a signatory to the United Nations Framework Convention on Climate Change (UNFCCC), the government of Namibia has developed its Initial and Second National Communications on climate change (Chishwakwe 2010). Namibia's Second National Communication (SNC) commits the country to secure appropriate long-term sustainable resources for adaptation (MET 2011b). Specific adaptation priorities have been highlighted for sectoral planning such as water (e.g. improve integrated water resources management); agriculture (e.g. water harvesting, conservation agriculture); and disaster risk reduction (strengthen capacity to deal with climate extremes e.g. floods).

The Constitution of the republic of Namibia lays the foundation for all policies and legislation in the country including those that guide Namibia's climate changes response (MET 2011a). However, policies in Namibia, like elsewhere in Southern Africa, operate in isolation and are not necessarily complementary or consistently working towards the same outcome (*pers. comm.* Academic, University of Namibia November 2014). In addition to this there is limited awareness of existing policies (*pers. comm.* Academic University of Namibia). Namibia's Vision 2030 (Republic of Namibia, 2004) provides long-term alternative policy scenarios on the future course of development in the country e.g. improving access to clean water. The successful implementation of appropriate adaptation measures will contribute to the realisation of Vision 2030 goals. In particular, it is anticipated that adaptation measures will alleviate the effects of climate change that would otherwise hinder poverty reduction and improved standards of living.

Namibia's National Development Plans (http://www.npc.gov.na/) acknowledge that the country is threatened by fluctuating climatic and weather events and that limited water resources are the most important constraint to economic development. On the other hand, the National Policy for Disaster Risk Management (NPDDM) recognises that disasters lead to destruction of infrastructures, loss of human life and livelihoods of the poor people. It also recognises that climate change is likely to increase vulnerability to these disasters. The policy therefore aims to contribute to Vision 2030 by strengthening national capacity to reduce risk and build community capacity to climate change by facilitating partnership between state and private actors in disaster risk reduction. The Disaster Risk Management Act was enacted in 2012 to establish institutions for disaster risk management and enable integration and coordination of disaster risk management (Government of the Republic of Namibia 2012). The Directorate of Disaster Risk Management coordinates risk management efforts and conducts annual vulnerability assessments to understand how communities are impacted by disasters and how they cope.

In addition to this, Namibia's National Climate Change Policy (NCCP) provides a legal framework and overarching national strategy for the development, implementation and monitoring of climate change adaptation activities. It also includes sectoral and cross-cutting adaptation strategies for food security, water management, and disaster risk reduction. Recognising the cross-cutting nature of climate change, one of the main objectives of the NCCP is to mainstream climate change into sectoral policies as well as institutional and development frameworks. However, the NCCP is not a law and does not provide regulations.

The Cabinet of Namibia is the Government agency with overall responsibility regarding climate change policy (MET 2011b). The Cabinet is advised by the Parliamentary Standing Committee on Natural Resources and Economics on relevant policy matters. This committee also represents Parliament at international events on natural resource management (MET 2011b).

The Ministry of Environment and Tourism (MET) is the designated governing body accountable for all environmental issues in the country and was nominated as the lead ministry for coordinating climate change adaptation activities in Namibia through the Climate Change Unit (CCU) established within the Directorate of Environmental Affairs (DEA) in MET. The Climate Change Unit assists directly with planning, development, implementation and coordination of climate change activities at the local, regional and national levels (MET 2011b). MET has been responsible for overseeing the coordination of climate change issues in Namibia, and thus the development and submission of National Communications. The national Climate Analysis Unit (CAU) at the Meteorological Services Division of the Ministry of Works and Transport (MWT) supports the CCU, MET, and line ministries by conducting climatic monitoring, research, assessment and providing relevant information. The CCU is also supported by the multi-sectoral National Climate Change Committee – NCCC for sector-specific and cross-sector implementation and coordination. The NCCC was established in 2001 to oversee and coordinate climate change activities at the national scale and to advise the government on climate change related issues such as obligations to the UNFCCC and the adoption of policies and strategies (Chishwakwe 2010). It is chaired by DEA with membership from the Disaster Management Unit (DMU) in the Office of the Prime Minister, other Sector Ministries, international organisations e.g. United Nations Development Program (UNDP), Red Cross, EU, embassies, higher learning institutions e.g. Polytechnic of Namibia and University of Namibia, and non-governmental organizations (NGOs) such as the Desert Research Foundation of Namibia (DRFN) (MET 2011b).

There are also a number of civil society organisations, non-government organisations, community based organisations, local government and research institutions engaged in climate change related activities. For example adaptation interventions are implemented by various organisations including UNDP in semi-arid Namibia and the Contact Group on Climate Change (CGCC) conducts public awareness, public debate, and focuses on local and thematic issues.

5.6 Institutional structures and policies for climate change adaptation in South Africa

The government of South Africa has taken substantial effort to work towards implementing the UNFCCC, and to ensuring that climate change policies are informed by sound scientific evidence and a participatory process (DEA 2011). The South African National Climate Change Response Policy (NCCRP), GHG mitigation and climate change adaptation activities are top three on the president's priority list to the Cabinet, the Department of Environmental Affairs (DEA) is the lead department for directing and coordinating the national climate change response programme and hosts the NCCC and the IGCCC (DEA 2011). As a supportive function to the DEA, the Department of Minerals and Energy (DME) established a Renewable

Energy Finance and Subsidy Office to advise on and subsidise the development of renewable energy programmes, and eliminate the barriers to renewable energy development. Similarly the South African Environmental Observation Network, the Agriculture Research Council (ARC), Council for Geo-sciences (CGS), Council for Scientific and Industrial Research (CSIR), and the South African Institute of Aquatic Biodiversity (SAIAB) all support the DEA by continuing to provide innovative information management and comprehensive scientific research to inform policy-making (DEA 2011). The Department of Science and Technology also provides leadership on global change and energy science and technology innovation, while the South African National Biodiversity Institute (SANBI) and South African National Parks (SANParks) are responsible for coordinating measures that respond to science and technology, and for developing and revising biodiversity and habitat management plans such as the National Biodiversity Strategy and Action Plan.

South Africa's multi-stakeholder National Committee on Climate Change (NCCC) which is responsible for climate change policy development. The committee is chaired by the Department of Environmental Affairs (DEA) and has representation from seven other government departments as well as from provincial government representatives, research institutes, private sector, labour and NGOs. The committee is tasked with advising and consulting with the Ministry of Environmental Affairs and Tourism on matters of the government's national obligation to climate change as part of their commitments as signatories of the UNFCCC and the Kyoto Protocol (Richards 2008).

To facilitate co-operative governance in climate change, the Intergovernmental Committee on Climate Change (IGCCC) was established in 2008 and involves ten government departments. The committee: i) fosters the exchange of information, consultation and agreement among the spheres of government in climate change related issues; ii) informs South Africa's international position on climate change; iii) facilitates and coordinates the development of national climate change policies, strategies and actions plans; and iv) conducts information management.

To facilitate sectoral planning and implementation, the government developed a National Climate Response Strategy in 2011. The policy was formed as a result of the national climate change conference held in Johannesburg 2005 known as "Climate Action Now!" Participants agreed that South Africa must accelerate its national response as well as reinforce efforts towards climate change. The Cabinet approved a climate change policy development process in 2008 and the National Climate Change Response White Paper was released in 2011 (Lotz-Sisitka & Urquhart (2014). The strategy aims to address priority issues for dealing with adaptation to climate change including managing climate change impacts and integrating climate change responses in government.

In line with South Africa's climate change strategy many adaptation options in agriculture sector that relate to climate have been identified (DEA 2011) and a number of programmes have been implemented. These include the: i) Risk and Vulnerability Atlas programme which compiles vulnerability and adaptation information; ii) Climate Change and Agricultural Risk Management programme, which includes a focus on climate-resilient crop varieties, conservation agriculture practices e.g. multi-cropping and early warning systems; and iii) Climate Change and Water Programme which focuses on water conservation including rainwater harvesting (Chishwakwe 2010). The government of South Africa has also introduced a number of initiatives that make significant contributions to education and awareness-raising around issues related to climate change. These include a science plan and institutional architecture for responding to climate change.

5.7 Policies and institutional structures for climate change Adaptation in Botswana

Although Botswana is a constitutional democracy, the Constitution of Botswana contains no provision for dealing with environmental rights and duties for its protection. Likewise, until recently there was no policy that existed in Botswana that directly tackled climate change adaptation and mitigation (Omari 2010). However, Botswana has since recognised that environmental policy planning for climate change concerns underpins long-term sustainable growth in the country, and should therefore be a priority (Omari 2010). Botswana recently initiated the process to develop a national Climate Change Strategy and Action (CCSA) plan in 2013 (Urguhart & Lotz-Sisitka 2014), in conjunction with the National Management Policy of Disasters (1994), which provides a cross-cutting national policy framework for climate change adaptation. There are other related policies that indirectly support CCSA e.g. the National Conservation Strategy (1987). In line with commitments to the UNFCCC the Department of Meteorological Services (DMS) under the Ministry of Wildlife and Tourism formed an advisory board to the Climate Change Secretariats, known as the National Climate Change Committee - NCCC (MET 2001). These were some of the institutions governing climate change mitigation prior to introducing the cooperative focus on climate change adaptation. This shift in focus resulted not only in strengthening climate change legislation in the country, but also was a means of unifying existing but fragmented sector specific policies on climate change adaptation under an overarching national policy (MET 2001).

The National Policy on Natural Resources Conservation and Development (1990) was also one of the first steps Botswana took to ensuring that development occurs in an environmentally sustainable manner. Coupled to this was the National Biodiversity Strategy and Action Plan (2004), and the National Water Master Plan (1993); which was reviewed in 2006-2007, yielding the recommendation of the national rainwater policy to manage rainwater harvesting as a key strategy for climate change adaptation (Omari 2010). The National Strategy for Poverty Reduction (2003) and the Revised National Policy for Rural Development (2002), as well as the Strategy for Economic Diversification and Sustainable Growth (2008), and various National Development Plans including the current NDP-9 (2009-2015), are also useful policies directed at supporting the CCSA.

Botswana has established a Select Committee on Climate Change to oversee the development of associated policies. The structures that are important for implementing climate change and related policies at sub-national levels are the nine District Councils and five Town Councils, headed by District Commissioners and Council Secretariats. Within government, the DMS is the Designated National Authority which serves as the Secretariat of the National Committee on Climate Change (NCCC). The NCCC has representation from government ministries, parastatals and NGOs. The government departments represented on the NCCC are: Department of Mines, Energy Affairs Division, Department of Water Affairs, Attorney General's Chambers, Department of Agricultural Research, Crop Production and Forestry, Ministry of Agriculture, Ministry of Trade and Industry, and the Ministry of Finance and Development Planning. NGOs on the committee include the Forum on Sustainable Agriculture and the International Union for the Conservation of Nature and Natural Resources (IUCN). There are also quasi-government organisations involved in climate change activities such as Water Utilities Corporation; the Rural Industries Promotions Company (involved in solar energy and water harvesting); the Botswana Power Corporation (responsible for electrification), Botswana Development Corporation (country's main agency for industrial development); and educational institutions such as the Botswana Accountancy College and the University of Botswana, which are responsible for research in environmental, climate, water, wetlands, biological, energy and climate finance issues.

Although not climate change initiatives specifically there are government programmes worth considering that are relevant when considering vulnerability and adaptation to climate change. Two such programmes in Botswana are ISPAAD (Integrated Support Programme for Arable Agricultural Development) and Ipelegeng. ISPAAD was introduced in 2008 to improve agricultural extension, facilitate access to farm inputs and credit, increase grain production and improve food security. Support provided includes seeds, fertilizer, fencing, potable water, herbicides to control weeds, plough planting and access to credit. The Ipelegeng programme provides relief (e.g. food) and short term employment carrying out development projects such as maintenance of school and health facilities.

5.8 Drivers of adaptation

A number of adaptation interventions are being implemented in semi-arid areas of Southern Africa. These actions are largely driven by international funding and commitments to international agreements. Although national governments are also putting resources towards the implementation of their own adaptation interventions. The organisations implementing these projects include: i) government departments such as Directorate of Environmental Affairs in the Ministry of Environment and Tourism in Namibia, Ministry of Agriculture, Water and Forestry in Namibia; ii) non-governmental organisations such as Conservation South Africa, Creative Entrepreneurs Solutions (CES), Environmental Monitoring Group (EMG), Namibia Nature Foundation (NNF), Namibia Association of CBNRM Support Organisations; iii) United Nations agencies such as United Nations Development Programme, United Nations Environment Programme (UNEP) and Food and Agriculture Organisation (FAO) of the United Nations; iv) community based organisations such as Omalundu Limuna Kommitiye Elungameno (OIKE); v) networks such as Food, Agriculture and Natural Resources Policy Analysis Network (FANRPAN), Famine Early Warning Systems Network (FEWSNET); vi) international organisations such as International Council for Local Environmental Initiatives (ICLEI) and System for Analysis Research and Training (START); and vii) regional organisations such as the Southern African Development Community (SADC).

Funding for these projects has been received from: i) international funding such as from the Global Environment Facility, The International Fund for Agricultural Development (IFAD); ii) the United Nations (multilateral organisation) including the World Bank, United Nations Development Programme through the Africa Adaptation Programme, the Global Mechanism of United Nations Convention to Combat Desertification (UNCCD), the Adaptation Fund under the UNFCCC and the World Food Programme; iii) embassies of other governments such as the governments of Japan, Norway, Switzerland, Finland; iv) national government including the governments of Botswana, Namibia and South Africa; v) international development funding from other countries e.g. Department for International Development (DFID, United Kingdom), International Development Research Centre (IDRC, Canada), Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ, Germany), Swedish International Development Cooperation Agency (SIDA), United States Agency for International Development (USAID), Japan International Cooperation Agency (JICA), European Commission; vi) international development charities such as Voluntary Service Overseas (VSO).

5.9 Barriers to the implementation of adaptation actions

Barriers to adaptation are "factors that make it harder to plan and implement adaptation actions or that restrict options" (IPCC 2014b). They can be categorized as institutional, attitudinal, political and financial (Ekstrom and Moser 2014) and include conflicting timescales, motivation and willingness to act, as well as lack of awareness and communication (Biesbroek *et al.* 2011).

In Southern Africa barriers to adaptation include:

Awareness of climate change issues

- Positioning of climate change as an environmental issue rather than a development issue, a lack of integration with other developmental issues and lack of coordination between different stakeholder groups (Ziervogel *et al.* 2014; Namibia: *pers. comm.* respondent from GIZ Office, Namibia March 2015; *pers. comm.* respondent from Namibia Meteorological Services Office, March 2015) e.g. climate change adaptation is not mainstreamed in agricultural policies (Koch *et al.* 2007 in SA, Pasquini *et al.* 2013 in Western Cape, South Africa).
- Lack of understanding of climate change and attributing climatic changes to the hand of god (Botswana: *pers. comm.* chiefs of Bobirwa sub-district, Botswana January 2015).
- Limited awareness about climate change, its impacts and adaptation options (Dirkx *et al.* 2008, DEA 2011b, Giorgis 2011).
- Limited understanding of and expertise in tackling climate change-related issues (Ziervogel *et al.* 2014).
- Limited ability to understand 'big picture' concepts, such as the need for landscape approaches e.g. watershed management (Turpie *et al.* 2010).
- Low education levels (Dahlberg & Wingqvist 2008).

Planning for climate change adaptation and integration of climate change into other policies

- Central operation of government ministries constraining the implementation of adaptation at the local level for example lack of decentralisation in the Ministry of Environment which is responsible for climate issues in Namibia (Namibia: *pers. comm.* respondent from Ouamanzi Constituency Office, February 2015).
- Climate change not being a priority at the local level (Namibia: MET 2011b).

- Typically short term thinking and the implementation of short-term adaptation measures (Turpie *et al.* 2010).
- Planning for immediate and long-term adaptation activities is viewed as a challenge (*pers. comm.* respondent from GIZ Office, Namibia March 2015; *pers. comm.* respondent from Onesi Settlement Office - Omusati Regional Council, Namibia, February 2015).
- Lack of integration among land management policy and land management at the local level Newsham & Thomas (2011).
- Limited mainstreaming of climate change adaptation into national development policy (Dirkx *et al.* 2008).
- Absence of consideration of climate change in all the national development planning process, (Namibia: Giorgis, 2011).
- Lack of integration of climate change into policies and activities (Reid et al, 2007, Hove *et al.* 2011).
- Most government policies are very broad, therefore not implementable (pers.comm. respondent from Outapi Town Council Office, Namibia February 2015)
- Policy conflicts and lack of cohesion such that national climate change policies are conflicted by sectoral policies (MET 2011b).
- Ineffective and lack of coordinated rural and agricultural policy (Twyman *et al.* 2004).

Institutional capacity

- Limited institutional capacity in terms of lack of appropriate policy, lack of implementation of policies and low public participation in policy development (Dirkx *et al.* 2008, MET 2011b).
- Poor coordination and communication between departments and government at different levels (Christine *et al.* 2007, Dirkx *et al.* 2008, Ziervogel *et al.* 2014) as well as lack of coordination between donors (Dirkx *et al.* 2008). The lack of collaboration leads to inefficiencies, contradictory messages and heightened time requirements on both public servants and, more importantly, rural communities.
- Limited capacities to implement environmental regulation and laws at local level (need more financial and human capacities among local institutions) (Bourne *et al.* 2012 in the Namakwa District Municipality, South Africa).
- Limited access to government support particularly agricultural extension services (Akpalu 2005, Benhin 2006, Archer *et al.* 2008, Bryan *et al.* 2009, Gbetibouo 2009, Mpandeli & Maponya 2013, Muller & Shackleton 2014) but also relevant policies and institutions.
- Limited technical, human and financial capacity to provide extension services, provide relevant information, provide forecasts, provide early warning, and implement adaptation actions (Christine *et al.* 2007, DEA2011, MET 2011b, Ziervogel *et al.* 2014, Mufita 2012; South Africa: Akpalu, 2005, Moeletsi *et al.* 2013).
- Weak relationship between different stakeholder groups e.g. government, civil society, private sector, researchers (Christine *et al.* 2007, Ziervogel *et al.* 2014.
- Lack of communication and unclear mandates between local councillors and technical government staff at the local level (*pers. comm.* respondent from Agriculture Extension Office - Omusati Region, Namibia March 2015).

- Few platforms to allow engagement of civil society (DEA 2011).
- Resistance by government to forming genuine partnerships with landowners (e.g. park neighbours) and Civil Society, who could help limit vulnerability (Turpie *et al.* 2010).
- Inaction in the face of uncertainty risk and incomplete information (MET 2011b).
- Inadequate planning and spatial development (DEA 2011).
- Poor climate and disaster risk management (DEA 2011).
- Limited monitoring networks (DEA 2011).
- Different priorities at local and national scales and disregard for traditional approaches and community needs in design and implementation of adaptation interventions by government and other projects as well as in aid provision in some cases leading to maladaptation (Dirkx *et al.* 2008, *pers. comm.* respondent from UNDP Small Grants Programme, Namibia, November 2014).

Stakeholder engagement

- Lack of sufficient consultation leading to projects being stopped by ministers or counsellors if the project developers did not go through the right channels and the relevant people were not informed and consulted early on in the process (pers.comm. respondent from UNDP Small Grants Programme, Namibia, November 2014).
- Lack of sufficient consultation at the local level (the local councillors and community) creates tension and community resistance to participate in projects (*pers. comm.* respondent from Outamanzi Constituency Office, February 2015).
- Lack of continuity of ideas and plans due to changes in leadership - specifically where leaders have different visions (*pers. comm.* respondent from Outapi Town Council, Namibia, February 2015)
- Conflicts of interest and favoritism at the ministry level on allocation of funds for different projects (*pers. comm.* respondent from Outapi Town Council, Namibia, February 2015).
- Unwillingness to make unpopular political decisions, such as limiting stocking rates (and forcing/facilitating offtake) during dry cycle periods, committing to required, initial expenses at strategic level (Turpie *et al.* 2010).
- Overlap of services delivered by different government institutions (e.g. MAWF, DAPEES vs Regional Council, local councillors vs technical/extension officers at the local level (pers.comm. respondent from Onesi Settlement, Omusati Regional Council, February 2015).
- Lack of community or chief buy-in leading to projects getting stopped (*pers. comm.* respondent from UNDP Small Grants Office - Namibia, November 2014).
- Lack of community empowerment (Kandjinga *et al.* 2010, David *et al.* 2013).
- Social acceptability, stigmatisation and a lack of acceptance of risk (Dirkx *et al.* 2008, Botswana: Masters & Duff 2011).

Resource mobilisation/access to resources

- Development projects that are donor-funded are implemented as per the Terms of Reference of the funder (pers.comm. academic - Multi-disciplinary Resource Centre (MRC), University of Namibia March 2015).
- Most adaptation projects are driven by funders and people are just aligning themselves to the available funds (pers. comm respondent from Parliamentary Standing Committee on Economics, Natural Resources and Public Administration - Namibia, March 2015).
- Limited access to financial capital (Twyman *et al.* 2004, Akpalu 2005, Benhin 2006, Mukheiber 2007, Archer *et al.* 2008, Dirkx *et al.* 2008, Bryan *et al.* 2009, Gbetibouo 2009, Dougill *et al.* 2010, Muller & Shackleton 2014), credit (Huisman 2005, Bryan *et al.* 2009) and lack of insurance policies for agricultural enterprises (Nyambe & Belete 2013). Lack of financial resources restricts the ability of farmers to plant crops as they don't have access to tractors or labour at important times (Moeletsi *et al.* 2013), can't afford drought-resistant crops and can't access transport to buy seeds (Mpandeli & Maponya 2013). They are also not able to receive early warnings (Moeletsi *et al.* 2013).
- Limited access to fertile land (South Africa: Bryan *et al.* 2009, Namibia: Klintenberg *et al.* 2007, Eriksen *et al.* 2008, Angula & Menjono 2014, Kuvare et al 2008).
- Inadequate access to water (Gbetibouo 2009).
- Insecure land tenure rights (Gbetibouo 2009, Mogotsi *et al.*, 2011).
- Lack of access to markets (Gbetibouo 2009, DEA 2011).
- Use of inappropriate varieties (Unganai & Muriwa 2010)
- Lack of access to off farm activities / access to other opportunities (Gbetibouo 2009, Dahlberg & Wingqvist 2008).

Climate change information

- Communication barriers in communicating information on variability and changes in rainfall and forecasts (Simelton *et al.* 2013, *pers. comm.* respondent from Agricultural Extension Office - Omusati Region, Namibia February 2015; *pers. comm.* respondent from Namibia Meteorological Services Office, March 2015; *pers. comm.* Directorate of Water Supply and Sanitation Coordination Office - Omusati Region, March 2015).
- Lack of accessible information including information on forecasts and early warnings (Mpandeli & Maponya 2013, Giorgis 2011), climate change and adaptation options (Benhin 2006, Reid & Vogel 2006, MET, 2011b, Muller & Shackleton 2014), uncertainty of impacts of climate change (Benhin 2006), downscaled climate projections and appropriate impact simulation models (DEA 2011).
- Information from the Meteorological Office is not clear and the meaning of the information is not explained (*pers. comm.* respondent from Ministry of Agriculture, Water and Forestry (MAWF), Directorate of Engineering and Extension Services (DEES March 2015).
- Limited farming experience (Huisman 2005, Gbetibouo 2009) and market knowledge (Reid & Vogel 2006).

- Dependency on drought relief and handouts (Namibia: *pers. comm.* respondant Desert Research Foundation of Namibia).

Evidence of effectiveness

- There is insufficient information on benefits versus costs of adaptation (MET 2011b).
- "Perverse incentives" - the provision of aid discouraging the implementation of activities that reduce risks (MET 2011b). For example, in Botswana, the Ipelegeng programme provides short-term temporary employment and food assistance possibly creating dependence on government and taking people away from other activities such as ploughing their fields (pers. comm, January 2015).
- Lack of evidence of effectiveness of measures (MET 2011b) and resistance to new and unknown measures without assurance of success (*pers. comm.* respondent from Onesi Constituency Office, Namibia, February 2015).

5.10 Adaptation in the development context

5.10.1 Adaptation benefiting development

As climate change possesses risk to development (UNDP-UNEP 2011) adaptation interventions are expected to contribute towards improved development (UNFCCC 2007). In addition, adaptation interventions being undertaken in semi-arid areas in Southern Africa range from those that address drivers of poverty and are more closely linked to development e.g. livelihood diversification (Mendelssohn *et al.* 2000) to those that build capacity to respond to a specific climate risk e.g. the introduction of drought resistant crops (see McGray *et al.* 2007). As such development objectives are being met by adaptation interventions in semi-arid areas in southern Africa. For example adaptation interventions such as the conservation tillage project in Namibia have lead to improved agricultural yields and therefore improved food security.

5.10.2 Development impeding adaptation

On the other hand some development activities impede adaptation efforts e.g. the provision of drought relief (Sallu *et al.* 2008) and other interventions that prevent communities in semi-arid areas in southern Africa from implementing adaptation activities. In Botswana for some projects have been implemented which directly or indirectly impede adaptation such as Ipelegeng (which provides food and short-term employment. There was a concern that provision of food and short-term employment create a sense of dependency and reluctance to try other livelihood alternatives e.g. bees keeping (Botswana: *pers. comm.* Kglota meeting Bobonong, January 2015). Another example is the construction of dams on the Shashe River to provide the capital city Gaborone with water, while reducing water available to farmers residing in the Limpopo River basin (Botswana: *pers. comm.* Kglota Meeting Bobonong, January 2015). Development strategies can also increase dependency on climate sensitive resources (e.g. certain crops) or there can be a mismatch between adaptation activities supported by external aid and development priorities of recipient countries (OECD 2009, Huq *et al.* 2006).

Lack of development also impedes adaptation. For example the diversification of livelihoods is an important aspect of adapting to the effects of climate change. However, in the absence of markets goods cannot be traded to provide an alternative livelihood (Gremlowski 2010).

5.10.3 Maladaptation

Implementing certain adaptation measures (geared to specific groups of people, sectors or problems) may be effective in certain circumstances, but in the long-run may not necessarily produce the result that is needed (UNDP-UNEP 2011). Possible cases of maladaptation could arise in southern africa as a consequence of the implementation of measures without comprehensive consultation with local communities, knowledge of local context and sufficient knowledge about adaptation options in the face of the uncertainty of future climatic conditions.

5.11 Knowledge gaps in informing adaptation policy and practice

One of the biggest barriers to climate change action is the lack of relevant data, information and sector specific expertise (Botswana: MEWT 2011). Limited expertise or technical capacity also hinders the ability to collect and analyse relevant data and distribute climate change specific research results. This lack of knowledge coupled with limited awareness of policy makers impedes the development and implementation of climate change plans, policies and legal frameworks (Botswana: MEWT 2011).

Some issues related to knowledge gaps in Southern Africa are highlighted below:

- Limited data available to measure adaptation (Namibia: *pers. comm.* an academic Multidisciplinary Research Centre, University of Namibia, November 2014).
- The abstract nature of climate change, adaptation and effective climate change adaptation (Namibia: *pers. comm.* an academic Multidisciplinary Research Centre, University of Namibia, March 2015).
- Limited information on appropriate drought resistant crop varieties and adaptation options in general (Namibia: MET 2011a, *pers. comm.* respondent from UNDP Small Grants Office, November 2014).
- Lack of data on costing of adaptation measures and socio-economic impacts (Botswana: *pers. comm.* respondent from Department of Meteorological Services Office).
- Lack of capacity to conduct adaptation research (Namibia: MET 2011b, Mozambique: MICOA 2006).
- Poor climate change data records (Mozambique: MICOA 2006). hindered by fragmented inter-institutional coordination, insufficient publication of research results, lack of resources (both financial and human), loss of information from previous initiatives (Zimbabwe) and lack of linkages between new research areas on ongoing research focus (Mozambique: MICOA 2006; Zimbabwe: MENRM 2013)
- Lack of human, technical and institutional capacity to use the results from scientific research in socio-economic applications, through locals participating and engaging with the data (Mozambique: MICOA 2006).
- Lack of awareness of climate change and adaptation at a local level and poor dissemination of information (Urquhart & Lotz-Sisitka 2014, Mozambique: MICOA

2006, Zimbabwe: MENRM 2013, Namibia: *pers. comm.* respondent from GIZ Office, March 2015: *pers. comm.* respondent from Outapi Town Council Office - Omusati Region, March 2015).

- Limited monitoring of the progress and implementation of existing climate change related policy and adaptation interventions (Namibia: *pers. comm.* respondent from SASSCAL Office - Namibia, March 2015; *pers. comm.* academic Multidisciplinary Research Committee, University of Namibia, March 2015).
- Insufficient information on extreme events, planning for sustainable development and ensuring food and water security (South Africa: DEA, 2011).
- Limited information available at the local level on community needs during drought (*pers. comm.* respondent from Onesi constituency Office, March 2015).
- Limited information on the impacts of climate change on individual households (*pers. comm.* respondent from Uukolonkadhi Traditional Authority Office, March 2015).
- Limited knowledge to distinguish between changes in exposure (e.g. rainfall), the impact (e.g. yield change due to rainfall) and sensitivity of the farming system sensitivity (Simelton *et al.* 2013).
- Limited knowledge and lack of awareness of climate change issues among the stakeholders working in sectors that are sensitive to climate change (Namibia: *pers. comm.* respondent from DRFN Office, March 2015; *pers. comm.* respondent from DAPEES, March 2015).

CHAPTER 6

Recommendations and conclusions

Some conclusions and recommendations from the literature are outlined below.

Effective adaptation measures

- A review of adaptation measures that have been adopted in semi-arid areas in southern Africa suggests that there is an adaptation deficit i.e. a gap between the current state of a system and a state that would minimize adverse impacts from existing climate conditions and variability (Burton et al. 2002, Burton, 2004, Burton and May, 2004, Parry et al. 2009, IPCC 2014a).
- Into the future adaptation measures and livelihoods that are currently relied on may no longer be viable.
- There is limited information on the effectiveness of adaptation strategies. This information as well as information on the costs and benefits of implementation measures is required to make a case to policy makers.

Climate change adaptation and development

- Climate change issues need to be mainstreamed into development rather than being framed as environmental (Namibia: Ndeleki & Zeidler 2010; pers. comm. respondent from UNDP Office - Namibia, March 2015). There is a need to link adaptation and development (Ziervogel et al. 2014, Masters & Duff 2011). For example adaptation strategies in agriculture should be integrated into sustainable development strategies (Gbetibouo & Ringler 2009). The climate change adaptation agenda should be integrated into national development processes (Lesolle 2012).
- Planning and financing adaptation to climate change should consider the local context of vulnerability (including adaptive abilities, resilience and livelihood strategies of the local population) and how the various levels of governance enable or hinder local actors to improve their wellbeing (Namibia: Ndeleki & Zeidler 2010, South Africa: Gbetibouo & Ringler 2009).
- There is a need to create an enabling environment for the promotion of arable land use practices that rely less on natural rainfall (Kori et al. 2012).
- Policies and programmes should accommodate and encourage diverse livelihood strategies (Twyman et al. 2004, Gbetibouo & Ringler 2009, IECN 2011) and generation of financial capital (Sallu et al. 2010).
- There is a need for government, NGOs and private sector to increase funding for resource-poor farmers in rural areas i.e. for agronomic training, community tractors, farmers packages (Moeletsi et al. 2013), as well as provide access to credit and subsidised fodder to boost livestock production in drought-prone areas (Oyekale 2012).
- There is a need to define and nationalise the concepts related to climate change adaptation to suit the local context (pers.comm. an academic - Multi-disciplinary Resource Centre, University of Namibia, March 2015).

Climate change information

- Improved scientific and technical capacity is needed to understand the problem and its effects at the national and sub-national level, model its long-term impacts, and elaborate responses and adaptive strategies for implementation (Lesolle 2012).
- There is a need to promote and ensure capacity building of boundary organizations to facilitate feedback loops of information on climate change between science institutions, policy makers, and users (Namibia: MET 2011b).
- Improved capacity is needed to access, interpret, translate and communicate climate change information to policy makers and the general public for effective decision-making (Namibia: Kandjinga et al. 2010, Hove et al. 2011, Namibia: MET 2011b, David et al. 2013).
- There is also a need for capacity building for academics and professionals to apply and interpret climate models and impact models in sectors that are considered critical for the development (Namibia: MET 2011b).
- To foster long-term capacity for climate change, there is a need to integrate climate change into the education system to generate awareness and capacities at the early stages of educational development (Namibia: MET 2011b).
- Successful adaptation would requires citizen awareness to sustain and prioritize climate change actions (Lesolle 2012).
- Farmers should make use of information provided by extension and other agricultural related organisations for effective adaptation (Benhin 2006).

Knowledge systems

- Successful adaptation to changes in rainfall, would require a full understanding of the roles of farmers' perceptions of changing rainfall patterns e.g. how immediate or severe the problem is perceived to be (Simelton et al. 2013). For example, elders are perceived to be reluctant/difficult to change their attitudes (pers. comm. respondent from Directorate of Agricultural Production, Extension and Engineering Services, March 2015).
- There is a need to engage local knowledge systems to enrich and guide climate change adaptation policy and practice (Newsham et al. 2011, Bourne et al. 2012, Masters & Duff 2011).
- There is a need to communicate what is happening in a more simple language (pers. comm. respondent from Parliamentary Standing Committee on Economics, Natural Resources and Public Administration - Namibia, March 2015).
- To enable better accuracy of predictions and allow Kalahari agro-pastoralists to buffer their livelihoods against the adverse effects of climate variability, there is a need to integrate some traditional methods and timely, easily understood meteorology-based forecasts (Mogotsi et al. 2011b).
- Further research should be conducted on the utility of local knowledge (e.g. observing animal behaviour) in the face of climate change (Mpandeli & Maponya 2013, Mogotsi et al. 2011b).

- More research and scientific support is required to improve answers on how to adapt (DEA 2013), and support development of tools, approaches and case studies that inform water planning (DEA 2013).

Planning, monitoring and evaluation

There is a need for:

- Effective information management, monitoring and evaluation (DEA 2013).
- Finding appropriate approaches to measure performance of existing adaptation projects and upscale/replicate them to few communities to understand how well they perform in other cases (pers. comm. an academic - Multidisciplinary Research Committee, University of Namibia, March 2015).
- Multi-disciplinary and multi-scalar work between researchers and practitioners (Ziervogel et al. 2014).
- Engaging and considering farmers' and extension workers' understandings of how weather is changing to enrich and guide adaptation in the agricultural sector (Simelton et al. 2013).
- The use of integrated approaches to address climate change e.g. Social-Ecological-Systems (Lotz-Sisitka & Urquhart 2014), and ecosystem services approach (Bourne et al. 2012) to address the multifaceted issues such as climate change (Christine et al. 2007).
- Increased awareness and monitoring so that adjustments in management strategies can be made (CSIR 2012).
- Planners and managers to be reasonably informed about trends in climate, and potential consequences of climate change (CSIR 2012).
- The development of effective responses and understanding the nature of the climatic and ecological changes that are likely to occur locally (CSIR 2012).
- Revision of national sectoral policies e.g. agriculture policy to embed climate change issues into the implementation of projects and programmes (Namibia: Nhuleipo et al. 2011).
- Enhanced efforts to integrate adaptation into core policy-making (Kuvare et al. 2008).

Governance and institutional support

There is a need to:

- Strengthen the levels of stakeholder engagement as a central element in implementing adaptation measures (Masters & Duff 2011), e.g. apply a people-centred approach to increase community willingness to engage in the implementation of adaptation measures.
- Develop adequate institutional arrangements including systematic planning capacity in a cooperative institutional setting, consistent policies and measures and regulatory frameworks (Lesolle 2012).
- Strengthen the governance of climate change, by establishing all-inclusive climate change platforms for coordination and cooperation amongst various stakeholders, integrating sectors on climate change issues, involving private sectors in climate

change adaptation initiatives and setting a specific budget for specialized activities to support various capacity building activities (Goreseb 2010).

- Put in place better government services and training on improved security to prevent theft in South Africa (Oyekale 2012).
- Strengthen local leadership from policy decision makers as well as those outside formal government structures and implementers on the ground (Bourne et al. 2012).
- Improve agricultural extension services (Akpalu 2005).

6.1 Conclusions

Some of the key insights that emerge from the RDS report include:

- Current adaptation actions are not sufficient and there are many measures that could be applied that are not being applied or are only being applied in localised areas;
- Based on climate projections, adaptation measures and livelihoods that are currently relied on may no longer be viable into the future;
- Information on adaptation options needs to be made more readily available to practitioners;
- Alternative livelihood options need to be created at the local level and this requires policies that enable and promote new and diverse livelihood options e.g. increasing markets;
- More integration and a common goal is needed across different sectors in their policy and practice to work towards achieving the implementation of widespread and effective adaptation;
- An evidence base as well as demonstrations of the benefits of adaptation to communities is required especially in relation to the costs to convince policy makers, practitioners and communities; and
- In addition to the point above, there is a need for an approach to measure adaptation.

The Regional Research Programme (RRP) of ASSAR will build on the findings of the RDS report and provide an evidence base towards addressing some of the gaps identified. For example, further analysis will be conducted on measuring the effectiveness of adaptation projects and a more in depth study will be conducted on barriers to widespread and sustained adaptation. Expected outputs from the RRP include information on which adaptation measures are appropriate and effective in semi-arid regions in Southern Africa. During the RRP there will also be a line of research looking at expected future climate conditions and the implications for adaptation responses.

CHAPTER 7

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CHAPTER 8

Annexes

8.1 Annex - key informant interviews

Summary of participants - stakeholder engagement activities in Namibia

Date	Organisation	Number of people		
		Male	Female	Total
6th November 2014	Academicians - University of Namibia (UNAM), Windhoek - Faculty of Agriculture and Natural Resources, - Geography, History & Environmental Studies - Multi-disciplinary Research Centre	4	4	8
6th November 2014	Department of Environmental Affairs (DEA), Ministry of Environment and Tourism	4		4
6th November 2014	Ministry of Environment and Tourism	1		1
7th November 2014	UNDP – Namibia	1		1
7th November 2014	University of Namibia (UNAM) - External and Internal Relations –	1		1
7th November 2014	UNDP Small Grants - Namibia	1	1	2
7th November 2014	Desert Research Foundation (DRFN) – Namibia,	1	2	3
7th November 2014	Ministry of Agriculture, Water and Forestry (MAWF) - Windhoek	2		2
10th November 2014	Ministry of Agriculture, Water and Forestry (MAWF – DAPEES) - Ongwediva Office	3	1	4
10th November 2014	Onesi Constituency Office - Omusati Region		1	1
10th November 2014	Directorate of Regional Services and Park Management	1		1
11th November 2014	University of Namibia – Ogongo Campus, Faculty of Agriculture and Natural Resources	7	3	10
11th November 2014	Omusati Regional Council		1	1
23rd February 2015	Outapi Town Council, Omusati Region	2	2	4
24th February 2015	Agriculture Extension Office, Omusati Region	1		1
24th February 2015	Directorate of Water Supply and Sanitation Coordination, Omusati Region	1		1
25th February 2015	Traditional Authority at Uukolonkadhi, Omusati Region	1		1
25th February 2015	Onesi Settlement Office, Omusati Region	1		1
25th February 2015	Onesi Constituency Office	1	1	2
26th February 2015	Outamanzi Constituency Office	1		1
27th February 2015	Basin Management Committee – Olushandja Sub-basin Management Committee	1		1
28th February 2015	Agribank, Oshakati Region	1		1
2nd March 2015	Multi-disciplinary Research Committee - UNAM	1		1

2nd March 2015	Parliamentary Standing Committee on Economics, Natural Resources and Public Administration	1		1
3rd March 2015	GIZ Office - Namibia	1		1
3rd March 2015	Ministry of Water, Agriculture and Forestry - NWD, DAPEES		1	1
3rd March 2015	DRFN - Associate		1	1
4th March 2015	SASSCAL Office - Namibia	1		1
4th March 2015	DRFN	1		1
4th March 2015	Namibia Meteorological Services, Windhoek	1	2	3
16th March 2015	Environmental Investment Fund of Namibia	1		1
19th March 2015	Disaster Management Risk Directorate		2	2
Grand total of respondents		**43**	**22**	**65**

Summary of participants - stakeholder engagement activities in Botswana

Date	Organisation	Number of people		
		Male	**Female**	**Total**
19/1/2015	Academicians - University of Botswana	5	3	8
19/1/2015	Ministry of Environment, Wildlife and Tourism	2		2
19/1/2015	Ministry of Environment - Crop Production	2		2
19/1/ 2015	Ministry of Infrastructure, Science and Technology	4		4
20/1/2015	Ministry of Agriculture	4		4
20/1/2015	Stakeholder Workshop, University of Botswana ● UB academics ● Kalahari Conservation Society ● Departments of Environmental Affairs; ● Ministry of Agriculture - Animal Production – Vet Section; Crop Production; ● Waste Management and Pollution Control	5	3	8
22 January 2015	Meeting with the Chiefs - Babonong	27	1	28
22 January 2015	Crop Production Office, Baboonong		1	1
22 January 2015	District Administration Office	1	1	2
23 january 2015	Babonong Kgolta Meeting	51	37	98
22 january 2015	District Extension Committee	5	3	8
23 january 2015	Public Health Office		2	2
Grand total of respondents		**116**	**51**	**167**