Final Technical Report

Intended Nationally Determined Contributions




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1 Introduction

The purpose of preparing Intended Nationally Determined Contributions (INDCs) by all Parties to the United Nations Framework Convention on Climate Change is to inform the outcomes on the 2015 agreement under the United Nations Framework Convention on Climate Change (UNFCC). The Parties envisage signing this new agreement at the 21st Conference of the Parties (COP) that will be held in Paris towards the end of 2015. The INDCs should be communicated to UNFCCC during the course of the year but before COP 21 in accordance with provisions agreed in Lima in respect of upfront information to be communicated by Parties, as well as the aggregation of INDCs by October 2015. The South African government has appointed the Council for Scientific and Industrial Research (CSIR) to develop the technical contents of the adaptation component of their INDC, as well as contribute a draft to the documents that will be submitted by the government of the Republic of South Africa to the UNFCCC. The CSIR undertakes to finish this process by the end of June 2015 to allow for national consultation on the document.

2 Design of an INDC template for adaptation

The adaptation component of the INDC (a-INDC) is structured along the guidelines of the African Group of Negotiators, and further guidance from the Department of Environmental Affairs, and the project steering committee. The a-INDC is presented as shown in the **Table 1**.

Element	**Undertaking for the period 2021-2030**	**Assumptions / Methodologies**	**Adaptation needs (2021 – 2030)**	**UNFCCC context**
Adaptation objectives and planning	**Goal 1:** Develop a National Adaptation Plan as part of implementing the NCRP by 2020 **Goal 2:** Take into account climate consideration national development and sectoral policy framework by 202/2025 **Goal 3:** Strengthen the capacity of institutions, and institutionalisation of climate	National Development Plan, sectoral plans and any future variants thereof will form the basis for development planning - the National Climate Change Response Policy continues to be the guiding principle. Flexible and adaptive sectoral	US$[1] 0.17bn	International agreement that supports a continuous refinement of South Africa's INDC, reporting *ex post* for rolling five year implementation periods 2016-2020, 2021-2025, 2026-2030.

[1] Currency exchange rate used in 10 South African Rand to 1 US Dollar

Element	Undertaking for the period 2021-2030	Assumptions / Methodologies	Adaptation needs (2021 – 2030)	UNFCCC context
	change policy frameworks by 2025/2030 **Goal 4:** Develop an early warning and reporting system for all climate adaptation sectors by 2025/2030	policies that will increase institutional capability to implement climate change adaptation programmes and projects; in anticipation of adaptation being a global obligation. Development of national framework for vulnerability and needs assessment well before 2020.		
Adaptation needs and costs.	**Goal 4:** Development of a vulnerability assessment and adaptation needs framework by 2020 to support a continuous presentation of adaptation needs	Damage costs associated with high impact climate events (wild fires, storms, droughts and floods), including both direct and downstream costs were calculated. These were estimated for the present-day climate and for the near-future under low and moderate mitigation scenarios. Emission scenarios considered are RCP 8.5 (low mitigation) and	**Annual costs range for the period 1971-2000:** US$ 0.4 bn to US$ 22.8 bn **Annual costs range for the period 2021-2030:** Low mitigation scenario: US$ 0.42 bn – US$ 30.8 bn; whereas in a high mitigation scenario: US$ 3.4 bn – US$ 29.8 bn. **Annual costs range for the period 2021-2050:** Low mitigation scenario: US$ 0.2 bn – US$ 53.1 bn	Subject to an international agreement that provides upfront information on support available for adaptation in the context of Article 4.7 and an assessment of adequacy support *vis a vis* needs

Element	Undertaking for the period 2021-2030	Assumptions / Methodologies	Adaptation needs (2021 – 2030)	UNFCCC context
		RCP 4.5 (moderate-high mitigation). The costs estimated are in terms of the 10th and 90th percentiles of annual costs occurring within the periods of interest. Annual costs were calculated for 2021-2030 and 2021-2040. Sectors covered; Water, Agriculture, Forestry, Energy, Settlements, Biodiversity, Disaster Risk Reduction (DRR)	whereas in a high mitigation scenario: US$ 0.2 bn– US$ 50 bn	
Adaptation investments	**Goal 5:** Communication of past investments in adaptation for international recognition Identify adaptation investments from official annual reports. The years covered are 2010 – 2015.	Development & implementation of a monitoring and evaluation framework, which includes indicators, to tracking domestic investment and tracking of international support.	Domestic investment into capacity to facilitate climate change adaptation increased from US$ 0.26 Million to US$ 1.1 Million from 2011 to 2015 Implementation investment increased from US$ 0.71 bn to US$ 1.88 bn from 2010 to 2015. Support from the international financial	Report on a 5 year ex-post cycle, subject to CoP determined rules that build on existing reporting mechanism/instruments

Element	Undertaking for the period 2021-2030	Assumptions / Methodologies	Adaptation needs (2021 – 2030)	UNFCCC context
			mechanisms : Adaptation fund: US$ 10 Million; UNEP: US$ 3.5 Million	
Equity considera-tions in adaptation	South Africa views adaptation as a global responsibility in the light of Article 2 of the Convention as further codified in the UNFCC as a temperature goal. Further understanding climate impacts as being driven by global action/inaction on mitigation, the adaptation burden is therefore a global responsibility, which requires international cooperation in accordance with principles of the Convention. It is in that light that South Africa considers its investments in adaptation as a contribution to the global effort, which should be recognised as such. Further information is provided in the equity section of the INDC.			

3 Integration of adaptation into development plan objectives, as per Article 4.1

3.1 Sectoral planning and adaptation needs

3.1.1 Introduction

To successfully integrate adaptation planning into South Africa's development objectives, a general context within which this should take place needs to be developed. This context is provided by the long term vision of the country, policies and sectoral strategies. In addition to these, the context needs to factor in relevant multi-institutional studies that have been conducted, so as to take what has been achieved thus far into consideration in the INDC. First and foremost the National Development Plan (NDP) provides a long-term perspective to guide the country's development trajectory such that poverty is eliminated and inequalities are reduced by 2030 (RSA, 2011). Government sectoral plans therefore have to ensure long-term alignment with the NDP to ensure that the planning and implementation outcomes can be achieved. Furthermore, the NDP states that climate change is already having an impact on South Africa with marked temperature increases, rainfall variations and rising sea levels. The NDP therefore recognises that in the short-term policy needs to quickly and effectively respond to ensuring the natural environment is protected from the effects of climate change.

South Africa has in fact positively responded to climate change, as the country is a signatory of numerous global climate change responses including the United Nations Framework Convention on Climate Change (UNFCCC), the Kyoto Protocol, and the agreed outcome of the Bali Action Plan and in 2011 gazetted its National Climate Change Response Policy (NCCRP) White Paper (DEA, 2011). The NCCRP provides a policy framework for country's response to both climate change mitigation and adaptation. From an adaptation perspective the goal of the NCCRP is to ensure that the country is able to manage the impending climate change impacts through interventions that build and sustain South Africa's social, economic and environmental resilience and emergency response capacity (RSA, 2011). However, to mainstream climate-resilient development, all government sectors have to ensure that all policies, strategies, legislation, regulations and plans are in alignment with the NCCRP (DEA, 2011). All national departments are thus further mandated to develop sector specific climate change adaptation plans. In addition to the development of climate change adaptation sectoral plans the country also recognises the need to prepare for climate related disasters. Specifically, the NDP highlighted the need to improved disaster preparedness in light of extreme climate events. South Africa's national policy for disaster management includes the National Disaster Management Act (Act No. 57 of 2002) and the related National Disaster Management Framework (NDMF). However the NCCRP recognises that climate change related impacts on the frequency and severity of extreme weather events will require more effective disaster risk management thus indicating the sectoral adaptation plans should consider disaster risk management. The complex linkages between vulnerability, risk and climate change across sectors has been recognised in platforms such as the South African Risk Vulnerability Atlas that provide cross-sectoral information to decision-makers.

Section 3 presents an overview of the policy and planning goals of the key sectors that is, health, agriculture and forestry, human settlements, biodiversity and water, that are expected to be impacted by climate change. This review provides a basis to understand how South Africa has responded to climate change adaptation needs thus far, and the remaining policy and research gaps that have to be addressed to ensure that these plans can be implemented. Section 3.2 of this chapter discusses potential aspiration goals that can be pursued in light of the gaps identified.

3.1.2 Health sector

The NDP aims to promote health and well-being of all South Africans and to provide affordable access to quality health care by 2030. Furthermore, the plan seeks to ensure that citizens will have a decent standard of living, which in addition to income, include important elements such as the need for adequate nutrition, housing, water, sanitation, electricity and a clean environment. The NDP further recognises women as vulnerable members of society, especially in rural areas and as such proposes measures that are aimed at advancing women's equality in terms of health and nutrition.

The National Health Act of 2003 (Act No. 61 of 2003) and the related strategic plans (e.g. National Department of Health Strategic Plan (NDHSP) for 2014 - 2019) seek to address issues related to illness, and the promotion of health lifestyles. However, many of the existing health challenges facing South Africans, such those caused by heat and air pollution, are likely to be impacted and exacerbated by climate change. Therefore, climate change and its impacts are likely to place an additional strain on South Africa's health care system and so for the system to cope in future the implementation of social, institutional, technological and behavioural interventions will be required (Scholes et al., 2007).

The National Environmental Health Policy (SA, 2013) provides a framework for the implementation of Environmental Health Services in the country, to reduce the impact on human health from the physical, chemical biological and social threats in the environment. This policy emphasizes the need to stream line environmental health interventions into the adaptation plan; though no guidance pm how this can be achieved is provided. However, a climate change adaptation plan has been drafted for the health sector for the period of 2012-2016 (DoH, 2012). This adaptation plan focuses on nine health and environmental risks that include, heat stress, natural disasters, housing and settlements, communicable diseases, exposure to air pollution and respiratory diseases, non-communicable diseases, vector and rodent borne disease, food insecurity and mental ill health. The main goals of the plan are to conduct vulnerability assessments, improve on the monitoring and surveillance of key indicators, improve inter-sectoral partnerships through a National Climate Change and Health Steering committee, improve health systems readiness, and prioritise research and development. In the case of natural disasters for example, the plan highlights the impacts of weather-related disasters on human life, stating that between 1980 and 2010, such disasters have resulted in 1969 deaths, and affected 18 456 835 people. In this example, as the effects of extreme weather events on health are difficult to quantify due to under-reporting, the plan recognised the need to improve reporting and information systems. Furthermore, the need for adequate surveillance measures to be in place to respond to disease outbreaks and ensure that the health system is also able to respond to such disasters was highlighted.

On one hand, the adaptation plan provides a framework for the implementation of the NCCRP during the timeframe of 2012 – 2016 and the NDHSP (DoH, 2014), furthermore, does not consider climate change. One the other hand, it is well known that the effect that climate change has in human settlements and vulnerability is an important consideration to be included in the NDHSP, as it is likely to increase human health risks. Therefore opportunities exist for a longer term plan climate change and health plan that incorporates cross-sectoral interactions, such as those in the water, agriculture and human settlement sectors.

3.1.3 Human settlements

A key aspect to the improvement of urban and rural settlements in the country is the need to address the problems of poor spatial and development planning inherited from the apartheid era. Specifically urban settlements were planned in maladaptive ways, with more vulnerable (historically disadvantaged) households planned on the urban periphery away from the urban economic centres (DEA, 2014a) which makes them particularly more vulnerable to climate change. The NDP therefore speaks of the need for spatial reform, where people need to live closer to the places they work and the need for more efficient and competitive infrastructure in the context of economic growth. As such infrastructure that is conducive to growth and job creation is needed and would require the long-term affordability and sustainability of commercial transport, energy, telecommunications and water. These types of infrastructural upgrades are important not just from the perspective of growing the economy but are imperatives for people to improve their own lives. Due to diverse nature of settlements in South Africa these settlements can be considered as being as urban, rural and coastal settlements, each with their own set of developmental challenges and potential to be impacted by climate change.

3.1.3.1 Urban settlements

The majority of the country's population live in urban areas that have increasing water and energy demands, and complex social-ecological systems (DEA, 2011). The challenges are likely to be exacerbated by climate change. In response, critical interventions are needed that include the building of climate resilient infrastructure, water and energy sensitive urban design, and consideration of ecosystem services when planning for development.

The Spatial Planning and Land Use Management Act, No. 16 of 2013 (SPLUMA) provides a framework to guide spatial planning and land-use management in country. Draft regulations made in terms of this Act were published for comment in 2014. Of specific relevance is that the spatial planning system which consists of the management and facilitation of land use through the mechanisms of land use schemes (SPLUMA) has to, according to these draft regulations, incorporate environment requirements, such as climate change, however no specific details of the aspects of climate change that should be considered are provided.

Furthermore, the planning of housing and the provision of essential services (electricity and water) are key to meet the development goals for this sector. From an energy perspective, South Africa's energy supply is dominated by the use of fossil-fuels, with coal-fired electricity generation being particularly vulnerable to climate vulnerability. For example, extreme weather events are known to affect both generation and transmission infrastructure (DEA, 2014a). In light of the problems that can arise from impacts of extreme-weather events on electricity generation, climate change mitigation responses taken in the country are likely to have co-benefits for adaptation. For example, all new buildings and extensions have to comply with the National Building Regulations requirements to meet minimum standards for energy efficiency in buildings (Mnguni and Tucker, 2014) which result in buildings being more efficient and require less energy for heating and cooling. The National Home Builders Registration Council (NHBRC) is the regulatory authority for the home building industry, responsible for monitoring compliance with the building regulations.
In the case of water, the country faces deteriorating water resources due to quality and quantity, as well as infrastructure and there are numerous people that still do not have access to piped water. The provision of clean potable water to all and other key services is a key facet of the NDP and therefore there is a need for cross-sectoral approaches to understanding water demand, infrastructural needs, potential impacts of climate change and the potential for large population movements in light of deteriorating environment conditions and access to services.

The urban landscape further consists of informal settlements that are more vulnerable to extreme weather events due to a lack of services, infrastructure and well-built dwellings (DEA, 2014a). As these informal settlements are typically located in climate-vulnerable areas these households are likely to be placed at increased risk. As such there is a need to ensure that such settlements are upgraded or moved to more resilient locations (DEA, 2014a) and further a need to ensure that appropriate disaster risk management plans are in place.

3.1.3.2 Coastal settlements

Many South African cities are built along the coastline. With climate change expected to increase both the frequency and intensity of storms that are associated with sea level rise. So the country's coastline will become increasingly vulnerable to storm surges, coastal erosion, sea-level rise and extreme weather events (DEA, 2011). As climate change impacts are expected to negatively impact on the coast and coastal infrastructure, creating the need for coastal management plans need to incorporate relevant climate information systems and adopt a risk-based approach to planning.

Climate change is not directly incorporated into the Environmental Impact Assessment (EIA) legislation in the country and there is no legal mandate to ensure that EIAs consider climate change. However, according to the National Environmental Management Integrated Coastal Management Act, 2008 (Act No.24 of 2008) estuary management planning must consider the predicted impacts of climate change and potential disasters, so as to minimize the potential detrimental impacts of predicted climate change through a precautionary approach to development in and around estuaries and with regard to the utilization of estuarine habitat and resources. Furthermore, Integrated Coastal Management Act (Act No.24 of 2008) has been amended with respect to the coastal protection zone. This protection zone aims to manage, regulate and restrict the use of land that is adjacent to coastal public property. As such it has been amended to increase the surface area of flood prone areas as a consequence of climate change. The Integrated Coastal Management Act 24 of 2008 further requires that coastal provinces and municipalities develop management programmes with the potential for climate change impacts to be taken into account in all coastal planning and management. Rural settlements

According to the NDP there is further need to develop an inclusive and integrated rural economy, as rural settlements are typically characterised by poverty and limited employment in agriculture. In response there is a need to 'create more jobs through agricultural development based on effective land reform and the growth of irrigated agriculture and land production" and to 'develop industries such as agro-processing, tourism, fisheries and small enterprises where potential exists." (RSA, 2011).

Spatially resilient rural development is also envisaged by the NDP. The NDP states that the country's 'rural communities should have greater opportunities to participate fully in the economic, social and political life of the country". The NCCRP states that over 39% of South Africans live in rural areas, with a large proportion of the impoverished people living on communal farming areas (DEA, 2011). Climate change is likely to have impacts on food production and spatial planning and land distribution and thus affect rural settlements. Furthermore as rural communities are more reliant on natural water sources, they are more likely to be impacted (DEA, 2011). In response to this the NCCRP recommended that subsistence and small-scale farmers should be educated about climate change and supported to develop adaptation strategies, prioritising indigenous knowledge and local adaptive responses.

The Climate Change Adaptation Sector Plan for Rural Human Settlements (2013) was developed to support the creation of sustainable livelihoods that are resilient to climate change. A significant focus is therefore on the integration of climate change responses into the Comprehensive Rural Development Programme (CRDP). The CRDP is the key strategy in the department's campaign to reduce poverty, malnutrition, unemployment and shortage of infrastructure in rural South Africa. It is reported that under the CRDP, during 2012, 2 447 household food gardens were established and that 39 331 rainwater harvesting tanks were distributed to households, among other initiatives carried out in rural communities (RSA, 2014).

A further goal is to ensure that EIAs, spatial development frameworks and land-use schemes take cognisance of climate change risk, with a focus on therefore developing norms and standards for climate resilient land use management and spatial planning. Furthermore, whilst numerous early warning systems (EWS) have been developed challenges are faced with respect to the dissemination of warnings in local languages and in the appropriate format (DEA, 2014b).

In support of creating sustainable rural settlements, improved local disaster risk local and vulnerability assessments to inform local government planning are needed. This requires the improvement of EWS, and research to support the development of disaster response strategies and programmes to support climate resilient small-scale and subsistence agriculture. The sectoral adaptation plan further emphasizes that local and community-level adaptation planning, and leveraging community experiences and indigenous knowledge must form part of the response.

3.1.4 Water sector

A key focus of the NDP is to ensure that there is sufficient water for the core economic generating industries in the country and that all South African citizens have access to safe drinking water. South Africa is a water scarce country and it is projected that it will exceed the limits of its economically usable, land-based water resources by 2050. Furthermore, the NCCRP highlights that climate change will adversely impact on the availability and distribution of rainfall and, therefore, water resources throughout the year.

The National Water Act (Act 36 of 1998) (NWA) facilitates the development and implementation of an integrated water strategy which is legally binding on any institutions implementing the National Water Act. The second National Water Resources Strategy of 2013 (commonly referred to as "NWRS2") specifically aims to set out how the country will achieve the core objective to ensure water for an equitable and sustainable future. The NWRS2 has dedicated a chapter to climate change, in which it seeks to address the core issues raised for water in the NCCRP. Furthermore, a Climate Change Strategy for Water has been drafted in 2013 that aligns with the NWRS2, and specifically highlights the importance of monitoring and assessing the implementation of the NWRS2. Furthermore, reconciliation studies provide a short-to-medium term perspective on planning new water infrastructure, but typically climate change is not a consideration in forecasting the water supply or demand within these studies. The Water for Growth and Development Framework 2030 provides a medium to long-term perspective on managing water resources in the country. This framework states that all scenario planning responses such as reconciliation strategies must consider climate change to ensure that measures are implemented timeously (DWAF, 2009).

Thus whilst South Africa has made significant strides in developing water policy that includes climate change considerations, implementation of these policies will be important. Furthermore, there is a need to understand where conflicts are likely to arise in terms of the needs for urban supply of water, water for agriculture, water for industrial activities and heightened exploitation of ground water resources within the context of climate change

3.1.5 Biodiversity

Biodiversity plays a crucial role in providing ecological functions that support land and marine ecosystems, and healthy ecosystems are central to human well-being. South Africa is considered as one of the most biologically diverse countries in the world due to its species diversity and endemism and diversity of ecosystems. All South Africans depend on healthy ecosystems for economic and livelihood activities which include agriculture, tourism and numerous income generating and subsistence level activities.

South Africa's policy and legislative environment for biodiversity is relatively strong and includes key central elements such as the White Paper on the Conservation and Sustainable Use of South Africa's Biological Diversity (1997) (DEAT, 1997); the Natural Environmental Management Act (Act 2017 of 1998); National Environmental Management: Protected Areas Act (Act 57 of 2003); and National Environmental Management: Biodiversity Act (Act 10 of 2004) (CBD, 2014). Other key strategic documents include the National Biodiversity Strategy and Action Plan (NBSAP) (2005) (DEAT, 2005), the National Biodiversity Framework (2008) (DEAT, 2009) which is required in terms of the Biodiversity Act and draws strongly on the NBSAP; and the National Protected Area Expansion Strategy (2008) (RSA, 2010). The second national biodiversity assessment (NBA) of South Africa's biodiversity was completed in 2011, which followed from the National Spatial Biodiversity Assessment (NSBA), undertaken in 2004. South Africa's fifth national report to the Convention on Biological Diversity provides an update on South Africa's biodiversity status; biodiversity targets, protected area targets, and targets in the National Biodiversity Strategy and Action Plan (NBSAP) and National Biodiversity Framework (NBF); and progress towards the 2020 Aichi Biodiversity Targets and contributions to the relevant 2015 targets of the Millennium Development Goals (CBD, 2014).

Significant research has been conducted in South Africa in the areas of climate and CO_2 impacts on vegetation structure and function, ecosystem-based adaptation and conservation adaptation approaches. Climate change is one of the key pressures on terrestrial ecosystems, along with loss and degradation of natural habitat, invasive alien species, and pollution and waste. However, the combined impacts of climate change and other pressures such as invasive alien species, habitat loss and fragmentation are also of concern. South Africa's 2nd National communication (SNC) (DEA, 2011) highlighted information needs to facilitate adequate adaptation to climate change in the biodiversity sector. These included a need for more monitoring studies at national and sub-national scale for evaluation of future risk, improving model projections of impacts, and designing and assessing adaptation responses; more information on ecosystem-based adaptation (to use biodiversity in assisting social adaptation to the adverse impacts of climate change) and an assessment of the effectiveness of these options; and further verification of the modelling methods on which projections of biodiversity loss due to climate change are based. In addition, the SNC highlighted a need for a quantitative and spatially integrated evaluation of future climate change scenarios on the majority of marine systems and a better understanding of the nature of change in SA's marine and coastal environment.

The NCCRP (RSA, 2011b) outlined projected impacts of climate change on South Africa's key biodiversity assets along with recommendations on how to meet the challenges through integration of climate change into the management of biodiversity and ecosystem services.

Approaches suggested in the NCCRP included the need for increase institutional support to biodiversity management and research institutions; expansion of protected area network (in line with the National Protected Area Expansion Strategy); prioritisation of climate change research into marine and terrestrial and ecosystem services; expansion of existing gene bank to conserve critically endangered species; and prioritisation of impact assessments and planning to include full-range of possible climate outcomes.

The LTAS Phase I findings summarises climate change impacts under an unconstrained global fossil fuel emissions scenario (IPCC A2 emissions scenario) as well as general adaptation response options and future research needs for the biodiversity sector, which is informed by relevant past and current research (DEA, 2013a). The report provided an update to previous understanding of the rate and extent of climate change impacts on biomes, ecosystems and biodiversity in South Africa. Vulnerability assessments for the sector were revised using updated, refined climate results, revised severe climate change scenarios for the South and Western parts of South Africa projected by earlier studies (reported in SA's 2nd National communication (DEA, 2010)), and an updated biome-and species based approach. Integrated assessment approaches are needed to make findings of the models and impact assessments more relevant to policy formulation and implementation related to land use and infrastructure planning and investment-decision-making (Ziervogel et al. (2014).

The draft report on 'Climate Change Adaptation Plans for South Africa's Biomes' (Davis et al., 2014) builds on work conducted as part of the LTAS programme (DEA, 2013a) and presented potential adaptation responses to guide current and future decision makers in protecting South Africa's natural ecosystems and biodiversity in the face of climate change.

3.1.6 Agriculture, Forestry and Fisheries

The agriculture and commercial forestry sectors are important to South Africa's GDP and employment in the country, and also in terms of the role these sectors play in either contributing to GHG emissions or reducing GHGs. These sectors are vulnerable to changes in water availability, increased water pollution, soil erosion from intense rainfall events and increased evapotranspiration. The potential adverse implications of climate change on food production, agricultural livelihoods and food security were highlighted as significant national policy concerns in NCCRP (RSA, 2011b) and South Africa's SNC (DEA, 2011). Climate-resilient responses in these sectors should promote food security, conserve soil quality and structure, contribute to biodiversity and contribute to empowerment goals. Priorities to build climate resilience in the agriculture and forestry sector included the integration of climate-smart agriculture into climate-resilient rural development planning, development of long-term scenarios, use of early warning systems, improving food security, and increased integration into other sectors (e.g. water sector, rural development) (RSA, 2011a; DAFF, 2012).

The Department of Agriculture, Forestry and Fisheries (DAFF) has been proactive in initiating sector-related climate change strategies and scenarios to promote awareness of climate change, to advocate sustainable practices which aimed to contribute the least to emission of green-house gases, conserve the sectors natural environments and mitigate the effects of climate change as much as possible (DAFF, 2012b). The Integrated Growth and Development Plan (IGDP) for the Department of Agriculture Forestry and Fisheries (DAFF, 2012) describes the current realities and challenges of the agriculture, forestry and fisheries sector and outlines the goals, objectives and interventions that need to be made to as part of their long-term strategy to address key national issues. The agriculture, forestry and fisheries sector each impact on climate change and/or the other sectors. Selected interventions proposed in the IGDP (DAFF, 2012) include developing a water demand management strategy for Agriculture, Forestry and Fisheries, an Integrated Climate Change Strategy and a National food policy.

The Climate Change Sector Plan was gazetted on January 2013 (DAFF, 2013a). DAFF is currently developing the 'Climate change adaptation and mitigation plan for the South African Agricultural and Forestry sectors'. DAFF's Strategic Plan for 2013/14-2017/18 (DAFF, 2013b) includes a medium-term target of monitoring the implementation of climate change adaptation and mitigation programmes between 2014/15 – 2015/16 and to review climate change adaptation and mitigation plans by 2016/17. The agriculture, forestry and fisheries sectors are discussed in the following sections in terms of existing policy, measures implemented or required and information needs to facilitate climate change adaptation.

3.1.6.1 Agriculture

The White Paper on Agriculture (1995) provided a good framework for the formulation of development programmes. Sustainable resource management was identified in the Strategic Agriculture Sector Plan (NDA, 2001) as one of the main areas which required intervention. This plan was reviewed in 2008 (Sebakwane, 2008) and resilience to climate change and food security, were identified among others, such as land reform, support services and participation of vulnerable groups, as key areas which needed urgent strategic action (Sebakwane, 2008). Due to the influence of the Kyoto Protocol, the Clean Development Mechanisms and other climate change frameworks, government has started programs to monitor trends regarding status of natural resources (Sebakwane, 2008).

The Agriculture sector is identified in the National Development Plan (NDP) (RSA, 2011a) as a critical sector for employment and food security since it is often the primary economic activity in rural areas. Targets for an inclusive rural economy include creating an addition 643 000 direct jobs and 326 000 indirect jobs in the agriculture, agro-processing and related sectors by 2030 and maintaining a positive trade balance for primary and processed agricultural products (RSA, 2011a). One of the risks related to agricultural expansion is the need for additional water. To support this need, increased investment in the water resource and irrigation infrastructure, where the natural resource base allows, is required, and the efficiency of existing irrigation also needs to be improved. Integrated assessments of adaptation in the agriculture sector and water sectors need to be conducted to assess implications of climate change on, for example, groundwater recharge on which the agriculture sector is heavily dependent. The NDP proposes that these needs related to environmental sustainability and resilience can be supported by the establishment of an independent Climate Change Centre, in partnership with academic and appropriate institutions, development of regulatory framework for land use to ensure the conservation and restoration of protected areas, channelling of public investment into research, new agricultural technologies for commercial farming, as well as for the development of adaptation strategies and support services for small-scale and rural farmers.

A general recommendation in the SNC (DEA, 2011) for both large-scale commercial farmers and farmers at the rural livelihood scale was that adaptation to climate change required an integrated approach that addresses multiple stressors and combines the indigenous knowledge/experiences of vulnerable groups with latest specialist insights from the scientific community. It was noted that due to the local repercussions of climate change, agricultural programmes which are usually initiated at high levels in government for regional implementation and planning strategies in regard to climate change needed to focus on local conditions. Conservation agriculture (as an integrated approach to address multiple sectors) and water and nutrient conservation technologies (as a measure for sustainable dryland agriculture) were highlighted as some of the adaptation options needed for the sector.

The IDGP (DAFF, 2012) identified the need to develop both adaptation and mitigation strategies for the sector. Adaptation strategies in the agricultural sector would include diversification in crop and livestock production (varieties and breeds), income diversification, and changing seasonal migration (e.g. for livestock farmers). However, since the adaptive capacities of the poor may be most constrained, public policies to support adaptation by poor producers, on the grounds of human rights, economic development and environmental sustainability are favoured. The most effective adaptations will require substantial public and private investments in irrigation, support of stress-tolerant crop varieties and animal breeds, and support to improve roads and marketing infrastructure for small famers. Water-efficient production technologies and rainwater harvesting for smallholder production will be essential in South Africa.

Adaptation responses recommended in the LTAS report for both the agriculture and forestry sectors (DEA, 2013b) included utilisation of best management practices based on the principles of ecosystem and community-based adaptation, conservation agriculture, climate-smart agriculture and agro-ecology, and diversification in the agriculture sector. Research needs included the need for an integrated approach that addresses multiple stressors, and combines indigenous knowledge and experience with the latest scientific insights and the need for a holistic assessment of adaptation related future research needs that consider the full range of plausible climate scenarios.

3.1.6.2 Forestry

The White Paper on Sustainable Forest Development in South Africa (DWAF, 1997) provided a policy framework for the management and sustainable development of forests, and set out goals to be pursued over a five-year time frame (1996-2001). The National Forest Act, 1998 (Act No. 84 of 1998) was promulgated to give effect to the provisions of the White Paper. Strategies related to urban greening, woodlands, participatory forestry, and forestry enterprise development were subsequently developed, as well as policies related to transformation of the forestry sector (e.g. Forestry Sector Transformation Charter (DWAF, 2007) gazetted in 2009) and transfer of state owned industrial plantations (DAFF, 2012).

Climate change will impact current and future initiatives to ensure sustainable forest management; however, this was not taken into account by previous policies and strategies. Development of adaptive responses to economic, market and technology scenarios as well as climate change scenarios was one of the long term actions recommended as part of a strategic objective in the Forestry 2030 Roadmap in terms of managing risks to growth to the sector

(DWAF, 2009). Management of wildfires, tree selection and breeding, and optimised site-species matching using empirical and mechanistic modelling techniques to predict site suitability were among the adaptation options presented for the forest sector in the South Africa's SNC (DEA, 2011).

3.1.6.3 Fisheries

The White Paper on Marine Fisheries Policy for South Africa (Anon, 1997) considers all natural marine living resources, the environment in which they exist and in which mariculture activities may occur, as a national asset and the heritage of all South Africans which should be suitably managed and developed. The policy is based on objectives and principles related to sustainable utilisation and the replenishment of living marine resources, long-term social and economic benefits, and aspects of marine resource management (Anon, 1997). The Marine Living Resources Act, 1998 (Act No. 18 of 1998) was promulgated to give effect to the provisions of the White Paper. Strategies and policies were subsequently developed which related to management and allocation of long-term commercial fishing rights and small scale fisheries. There is a need for the development and implementation of options to reduce the impacts of climate change on the South African fisheries. According to the interventions required for the fisheries sector in DAFF's IGDP, strong decadal variability implies a need for adaptive management strategies to be used at five- to ten-year intervals as productivity and distribution of resources change" (DAFF, 2012).

In LTAS Phase 1, a semi-quantitative approach was used to assess the likely impacts of climate change on marine fisheries in South Africa (DEA, 2013c). An assessment of the estuarine and inshore, and the offshore fisheries trends; and the current potential for projecting climate change impacts was conducted. Needs for marine fisheries sector included needs related to a need for robust stock assessments, effective data management and science-based management action grounded in the realities of resource abundance are needed to secure resource sustainability in the long term. Key modelling capacity is also needed need to develop more likely scenarios of physical oceanographic and coastal habitat change. In addition, greater emphasis needs to be placed in policies on diversification of activities and income generation of the vulnerable coastal and fisher communities and socioeconomic linkages from climate change impacts on the fisheries sector to other sectors is required. The interactions between the impacts of unsustainable fishing and climate change need be considered in tandem and not as separate issues.

3.2 Adaptation planning objective for South Africa

As a developmental state, South Africa has embarked on tackling the root causes of poverty and inequality. The country further has recognised the need to respond to climate change and recognises that climate aspirations are likely to have an unsuccessful/slow rate of implementation if not understood in the context of poverty and equality (RSA, 2011a). As such, an overarching aspiration is to place the availability and vulnerability of natural resources and the vulnerability of the South African population to climate change at the centre of the NDP initiatives This is needed to ensure long-terms plans incorporate climate resilient development and enhance the country's contributions towards global efforts to respond to climate change. Whilst all stakeholders, across all sectors, will collectively have to make contributions to resolving these issues, it is the role of government to ensure that the appropriate policies to mainstream climate change into planning occurs and that appropriate skills and capacities are developed.

The NDP (RSA, 2011a) provides a timeline that can be used to guide the approach taken to achieving the country's adaptation goals. Specifically, the NDP states that by:

- 2020 - annual data on climate impacts should feed into assessment, reporting, policy and regulatory process and that by this time plans to strengthen the states capacity would start to pay off, with rigorous skills development interventions active across the country. It is further required that resilience planning is integrated into all planning processes in the country.

- 2025-2030 - it is proposed that the investments in climate resilient infrastructure made in the previous decade would start to bear fruition and that the state would be well capacitated to comfortably manage its policy, regulatory and support functions, and report to the national and international arenas as appropriate.

South Africa aims to develop by 2017 a National Climate Change Adaptation Strategy that will be used as the National Adaptation Pan (NAP) for the country which will prioritize the key activities to co-ordinate and prioritise the country's climate change adaptation needs. The following aspirational goals aim to inform the above plan.

Goal 1: Develop a National Adaptation Plan as part of implementing the National

Aspiration: To provide information relevant to potential climate change impacts and adaptation responses at an appropriate scale that can be embedded at key junctions of decision-making and regulatory processes

1.1 To generate information relevant to vulnerability and potential climate change impacts at an appropriate scale, this would include, for example:

- Information that can support the implementation of the SPLUMA, specifically to provide contextualisation and localisation of climate change impacts so as to provide information to assist planners and decision-makers in understanding when land-use options may be adaptive
- Provision of climate information at a scale that can be integrated into medium- and long-term spatial development plans and information systems

1.2 To enhance the knowledge base and research capacity to support the identification of adaptation needs to the impacts of climate change

- To perform an audit of R&D gaps across all key sectors and of the investment that is required to support the required the R&D strategy
- Examples of current research needs identified in recent literature for the key sectors include:
    - Human settlements: the key research areas in this programme will need to include climate resilient agriculture relevant to small-scale and subsistence farmers,

technology innovation in service delivery to rural human settlements, and an audit of indigenous agricultural knowledge and practices (DEA, 2014c)
    - Urban settlements: The NCCRP states that there is a need to develop effective information, monitoring and assessment tools to evaluate the resilience of cities and towns to climate change and assist urban planners in identifying priorities for scaling-up climate change responses
    - Health: Ziervogel et al. (2014) highlights that there is a need for further research on understanding the links between climate change, food security, nutrition, and health
    - Water: Model water parameters and understand how ground water recharge will be impacted by climate change. There is a further a need to understand how the country's developmental pathways in terms of agriculture and energy are likely to be impacted by water
    - Biodiversity: The NCCRP included the prioritization of climate change research into marine and terrestrial and ecosystem services, and the need for monitoring studies to evaluate and quantify risk to better design and refine adaptation responses
- To inform options for adaptation and costs across sectors:
    - To use sectoral research outputs in the development of new products and technologies to support adaptation objectives
        - For the adaptation options identified develop an understanding of the public and private investments that are needed
- To perform an R&D audit and user-need assessment for the development of early warning systems

1.3 To strategically focus research efforts and co-ordinate cross-sectoral investigations and to develop a climate change data repository to collect and store the key data that is needed for climate modelling and impact studies

- An independent "Climate Change Centre" is proposed that can work in partnership with academic and other institutions to support the actions of government, business and civil society. The NDP does not, however, give details of the nature and function of this proposed Centre and as part of this goal, the development of this centre could be explored.
- A consistent set of climate data is needed to be centrally collected and stored so as to support the aspirations of Goal 1
- These data should be made available freely to the public (using platforms such as the South African Risk and Vulnerability Spatial Portal) to support localised impact and vulnerability studies

Goal 2: Take into account climate consideration the national development and sectoral policy framework by 2020/2025

Aspiration: To ensure that there is alignment between sectoral plans, economic growth and potential climate change impacts

Based on the NCCRP key sectors the following are examples of key alignment trajectories that should be sought:

2.1 To ensure that planned agricultural growth aligns with projected long-term climate impacts

- The NDP described the need to increase exports in the agriculture and agro-processing industries in the context of economic growth, with the creation of an addition 643 000 direct jobs and 326 000 indirect jobs in the agriculture, agro-processing and related sectors by 2030 as a means of creating an inclusive economy. The NDP further mentions that the aim is to have a positive trade balance for primary and processed agricultural products. As such there is a need to ensure that these expectations are considered within the context of expected climate impacts on this sector and that appropriate interventions can be implemented to meet these goals.

2.2 To ensure that implications of climate change on human health, water, rural settlements and agriculture are considered within the context of ensuring food security in the country through the development of a food security plan that includes climate change considerations

- Cross-sector linkages and trade-offs and synergies between water and agriculture have implications for nutrition and poverty reduction, that are likely to impacted on in a changing climate
- These impacts are likely to be exacerbated by issues of vulnerability and resilience of rural communities

2.3 To ensure that the health care system is able to respond to the health risks associated with a changing climate through the development of a climate change and health strategy

- The current adaptation plan for the health sector was developed for the period of 2012-2016 and the current NDHSP does not consider climate change.
- Policies and plans within the health sector to respond to climate change are fragmented and implemented with a short-term view
- As such there is a need to develop a strategy that provides the direction for climate change and health over the medium-to-long term
- An overall climate change and health strategy would seek to address the gaps between the adaptation needs for the sector and the NDHSP. The strategy could further incorporate the needs to move toward energy efficient health infrastructure

Goal 3: Strengthening capacity at institutions and institutionalisation to climate change

Aspiration: To strengthen government's capacity to respond to climate change and educate the public on climate change

3.1 Build institutional capacities to ensure that climate change considerations are integrated into governmental policy and decision-making

- Local governments need support to build capacity (in terms of not being able to respond to disasters)
- Institutional arrangements should support integrated approaches to dealing with climate change across different sectors
- In addition to building government's capacity, there is a need to build capacity and awareness around climate change impacts on infrastructure for planners and engineers; to educate farmers and raise the public's awareness of climate change (e.g. heat stress) and increase capacity within health sector on climate change issues

3.2 To support institutionalizing climate adaptation across all spheres of government

- With the generation of information on vulnerability and adaptation needs, as well as the integration of climate change considerations into policy there is a need to ensure that processes are put in place whereby policies on climate change adaptation become institutionalised
- In determining the operational budgets, the budgets associated with actioning climate change adaptation plans should be allocated
- Assignment of responsibility for the implementation of climate change actions and advocacy of related policy should be established

3.3 To ensure that the most suitable technologies as identified in Goal 1 are used and that there are sufficient finances to support the implementation thereof

- Aspiration goals listed above provide opportunities for various forms of 'softer' technology transfer, that include institutional arrangements, management practices and knowledge, skills and capacity building
- Additionally there is also a need to ensure that the appropriate 'hard' technologies (e.g. early warning systems) as identified through the R&D strategy (Goal 2) are adopted
- Costs and benefits of implementing these 'soft' and 'hard' technologies needs to be understood and appropriate investments need to be leveraged to support the uptake thereof

3.4 To ensure that effective co-ordination, good governance and action plans in place and appropriately implemented

- Achieving this goal will depend on ensuring that the goals related to vulnerability assessments and capacity building are also achieved
- Implementation of risk mitigation and management systems as a basis for the allocation of disaster management funds and interventions

Goal 4: Development of an early warning and reporting system for all climate adaptation sectors

Aspiration: To use information on vulnerability and risk to enhance early warning systems and report on progress and implementation of adaptation plans

4.1 To facilitate the reporting of adaptation policy implementation and outcomes across sectors using existing reporting structures and sources of information

- Institutions /organisations submit reports on climate change adaptation activities in relation to costs, outcomes and impact
- Report on climate change risks and proposed adaptation measures in key sectors
    - Contribute to the national monitoring and evaluation system for gathering information and reporting progress on the implementation of climate change interventions
- Utilise the above information to compile national reports and support reporting to UNFCCC, for example

4.2 To ensure regular monitoring and review of adaptation plans

- Regular monitoring and review of adaptation plans across sectors will be necessary as new and improved information which takes into account a changing environment of vulnerability becomes available through the outputs of Goal 1

4.3 To ensure that early warning systems are well integrated into governmental policy and decision-making processes and emergency management systems at both the national and the local levels, and are subject to regular system testing and performance assessments

- Early warning systems are developed/enhanced for key sectors
    - Goal 1 (outputs from the R&D audit) would inform the development of early-warning systems across the sectors
    - Goals 2 and 3 would facilitate the implementation of plans and effective responses and dissemination of information to communities
- Communication of risk information
    - To ensure the effective dissemination and communication of warnings related to climate change, in all local languages

Goal 5: Development of a vulnerability assessment and adaptation needs framework y 2020 to support a continuous presentation of adaptation needs

Aspiration: Consider adaptation to the impacts of climate change and means to increase resilience in sectoral plans and National Adaptation Plan, revised after each five-year implementation period.

Goal 6: Communication of past investments in adaptation for international recognition

Aspiration: The government of South Africa will invest in adaptation to ensure its citizens – and particularly poor communities – are less negatively impacted by climate change. It will seek recognition of such efforts in the UNFCCC.

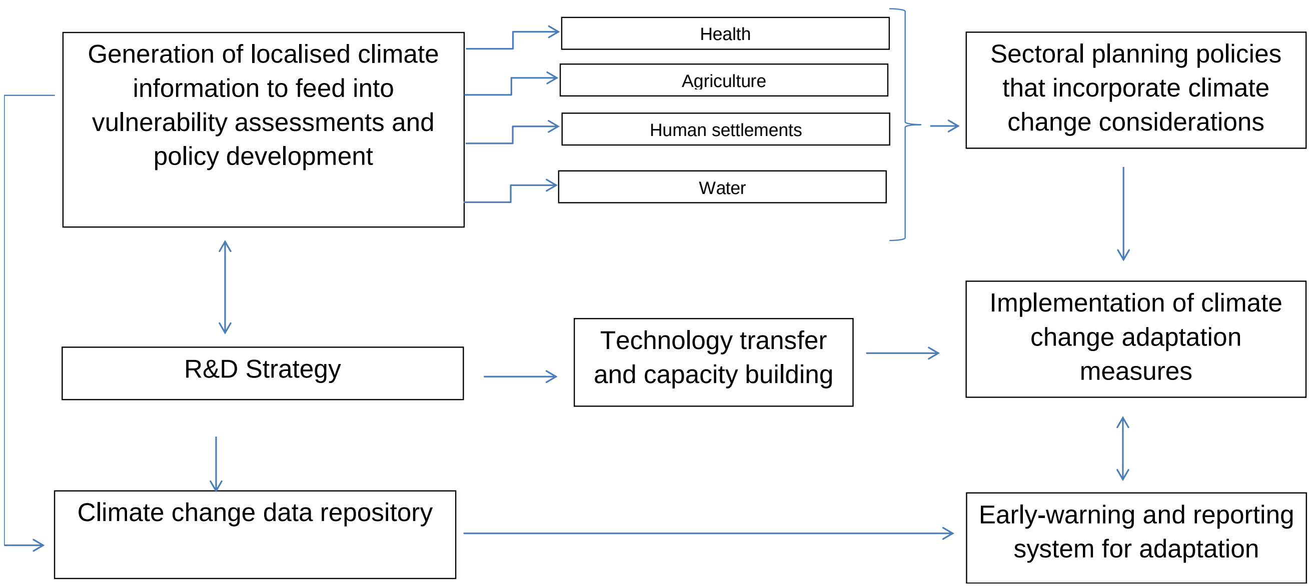


Figure 1: Representation of the aspirational goals that the country could potentially strive towards in terms of contributing to adaptation.

4 Adaptation needs for South Africa for upcoming contribution cycles

4.1 Analysis of existing information for quantifying adaptation needs

4.1.1 Introduction

Adaptation needs in this study are informed by adaptation costs. In this section, adaptation costs associated with extreme climate events that are reported in the literature or in national and international databases are presented. The work builds on previous investigations done by the LTAS and should be seen as supplementary to those national studies. Much of the existing data used in the LTAS reports is extracted from the National Disaster Management Centre (NDMC) reports and the Centre for Research on the Epidemiology of Disasters (CRED). The information in this report does not necessarily repeat any of the LTAS work, but is rather aimed at providing a supplementary dataset to the already existing LTAS information. Similarly, although simulation modelling studies were used in the LTAS work to characterise historical and future flood and drought events in South Africa. It was not possible in that phase of the project to analyse this data in association with reported damage costs by different groups as part of the current study.

The basis for reported costs here comes from CRED, who has been maintaining an Emergency Events Database EM-DAT, initially created to support the WHO and the Belgian Government and now provides a global repository of extreme event damage costs. The EM-DAT data is widely used and provides the basis for the costs reported as part of this project. It was, however, necessary to supplement and in some cases adjust information from EM-DAT and the NMDC with additional data extracted from other sources for the following reasons:

- The EM-DAT defines estimated damages (given in US$ ('000)) as the amount of damage to property, crops, and livestock.
- The EM-DAT statistics for each event are summarised as a single value, with no information regarding the number of events within and across years or the spatial variability within each country.
- Reported values represent the damage value at the time of the event, but on further investigation, it became clear that this is not always the case. Here, the inclusion or exclusion of future economic losses due to an extreme event in a specific year depend on which source was used; and/or the characteristics of the extreme event itself such the variability in the size of the area affected, duration, location and the main cause of individual events.
- The EM-DAT/NMDC dataset was updated to include such details (when possible) in order to determine whether differences in reported damage costs can be characterised by area type affected and frequency of occurrence. Examples of area type include temporal variation such as summer versus winter rainfall areas; spatial variation such as northern KZN coastline versus southern Cape coastline or inland versus coastal areas; and land use variations such as natural areas versus built-up and agricultural areas. The return period and duration of an extreme event and the spatial location of an event should in general be reported and validated accordingly at least at the provincial scale.

- Reported damage values were traced through the literature and other data sources and in some instances generally correspond with each other, but the currencies in which these values are reported are inconsistent or in some cases reported for different years.
- In some cases, extreme events span multiple years, for example a drought. It is not clear from the data sources like EM-DAT/NMDC how the yearly costs were partitioned for multiple years or if the costs were reported only for one year.

Additional data sources used for this project include information from the Forestry Industry of South Africa (www.forestry.co.za/, last accessed on 27 Feb 2015), the Flood Observatory at the Colorado University in the USA (, last accessed on 22 Feb 2015), the Global Disaster Alert and Coordination System (GDACS) (http://www.gdacs.org/ last accessed on 27 Feb 2015), the Preventionweb-Disaster Mitigation for Sustainable Livelihoods Programme (DIMP) of which the work done and published by the University of Cape Town in South Africa forms part of (www.preventionweb.net, last accessed 27 Feb 2015). GDACS is a combined effort of the United Nations, the European Commission and disaster managers worldwide to improve alerts, information exchange and coordination. It should be noted that the EM-DAT dataset is used as the basis for the costs (monetary and number of people affected) reported by Preventionweb. The work done by the University of Cape Town as part of DIMP for the southern Cape coastline contains detailed breakdowns that were used in this DEA-INDC report.

Currently, no national or international consensus exists with regards to how to calculate in a comparative, equitable and consistent manner the adaptation costs and needs associated with the impacts of extreme climate events. There is a lot of inconsistency between data sources and almost no verification. In this report adaptation costs only include the damage costs associated with the impact of extreme climate events (but not all of these could be fully verified without further investigation). Data from a combination of sources were used to update the dataset reported in the LTAS.

4.1.2 Global overview

The global climate is changing and countries are increasingly confronted by mounting losses from extreme weather events. According to (ref), by the year?, as much as 325 million people will be entombed in poverty, most of whom live in sub-Saharan Africa, and will be more vulnerable to the impacts of extreme weather events. The severity of impacts experienced in different locations varies due to the intensity of the events and the main cause of the event for example floods resulting from a tropical cyclone followed by heavy rains have a larger impact than the floods caused by heavy rains alone etc. However, an impact is almost always more pronounced in vulnerable societies in developing countries or in smaller geographic areas. In contrast, the damage costs and consequences are less severe in developed or higher income countries if gross capital formation is normalised.

Extreme climate events usually result in immediate loss of lives and assets as well as longer-term damage to livelihoods and economies (Royal Society, 2013). Between 1980 and 2004, the global economic cost of disasters worldwide has increased significantly to an estimated total of US$1.4 Trillion per year. It is further anticipated that a combined annual loss of US$1 Trillion will be experienced by middle income nations, including countries with large coastal cities by the mid-century (World Bank, 2013). These figures are probably underestimates given the limitations and gaps concomitant with assessing the impacts of extreme climate events. Often, the direct costs are recorded, while other undocumented costs from informal sectors (which are predominant in developing economies such as South Africa) are not easy to measure, and other impacts such as the loss of ecosystems services and cultural heritage are not recorded.

Estimating the full range of economic losses from natural disasters is an intractable task, both conceptually and practically. There is a dearth in comprehensive and methodical data on disaster impacts, but most of the available datasets still tend to underestimate the negative consequences from disaster losses (Kousky, 2012). The approach of separating disasters into direct and indirect damage costs and then summing them appears to be a theoretically straightforward accounting method for estimating the total economic impact of natural disaster. However, in practice this has proved to be difficult, and damage costs are often calculated from macroeconomic variables. Another way to view disasters is based on the assumption that direct and indirect impacts could be reflected in macroeconomic accounts for substantial events such as droughts. The focus on macroeconomic variables is probably due in part to the fact that good data are available, but caution should be applied as the ease of data availability does not imply that macroeconomic variables are the best measure (Kousky, 2012).

Damage costs can be split into two categories, namely direct costs and future income or economic value losses including indirect losses. Direct costs include costs associated with the repair or replacement of (a) infrastructure such as transport infrastructure including railway, air and road infrastructure, communication infrastructure towers and lines, water supply and sanitation infrastructure for commercial, government, private and agricultural water supply use; energy generation and supply infrastructure; and (b) property damage including government, private (formal and informal) and municipal owned buildings and houses. Future economic losses include the loss of agricultural, forestry, mining and manufacturing and service related outputs that can either translate into a direct economic loss when less products or raw material are available for trade purposes or an indirect loss when products or raw material need to be imported at higher prices to supplement a local shortfall. For purposes of this project direct damage costs were used where possible but when data included future economic losses as well these were noted and a range of costs were provided in order to capture these differences in reported damage costs.

Indirect losses include business interruption costs, including employment losses. Indirect costs have multiplier effects resulting from reductions in demand and supply of goods or interruptions caused to business due to loss of infrastructure and amenities, which further results in utility loss to households. Other impacts include diminished quality of life, increased commuting time as a result of damaged roads, or the extra costs of running private generators when there is no power (Kousky, 2013). There is also the possibility of double accounting (Rose 2004), for example counting both the aid disbursed by government and the rebuild costs as much of the aid is probably used for the reconstruction (Kousky, 2013).

4.1.3 South African overview

South Africa is vulnerable to a number of extreme weather events, with the most common being floods, droughts, fires and large storms (Figure 1 provides a classification of these events). The LTAS provides the context for the current risk and vulnerability profile of the country according to the socio-economic impacts of previous weather-related events, including costs associated with recovery (DEA (LTAS), 2014).

Box 1: Description of the four major categories of weather-related events included in this study

Disaster type	Description
Flood	*Rapid-onset flood*: the include flash floods, tidal surges, floods provoked by cyclones or accompanied by strong winds, high runoff from heavy rainfall, dam bursts and overtopping, canals and rivers bursting their banks. Typically water rising to dangerous levels within 48 hours (Smith 2009).
	Slow-onset floods: prolonged rainfall causing low-lying areas to gradually become flooded over a period of days or weeks (Smith 2009).
Drought	*Meteorological drought*: less than 70% of normal rainfall is received (Bruwer 1993).
	Agricultural drought: a reduction in water availability below the optimal level required by a crop during each different growth stage, resulting in impaired growth and reduced yields (Wilhite & Glantz 1985).
Wildfires[2]	The occurrence of fires is closely linked with high temperatures and dry spells, for example during Beg Wind conditions. Originally most fires were caused by lightning but today, more than 90% of fires are lit by people, either deliberately or accidentally (Forsyth et al. 2010). However any extensive propagation of a fire is also dependent on prevailing weather/climate conditions.
Storms	The classification of storms includes severe thunderstorms, cyclones, tornados, convective storms, frontal systems and cut-off low events (Department of Environmental Affairs 2011) which often cause flash floods. In this report we include in the classification of storm, storm surges, hail storms, severe cold fronts including some instances of snow. Storm surges are an irregular rise in sea level produced by a storm and characterised by heavy rains and high winds (Theron 2011).

According to South Africa's second national communication to the UNFCCC, the damage costs of weather-related disasters is estimated to be US$ 0.92 billion between 2000 and 2009 (DEA (LTAS), 2013). The NDMC Annual reports from 2006 to 2011, report that provincial and district municipalities bear a huge amount of financial burden from disasters with up to R 1 596 billion spent for rehabilitation and recovery in the 2010/2011 financial year (National Disaster Management Centre 2011).

As mentioned above, there are complexities associated with assessing damage costs from extreme weather events. For South Africa, the assessment of the impact of extreme weather events and their trends, at a national scale remains a challenge due to the scarcity of robust data for the country, including a lack of consistency in the reporting structure of the National Disaster Management Centre (NDMC). A conservative indication of costs is often taken from international databases such as EM-DAT (www.emdat.be). Other sources include media articles and previously reported incidents of extreme weather events.

According to the LTAS (DEA (LTAS), 2014), an estimated 17 million people (34% of the population) were impacted by drought while 570 000 people were affected by floods between 1900 and 2014. According to the international database EM-DAT, disasters have resulted in approximately US$ 4.6 billion in economic damages with approximately US$ 1.7 billion

[2] Also referred to veldfires in South Africa

attributed to floods alone. As noted in the introduction, the Centre for Research on the Epidemiology of Disasters (CRED)/Emergency Events Database (EM-DAT) underestimates the scope and prevalence of hazard events. EM-DAT only records data on events where ten or more people are reported killed, or 100 or more people need to be evacuated, provided with humanitarian assistance or otherwise affected; or the states declares an emergency or call for international assistance. This omits a myriad of small scale and day to day extreme events prevalent in South Africa such as the tornado in Duduza, despite the extensive damage it caused, only one child died, 160 people were injured and hundreds were left homeless (Extreme Planet, 2012; DEA (LTAS), 2014).

4.1.4 Approach

A spatial approach to determine the costs associated with extreme climate events in South Africa is suggested in order to derive cost functions for each type of extreme climate event. In future updates of this report the spatial distribution of losses to the economy (i.e. reductions in the Gross Value Added per spatial unit) need to be modelled using climate model outputs. Gross value added (GVA) is defined as the monetary value for the amount of goods and services that have been produced, less the cost of all inputs and raw materials that are directly attributable to that production. It can therefore be used for economically active areas but will underestimate natural areas or areas which do not have an economically productive value. Direct damage costs will be included in the adjustment of GVA values per sector selected. Non-economically active areas will have to be treated differently by applying a different measure than a pure loss in GVA value. This implies to incorporate the number of affected persons, loss in livelihoods, damage to biodiversity and land characteristics such as land degradation and soil erosion.

4.1.5 Preliminary results

The damage costs presented below are based on desktop studies, largely from media reports, of past socio-economic impacts associated with extreme climate events in South Africa. In the face of the large spatial and temporal variability associated with reported damage costs and events, combined with the limited amount of information available due to a sparse and often incomplete or inconsistent reporting structure, the costs reported are from a variety of sources (mostly the media), and based on broad assumptions to provide the costing basis. It is often difficult to make an objective judgement call based on media reports, and in the next version of this report simple mappings of damage costs will be used to clarify or fill in these values. Here, the mapping of assumptions from one spatial location to the next are based on a similar notion to Heisenberg’s inequality that damage costs are characterised by similar underlying topologies and events and therefore cannot simply be used across all reported locations or time periods, but rather have to be modelled using GIS based overlays of typology, economic variables, like GVA, and modelled extreme weather event outputs from climate models such as CCAM.

4.1.5.1 Fires

The most explicit data on annual wildfire damage comes from the forestry sector. The total damage costs due to fires however are not easily obtainable and are often compounded by downstream costs as well. These include a culmination of damage to round wood products (timber), which loosely translates into loss of downstream forestry products as well, these values are also somewhat ambiguous with the loss of future revenue, then there is the loss in employment, the cost of rehabilitation, and the cost of fire suppression among others. Forestry South Africa provides comprehensive timber statistics each year, which includes the annual burned area in hectares. From these statistics it is possible to estimate potential revenue losses based on the following broad assumptions:

- The annual R/ha value of plantations in South Africa can be estimated by dividing the round wood processing contribution to GDP through forestry by the total planted ha in South Africa.
- The maximum timber loss is derived by multiplying the average R/ha (from the above step) with the total burnt area.
- This assumption does not include fire suppression, or rehabilitation, etc.

It should be noted that the total burnt area reported includes slightly damaged and recovering trees, and therefore any costs derived will probably be an over estimation, or put another way a "worst case scenario" assumption. Table 1 provides a summary of the South African forestry and forestry products industry statistics from 1980 till 2012, Figure 1 presents the relationship between total burnt area and the estimated losses, and Figure 2 is a time series of assumed total damage cost losses.

Table 1. Summary of South Africa forestry & forestry products industry facts: 1980 -2012

Year	Forestry GDP (millions of US$)	Forestry Products GDP (millions of US$)	Total ha (All species)	Total burn area (ha)	Mean R/ha	loss millions of US$ (nominal)	Loss million US$ 2014 real
1979-1980	16.47	69.72	1096455	7784	150.2	0.12	2.75
1980-1981	21.62	95.01	1095157	12147	197.4	0.24	4.95
1981-1982	22.52	98.86	1131922	8591	199.0	0.17	3.06
1982-1983	28.47	115.36	1104737	6338	257.7	0.16	2.55
1983-1984	30.86	125.9	1110081	8459	278.0	0.24	3.27
1984-1985	36.21	166.82	1114958	5223	324.8	0.17	2.11
1985-1986	44.66	205.94	1133224	13080	394.1	0.52	5.53
1986-1987	57.83	288.56	1159780	5723	498.6	0.29	2.58
1987-1988	67.62	336.33	1182476	5953	571.9	0.34	2.65
1988-1989	83.27	467.36	1197850	6680	695.2	0.46	3.20
1989-1990	89.87	532.91	1241299	15923	724.0	0.115	6.94
1990-1991	91.21	543.25	1295531	6680	704.0	0.47	2.48
1991-1992	107.15	565.86	1301309	11469	823.4	0.94	4.30
1992-1993	101.9	509.05	1307207	13924	779.5	0.109	4.34
1993-1994	106.34	625.24	1365939	19915	778.5	0.155	5.65
1994-1995	161.0	747.88	1428630	26137	1127.0	0.295	9.85
1995-1996	179.79	899.83	1486923	11733	1209.1	0.142	4.37
1996-1997	174.59	914.27	1518138	13901	1150.0	0.160	4.58
1997-1998	212.78	1009.01	1383875	8276	1537.6	0.127	3.36
1998-1999	226.83	1181.34	1401800	16455	1618.1	0.266	6.57
1999-2000	257.41	1285.78	1330943	20221	1934.0	0.391	9.17
2000-2001	271.24	1186.65	1351760	17266	2006.6	0.346	7.72
2001-2002	326.62	1380.68	1351401	16727	2416.9	0.404	8.52
2002-2003	407.99	1459.07	1371628	28983	2974.5	0.862	16.64
2003-2004	421.63	1481.49	1339282	28326	3148.2	0.892	16.24
2004-2005	495.67	1502.54	1333562	22445	3716.9	0.834	14.98
2005-2006	516.65	1567.86	1281519	28895	4031.5	0.1165	20.24
2006-2007	51.67	1846.55	1266193	70697	4080.7	0.2885	47.89
2007-2008	60.47	2136.07	1257343	70812	4809.3	0.3406	52.80
2008-2009	670.48	2037.6	1274869	19805	5259.2	0.1042	14.48
2009-2010	679.39	2135.43	1271286	15812	5344.1	0.845	10.96

Year	Forestry GDP (millions of US$)	Forestry Products GDP (millions of US$)	Total ha (All species)	Total burn area (ha)	Mean R/ha	loss millions of US$ (nominal)	Loss million US$ 2014 real
2010-2011	701.15	2140.72	1273357	15348	5506.3	0.845	10.51
2011-2012	739.35	2065.2	1268443	9599	5828.8	0.56	6.63
Total	7460.71					**12.32**	**321.86**

The assumed total loss of revenue in real terms (2014 amounts) is US$ 0.32 bn over the last 33 years, or an average of US$ 9.75 million per year. The 2007 fire estimates however are severely underestimated in relation to the reported costs, but the relative magnitude of the events seems the same in relation to other years. With that said, the danger of relying on reported costs as verification can be describe by the following example: damage to structures and properties caused by cape peninsula fires in 1990 were reported to total US$ 1.04 million by the local municipality, US$ 4 million through insurance claims, and US$ 0.3 billion by press reports.

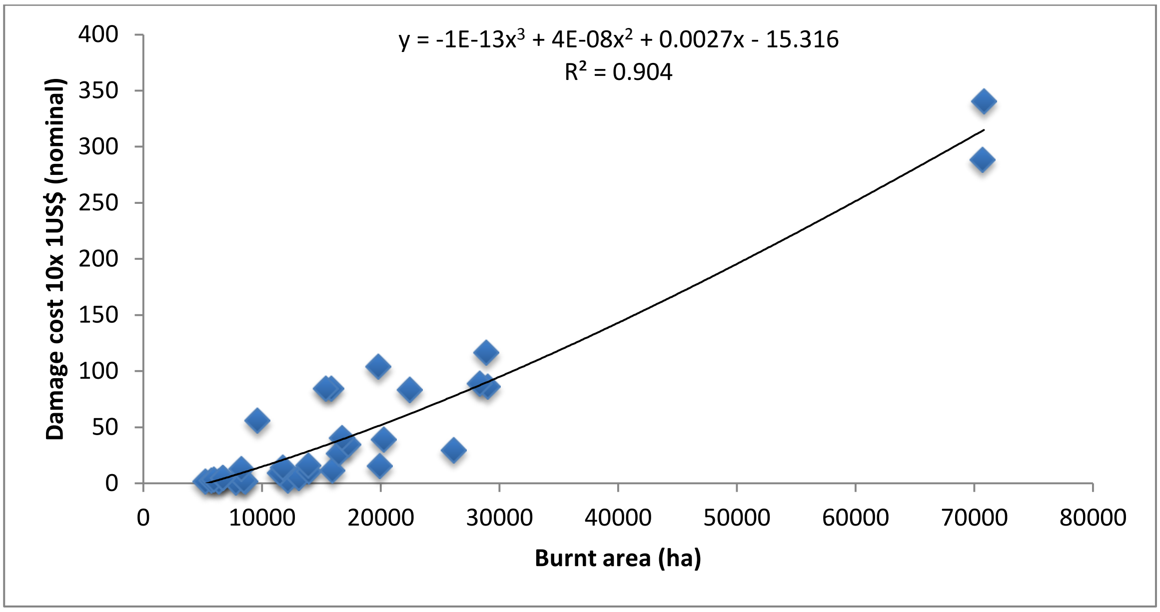


Figure 2. Relationship between burnt area (ha) and maximum estimated damage from statistical data obtained through ForestrySA. The fit is a 3rd order polynomial.

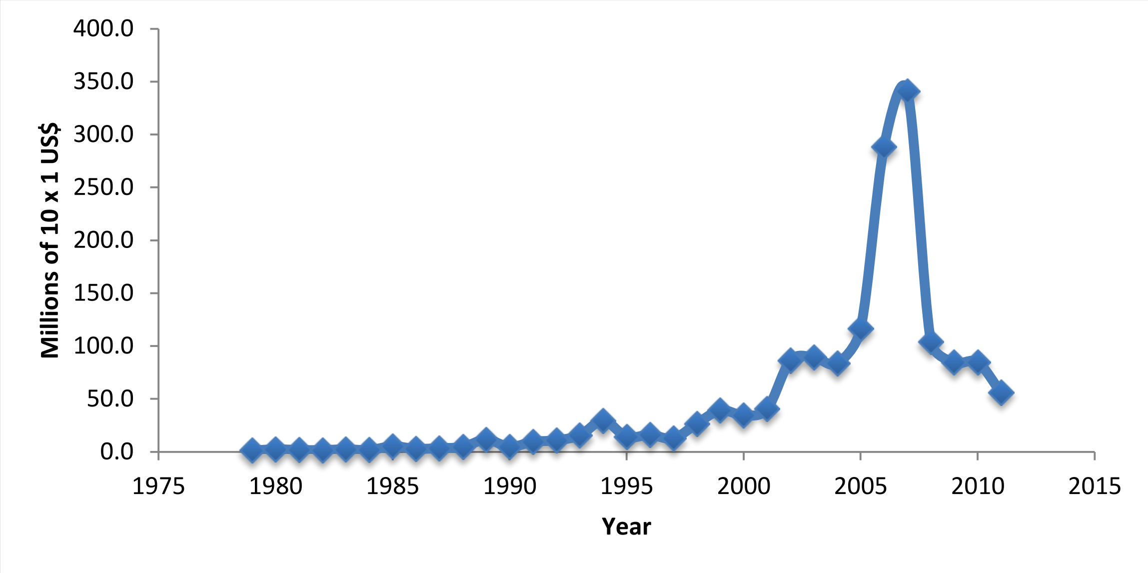


Figure 3. Comparison of assumed damage costs to the forestry industry between 1980 and 2011 from statistical data obtained through ForestrySA.

The relationship in Figure 1 between burnt area and cost provides a good basis to assume fire cost damages where no data exists. It is noted, however, that both round wood production and downstream forestry products are used in the calculation and do not represent any costs reported by the media. Table 2 on the other hand, provides a summary of available cost information found through desktop study, primarily through media reports. Although other incidents have been reported, only those with associated damage costs are reported here. Note that some costs are fire suppression values, specifically the Roburnia plantation, while others are total damage estimates.

Table 2. Reported wild fire damage costs from various desktop sources (excluding human settlement reported incidences)

Year	Location	Reported costs (millions of US$ - nominal)	Area affected (ha)	Costs in real terms (2014 millions of US$)
1970	Betty's Bay	0.050	5496	2.86
1979-1985	Eastern transvaal highveld	0.097	2290	2.28
1979-1985	Easteern transvaal lowveld	0.048	4411	1.12
1979-1985	Southern transvaal highveld	0.173	5544	4.05
1979-1985	Sabie area	0.003	541	0.07
1979-1985	Northern transvaal	0.004	14420	0.10
1979-1985	Natal midlands	0.856	7866	20.11
1979-1985	Natal interior	0.022	217	0.52
1979-1985	Zululand	0.004	5496	0.09
1985-1989	Eastern transvaal highveld	0.402	3055	4.31
1985-1989	Eastern transvaal lowveld	0.027	1825	0.29
1985-1989	Southern transvaal highveld	0.15	2804	1.64
1985-1989	Sabie area	0.01	377	0.06
1985-1989	Northern transvaal	0.01	263	0.10

Year	Location	Reported costs (millions of US$ - nominal)	Area affected (ha)	Costs in real terms (2014 millions of US$)
1985-1989	Natal midlands	0.15	2605	1.70
1985-1989	Natal interior	0.03	438	0.29
1985-1989	Zululand	0.04	873	0.38
1990	Western cape	0.29	NA	1.50
1990	Western cape	0.10	NA	0.54
1990	Western cape	0.10	120	0.52
1990	Western cape	0.10	24	0.52
1991	Kogelberg State Forest	0.28	NA	1.27
1991	Devils peak	0.45	NA	2.05
1994	Eastern transvaal	1.27	1270	0.33
1998	Plettenburg bay	0.55	15000.00	1.35
2001	Ermelo, Mpumalanga	2.00	50000.00	4.21
2007	Roburnia Plantation	0.06	25.98	0.09
2007	Kzn and Mpumalanga	133.00	77000.00	206.19
2008	Roburnia Plantation	0.01	309.57	0.01
2009	Roburnia Plantation	0.03	9197.00	0.04
2010	Roburnia Plantation	0.07	62.72	0.09
2011	Roburnia Plantation	0.06	141.99	0.07
2011	Sunset Ranch Game Lodge in Thabazimbi, Limpopo,	1.60	60000.00	1.89
2011	Klipfontein farm, ermelo	1.10	1300.00	1.30
2011	Koppies Nature Reserve,	0.15	NA	0.17
2012	Kuruman and Koopmansfontein	4.00	110000.00	4.48
2013	Ceres region	50.00	NA	53.02
2013	Gauteng and Port elizabeth	3.00	NA	3.18
Total		**199.45**		**323.53**

4.1.5.2 Hailstorm damages

There are reports of massive hail damage events that occurred in the first half of the twentieth century, but no cost information could be obtained for these. The reported costs in Table 3 are severely underrepresented and only represent 1995 and 2013 damages, and are further completely biased by the recent media and insurance reports from damages to Gauteng in 2013 and damages to fruits in Ceres in 2013. We note that these reported damages would not be useful to project any future damage information, but are nevertheless reported as a starting point.

Table 3. Hail storm damage costs.

Year	Location	Reported costs (millions of US$ - nominal)	Costs in real terms (2014 millions of US$)
1995	Bethlehem	0.01	0.01
1995	Ficksburg	0.07	0.21
1995	Fouriesburg	0.02	0.06
1995	Senekal	0.00	0.01

Year	Location	Reported costs (millions of US$ - nominal)	Costs in real terms (2014 millions of US$)
1995	Bethlehem	0.32	0.99
1995	Kroonstad	0.01	0.04
1995	Ficksburg	0.07	0.21
1995	Fouriesburg	0.01	0.01
1995	Senekal	0.13	0.39
1995	Lindley	0.01	0.02
1995	Reitz	0.02	0.03
1995	Harrismith	0.03	0.08
1995	Heilbron	0.02	0.05
1995	Frankfort	0.03	0.09
1995	Kroonstad	0.03	0.01
1995	Lindley	0.25	0.78
1995	Reitz	0.08	0.25
1995	Senekal	0.02	0.09
1995	Bethlehem	0.01	0.03
1995	Fouriesburg	0.01	0.01
2013	Ceres region	50.0	53.03
2013	Gauteng and Port Elizabeth	3.00	3.18
Total		54.08	59.53

4.1.5.3 Droughts

Detailed damage cost data is sparse for droughts. From the few available reports and articles the losses in current and future crop production and livestock numbers together with the cost of water supply to drought stricken communities and farmers and food relief funds constituted the majority of the total damage costs. Drought costs reported vary between emergency and relief costs and actual damage costs and potential future income losses for well documented industries such as commercial farming (e.g. sugarcane farming). The budgeted amounts for the different sectors are most definitely not a good reflectance of the actual costs incurred. These percentage splits between sectors are only included for reporting purposes and cannot be assumed to reflect the actual costs incurred in individual sectors. No data are readily available to determine the size of the total areas affected in the country during the drought years. This will require the modelling of for instance agriculturally defined drought conditions in order to determine the location and the size of the drought affected areas where crops are grown and livestock are kept in terms of crop and livestock losses due to water shortages, hunger and diseases. The effect of drought on the supply of water to humans for consumption may require a different definition of drought and the model has to be adjusted to take into account the drop in dam and borehole water levels in different locations to estimate the area and number of people that were affected in the past. It was not possible to find, extract and analyse such data as it will require a fairly detailed spatial and temporal model. The cost for the 1992 drought was reported as a US$ 0.12 billion reduction in the GDP contribution by the agricultural sector. The potential influence on the economy due to production output losses was not modelled as part of this first draft.

Table 5. Drought damage costs. More droughts occurred than the ones reported in the table. Due to incomplete data only data for the 2003/2004, 2010 and 2014/2015 droughts are included due to show the differences in costs between different provinces. The values reported are the immediate damage and response costs and do not include (as far as known) the possible future losses due to a decline in agriculture production.

Year	Province affected	Water Sector [%]	Agricultural Sector [%]	Human Settlements [%]	Health [%]	Total costs (Nominal values) [R million/year]	Total costs (real terms, 2014 values) [US$ million/year]
2003/2004	Limpopo, NC, EC, FS	40*	20*	26*	14*	500.00*	83.72
2010	WC					784.89	96.49
2014/2015	KZN		100**			274.00**	27.40
Average yearly total* **							69.25 276.86

*These are budgeted relief and emergency response values and not the actual expenses or costs incurred due to immediate and future losses.
**These are actual damages to the cane fields (US$ 27.4 million). Estimated future losses (US$ 57.4 million).
***Due to the differences in the areas affected in terms of agricultural activities, the general land cover and land use affected during these three droughts for which more detailed data were available it is assumed that an average cost value does not capture these differences sufficiently. More data points are needed and a spatial analysis is required to determine an accurate cost value.

4.1.5.4 Floods

Floods are the best documented of all the extreme climate events based on the review of different literature resources and online available datasets. Various initiatives exist to capture flood incidences and the associated impacts of such floods. However, no sufficiently detailed, up to date and a validated dataset for the whole of the country was available to use as the common basis for the cost estimates of extreme climate events including floods. The disaster and damage cost data collected and reported in the Disaster Mitigation for Sustainable Livelihoods Programme at UCT (DiMP) is the most comprehensive dataset available albeit only for the south coast in the Western Cape Province. The values reported in the publications by this group were used to determine the split between different sectors. A comparison of the values reported by LTAS with other available datasets and reported values in newspaper articles, reports and thesis dissertations highlighted the following differences:

1) Definitions and terminologies used for damage costs and flood events
2) Number of people affected
3) Damage cost values

The order of magnitude differences in the damage cost values ranged between thousands to hundreds of thousands of Dollars for the same year in which floods occurred. For example, the large flood in 1984 was not included in the EM-DAT data under the 'Hydrological' subgroup but under the ‘Meteorological’ subgroup as part of the ‘Storms’ subtype which led to the exclusion of this flood event being reported by different groups. In order to calculate a reasonable estimate of the total yearly damage costs for floods it was necessary to (1) create a dataset that captures most of the available data and information in the local and international literature and in online available datasets held by groups and organisations outside of South Africa, and then (2) compare the different results before an average yearly cost and cost function could be calculated. A decision was made to use the dataset collected and made available by the Flood Observatory in Dartmouth as the base dataset in the absence of any other detailed dataset. It is necessary to investigate the dataset in depth as for example the total size of the area affected may span multiple countries and the centre of the area affected may fall inside a neighbouring country. This was the case for the tropical cyclone Elina in 2000. These values needed to be adjusted to reflect only the area in South Africa. Due to time limits this was not possible to do for all the historical floods since 1985 and the areal data was only adjusted for the 2000 flood.

In some instances it became clear that different sources report the same actual damage cost numbers but use different currencies leading to wrong interpretations of the data. In other instances a data source or report will report the number of houses evacuated as the number of people displaced without converting the house numbers to actual number of people affected depending on the average size of the households.

In the time available an effort was made to correct for these errors but some may have been overlooked. These errors and inconsistencies contribute significantly to damage cost estimates and the interpretation of the data especially when using the averaged values.

The damage costs were allocated to the different sectors where such data were available. The work done by the DiMP group for floods along the southern coast of the Western Cape was used as the basis to calculate the percentage split between the different sectors in terms of direct costs incurred for coastal areas. It was assumed that this will be presentative of the sectoral impact costs incurred in coastal areas in KZN and the Eastern Cape. It was not possible to determine how representative this is of these provinces or inland areas that also experience floods. Further the data used is for the 2006 flood and it had to be assumed that it will also reflect future damage cost splits per sector. Again this assumption was not tested. In general for the overall situation in the country, not all costs are reported for each event leading to underestimates. Relief fund allocations were included with the assumption that although these funds do not represent the actual damages incurred; these amounts provide an indication of damages suffered by vulnerable groups. Based on the available data the bulk of direct (i.e. not including potential future losses) damage costs are incurred in the transport infrastructure sector (~44%); agricultural sector (~22%) and in human settlements (i.e. house damage and losses, ~9%). The picture changes when future losses as is the case with the agricultural sector is included which can lead to a doubling or even threefold increase in the total costs for this sector. Based on the southern cape study for the 2006 flood, damage to water infrastructure was amounted to about 3% of the total direct costs and the damages suffered by Sanparks equalled just more than 1% of the total costs. The DiMP (2007) study estimated a financial loss of US$ 1 970 – US$ 9 370 per household in an informal settlement and US$ 3 130 – US$ 3 480 per household in municipal houses for the 2006 flood. The number of persons affected, including deaths, needs to be expressed in terms of the total number of people who live in the affected area. It was not possible to generate such a dataset in the time available.

Flood damage costs are provided in Table 6. Only one data set (i.e. the data set provided by GDACS and the Flood observatory in Dartmouth) contained spatial data in vector format to calculate the total area affected.

Table 6. Flood damage costs and the number of people affected. The split between the damages incurred in the different sectors is provided where such data were available. Some major limitations of the data include the differences in actual numbers reported by the different sources for the same event occurring in the same location at the same time. It was not possible to only use one dataset for example the flood data collected and provided by the Dartmouth Flood Observatory group. This particular dataset is the only dataset that contains spatial information in terms of the exact location, duration and size of an event. Associated damage costs are not always included or if included the values do not correspond with other sources of data such as local newspaper articles, reports, peer reviewed articles and dissertations. It was therefore necessary to supplement and validate the Dartmouth dataset in order to calculate a realistic flood damage cost in terms of total US$ and US$ per unit area per year where possible.

	Total Damage Costs (nominal)	**Total Damage Costs (real, 2014)**	**Total area affected**	**Area costs (real, 2014 values)**	**# deaths**	**# displaced**
	[millions US$/year]	[millions US$/year]	[km^2]	[US$/km^2]		
Mean	**71.99**	**3 51.24**	**19 312.46**	**119 37.40**	**69**	**22 288**
Standard Error (of the mean)	17.45	1 31.43	5 676.24	49 66.28	25	10 907
Median	59.62	1 49.31	9 339.47	24 80.46	12	5 500
Mode	#N/A	#N/A	3 9581.29	#N/A	0	0
Standard Deviation	67.61	5 25.72	25 384.93	192 34.17	118	51 160
Sample Variance	457 07.82	2 764 363.64	6 443 948 275.67	36 995 281 27.20	13 974	2 617 359 616
Kurtosis	0.18	0.76	0.5.55	0.35	8	13
Skewness	0.18	0.25	0.22	0.20	3	3
Range	240.87	2 053.85	1027 1609.97	617 45.14	506	227 000
Minimum	**2.09**	**8.81**	**2 09.33**	**1 01.54**	**0**	**0**
Maximum	**242.90**	**2062.67**	**102 926.30**	**618 46.68**	**506**	**227 000**
Sum	1079.91	56 19.86	38 6249.29	1 790 62.39	1 588	490 340
Confidence Level(95.0%) of the mean	**37.40**	**2 80.16**	**11 880.54**	**106 51.51**	**51**	**22 683**

The results and outcomes are summarised below.

- The differences in damage costs per year over a period of time are significant. The main factors contributing to these and which need to be considered when reporting an extreme climate event damage cost include:
    - Differences in what costs and losses are included or excluded in total values reported for example direct damage costs versus estimated future losses due to loss of agricultural outputs.
    - The bulk of direct (i.e. not including potential future losses) damage costs are incurred in the transport infrastructure sector (~44%); agricultural sector (~22%) and in human settlements (i.e. house damage and losses, ~9%). The picture changes when future losses as is the case with the agricultural sector is included which can lead to a doubling or even threefold increase in the total costs for this sector. Based on the southern cape study for the 2006 flood, damage to

water infrastructure amounted to about 3% of the total direct costs and the damages suffered by Sanparks equalled just more than 1% of the total costs.

- Data for infrastructure related damage costs are more readily available than the costs incurred by individuals on a personal level. This implies that although these types of costs may not constitute a large proportion of the total damages incurred they may be devastating on the personal level. Financial losses of US$ 1 97 – US$ 9 37 (or US$ 326.8 – US$ 1614 in 2014 real values) per household in an informal settlement and US$ 313 – US$ 348 (or US$ 519.2 – US$ 577.2 in 2014 real values) per household in municipal houses were reported for the 2006 flood in the Southern Cape. About 74% of the households affected were from the informal and municipal houses sector during this flood. The number of persons affected, including deaths, needs to be expressed in terms of the total number of people who live in the affected area. It was not possible to generate such a dataset in the time available. It may therefore be necessary to represent such personal damages more in line with a vulnerability index or ability to cope with or afford such a loss.
- Transport and communications infrastructure is not listed as a climate impact sector to be considered in this study. The data however show that it should be considered as a sector in climate adaptation studies. In spite of years of flood damages to bridges in provinces such as KZN that regularly are hit by floods and the redesign of the bridges to reduce future impacts by floods, the costs associated with flood damage to for example transport infrastructure and mainly road and railways has not declined.

In summary, it would be better to provide simple cost function based on work that is currently being done by LTAS and supplemented through the adjustment of the GVA values at the mesoscale level using spatial overlays, rather than using reported damage costs as a basis. Merz et al (2010) showed that models at this level are sufficient to capture the impacts of extreme climate events after which no significant improvement in model accuracies is achieved to reflect the impact of for example floods on different types of land uses. The historical data collected as part of this phase of the project can be used to adjust these values where possible. Detailed cost functions are available for industries but require detailed site specific data which will not be feasible to do in this project.

A general assumption that was not tested with sufficient data points is that future economic losses can be estimated to be two to three times that of the actual damage costs incurred during an event depending on the type of output (for example agricultural sugarcane in the case of floods). This needs to be tested and if it produces acceptable results it can then be used to scale the damage costs to include future losses as well.

5 Projections of adaptation needs for the contribution term, under different scenarios

5.1 Projections of extreme weather events under low and high mitigation scenarios

5.1.1 Introduction

Climate change is projected to impact drastically in southern African during the 21st century under low mitigation futures (Niang et al., 2014). African temperatures are projected to rise rapidly, at 1.5 to 2 times the global rate of temperature increase (James and Washington, 2013; Engelbrecht et al., 2015). Moreover, the southern African region is projected to become generally drier under enhanced anthropogenic forcing (Christensen et al., 2007; Engelbrecht et al., 2009; James and Washington, 2013; Niang et al., 2014). These changes in the annual and seasonal rainfall patterns will plausibly have a range of impacts on the South African economy, including impacts on energy demand (in terms of achieving human comfort within buildings and factories), agriculture (e.g. reductions of yield in the maize crop under higher temperatures and reduced soil moisture), livestock production (e.g. higher cattle mortality as a result of oppressive temperatures) and water security (through reduced rainfall and enhanced evapotranspiration) (Engelbrecht et al., 2015).

However, climate change costs are not to manifest only through changes in average temperature and rainfall patterns, but also through changes in the attributes of extreme weather events. For the southern African region, generally drier conditions and the more frequent occurrence of dry spells are plausible over most of the interior (Christensen et al., 2007; Engelbrecht et al., 2009). Tropical cyclone tracks are projected to shift northward, bringing more flood events to northern Mozambique and fewer to the Limpopo province in South Africa (Malherbe et al., 2013). Cut-off low related flood events are also projected to occur less frequently over South Africa (e.g. Engelbrecht et al., 2013) in response to a poleward displacement of the westerly wind regime. Intense thunderstorms are plausible to occur more frequently over South Africa in a generally warmer climate (e.g. Engelbrecht et al., 2013). The purpose of this section of the report is to provide an update on the latest insights and evidence available regarding future changes in the frequency of occurrence of extreme events over South Africa, with a focus on extreme events that are known to impact on the South African economy. These projections are then used to estimate the associated changes in costs to the South African economy as induced by extreme weather events, through the application of suitably constructed cost functions.

The most recent downscalings of global circulation model (GCM) projections of the Coupled Model Intercomparison Project Phase Five (CMIP5) and Assessment Report Five (AR5) of the Intergovernmental on Climate Change (IPCC), obtained at the Council for Scientific and Industrial Research (CSIR) and the Commonwealth Scientific and Industrial Research Organisation (CSIRO), are used for this purpose. These downscalings are for the period 1971 to 2100, follow the experimental design recommended by the Coordinated Downscaling Experiment (CORDEX) and have been derived for both low and high mitigation scenarios. The regional climate model used to obtain the downscalings is the conformal-cubic atmospheric model (CCAM) of the CSIRO. The report also considers in addition evidence on plausible changes in extremes events over southern Africa as presented in Assessment Report Four (AR4) and AR5 of the IPCC (Christensen et al., 2007; Niang et al., 2014) and in the Long Term Adaptation Scenarios Report (LTAS, 2013) of the Department of Environmental Affairs (DEA).

5.1.2 Methodology: bias-corrected projections from a regional climate model

Regional climate modelling is used to downscale the projections of CMIP5 GCMs to high resolution over southern Africa. The regional climate model used, CCAM, is a variable-resolution GCM developed by the CSIRO (McGregor 2005; McGregor and Dix 2001, 2008). CCAM runs coupled to a dynamic land-surface model CABLE (CSIRO Atmosphere Biosphere Land Exchange model). Six GCM simulations of CMIP5 and AR5 of the IPCC, obtained for the emission scenarios described by Representative Concentration Pathways 4.5 and 8.5 (RCP4.5 and 8.5) were downscaled to 50 km resolution globally. The simulations span the period 1971-2100. RCP4.5 is a high mitigation scenario, whilst RCP8.5 is a low mitigation scenario. The GCMs downscaled include the Australian Community Climate and Earth System Simulator (ACCESS1-0); the Geophysical Fluid Dynamics Laboratory Coupled Model (GFDL-CM3); the National Centre for Meteorological Research Coupled Global Climate Model, version 5 (CNRM-CM5); the Max Planck Institute Coupled Earth System Model (MPI-ESM-LR); the Model for Interdisciplinary Research on Climate (MIROC4h); the Norwegian Earth System Model (NorESM1-M); the Community Climate System Model (CCSM4); the Meteorological Research Institute Global Climate Model (MRI-GCM3); and the Institute Piere Simon Laplace Climate Modelling Centre Coupled Model (IPSL-CM5A-MR). The simulations are performed on supercomputers of the CSIRO (Katzfey et al., 2012) and on the Centre for High Performance Computing (CHPC) of the Meraka Institute of the CSIR in South Africa.

Results from the downscaling of the first six of these CGCMs are presented here (the ensemble of downscalings is to be extended during 2015 and 2016). In these simulations CCAM was forced with the bias-corrected daily sea-surface temperatures (SSTs) and sea-ice concentrations of each host model, and with CO_2, sulphate and ozone forcing consistent with the RCP4.5 and 8.5 scenarios. The model's ability to realistically simulate present-day southern African climate has been extensively demonstrated (e.g. Engelbrecht et al., 2009; Engelbrecht et al., 2011; Engelbrecht et al., 2013; Malherbe et al., 2013; Winsemius et al., 2014; Engelbrecht et al., 2015). Most current coupled GCMs do not employ flux corrections between atmosphere and ocean, which contributes to the existence of biases in their simulations of present-day SSTs – more than 2 ºC along the West African coast. An important feature of the downscalings performed here is that the model was forced with the bias-corrected sea-surface temperatures (SSTs) and sea-ice fields of the GCMs. The bias is computed by subtracting for each month the Reynolds (1988) SST climatology (for 1961-2000) from the corresponding CGCM climatology. The bias-correction is applied consistently throughout the simulation. Through this procedure the climatology of the SSTs applied as lower boundary forcing is the same as that of the Reynolds SSTs. However, the intra-annual variability and climate-change signal of the CGCM SSTs are preserved (Katzfey et al., 2009).

Towards projections of changes in extreme temperature events over Africa, it is useful to first bias-correct the model simulations of temperature and rainfall, to remove any systematic errors that may otherwise affect the exceedance of critical threshold events. Here the monthly climatologies of the CRU TS3.1 data set (Mitchell and Jones, 2005) of the Climatic Research Unit (CRU) were used as reference climate. The model simulations were interpolated to the 0.5 degree latitude-longitude grid of the CRU data, to facilitate the generation of gridded bias-corrected simulations (Engelbrecht and Engelbrecht, 2015). After calculation of the model climatologies for each downscaling, the simulated daily precipitation was bias-corrected with a multiplicative factor, whilst daily temperature and maximum temperature underwent an additive correction based on the mean temperature biases.

5.1.3 Projected changes in extreme weather events

In the figures that follow, projected futures are shown for the time-slab 2021-2050 relative to the baseline period 1961-1990. The 10th, 50th (median) and 90th percentiles of the ensemble of projected changes are shown for each of the variables. In this way, it is possible to gain some understanding of the uncertainty range that is associated with the projections. The following extreme events were considered for analysis in this report:

- Drought: Here the impact of droughts are quantified through the occurrence of dry spells, with a dry spell being defined as a period of five consecutive days (or longer) without rainfall occurring over an area of 2500 km^2. The days that constitute a dry spell event are termed "dry spell days".
- Large-scale flooding: Defined as 20 mm (or more) of rain occurring within 24 hours over an area of 50 x 50 km^2, for a period of three consecutive days or longer. The days that constitute a heavy rainfall event are termed "heavy rainfall days". These events will typically include flooding caused by tropical cyclones and cut-off lows.
- Heat-waves: An event when the maximum temperature exceeds the average temperature of the warmest month of the year (at a specific location as calculated for the base-line period) by more than 5 °C for at least 3 days.
- High fire-danger days: A day when the McArthur fire danger index exceeds the critical value of 12.
- Intense thunderstorms: An event when more than 20 mm of convective rainfall occur over at a model grid box of area 2500 km2 within a period of 24 hours.
- Cold-snaps: An event when minimum temperature drops to below 0 °C.
- Storm-surge: A coastal flood caused by sea-levels rising and sea-water penetrating inland, in response to a low-pressure weather system such as a cut-off low or tropical cyclone.

5.1.3.1 Dry spells

- The model-simulated and bias-corrected annual average dry-spell day frequencies (units are number of days per model grid box per year) are displayed in Figure 4, for the baseline period 1971-2000. South Africa receives seasonal rainfall over most of the country, implying that most locations experience a dry season exhibiting many dry spell days. The dry spell day gradient over South Africa resembles the rainfall gradient.
- The ensemble of downscalings is robust in projecting an increase in dry spell days over South Africa for the period 2021-2050 relative to 1971-200, under low mitigation. Only a minority of projections indicative of slight decreases in dry spell length over the central interior. (Figure 5).
- The projected changes in dry spell day frequencies under high mitigation are very similar to the patterns projected under low mitigation (Figure 6).

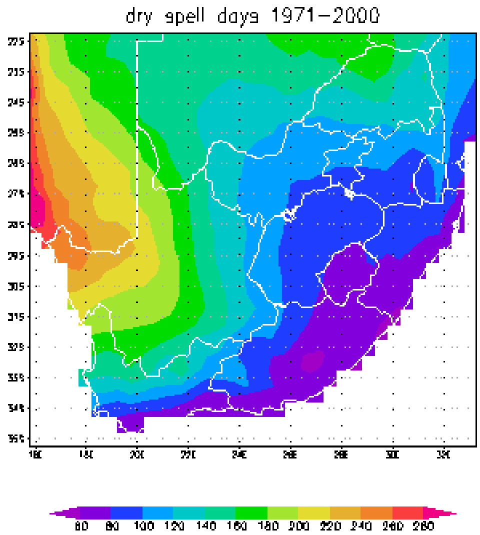
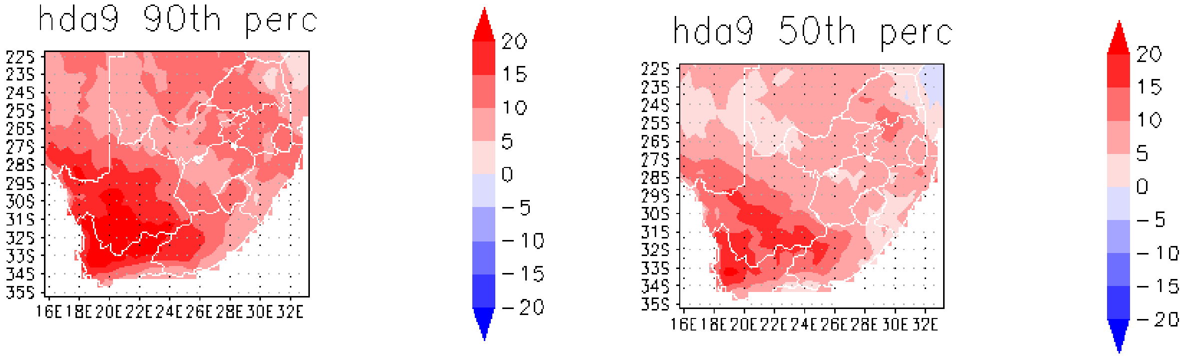


Figure 4: CCAM simulated annual average number of dry spell days (units are number of days per grid point per year) over South Africa, for the baseline period 1971-2000. The median of simulations is shown for the ensemble of downscalings of six GCM simulations.



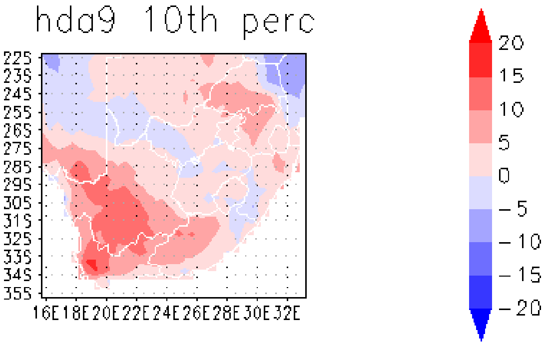
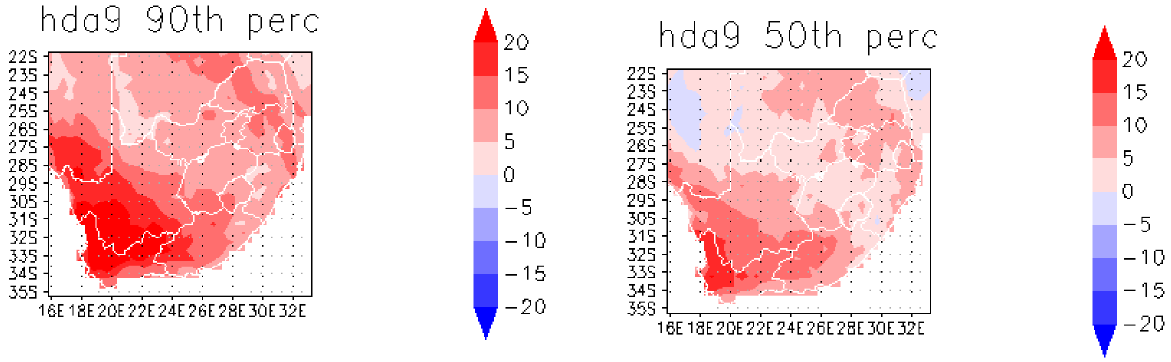


Figure 5: CCAM projected change in the annual average number of dry spell days (units are numbers of grid points per year) over South Africa, for the time-slab 2021-2050 relative to 1971-2000. The 10th percentile (bottom), median (middle) and 90th percentile (top) are shown for the ensemble of downscalings of six GCM projections under RCP8.5.



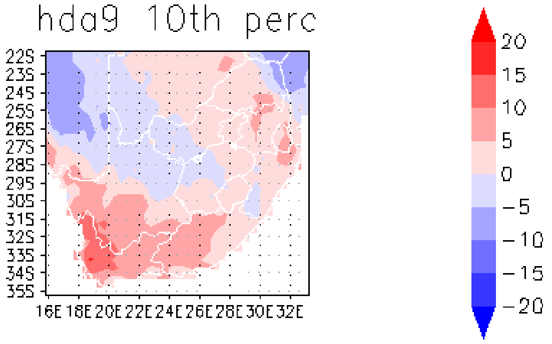


Figure 6: CCAM projected change in the annual average number of dry spell days (units are numbers of grid points per year) over South Africa, for the time-slab 2021-2050 relative to 1971-2000. The 10th percentile (bottom left), median (top right) and 90th percentile (top left) are shown for the ensemble of downscalings of six GCM projections under RCP4.5.

5.1.3.2 Large-scale flooding

- The model-simulated and bias-corrected annual average large-scale flood frequencies (units are number of days per model grid box per year) are displayed in Figure 7, for the baseline period 1971-2000. Prolonged rainfall events of this magnitude rarely occur over South Africa – most regions on the average experiences less than one of these events annually. The largest frequencies of large-scale flood events are simulated to occur along the east coast and eastern escarpment regions of South Africa.
- Increases in heavy rainfall events are plausible to occur over the central interior and north-eastern parts of South Africa under low mitigation, for the period 2021-2050 relative to 1971-2100 (Figure 8)
- The projected changes in heavy rainfall events under high mitigation are very similar to the patterns projected under low mitigation (Figure 9).
- The plausible increases in heavy rainfall events projected for most of eastern South Africa may have implications for the future occurrence of wet coal events in the country.

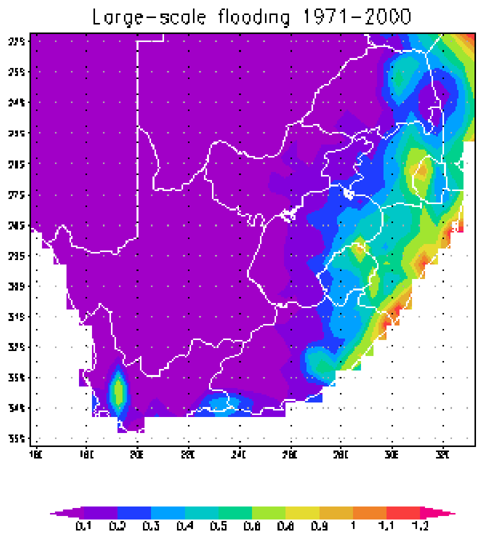
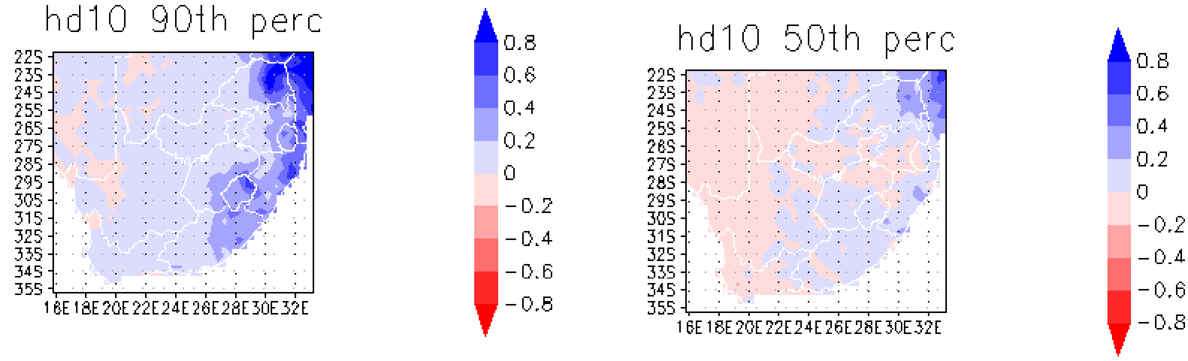


Figure 7: CCAM simulated annual average number of heavy rainfall days (units are number of days per grid point per year) over South Africa, for the baseline period 1971-2000. The median of simulations is shown for the ensemble of downscalings of six GCM simulations.



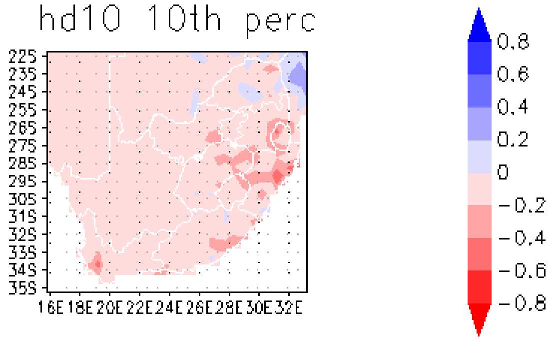


Figure 8: CCAM projected change in the annual average number of heavy rainfall days (units are numbers of grid points per year) over South Africa, for the time-slab 2021-2050 relative to 1971-2000. The 10th percentile (bottom left), median (top right) and 90th percentile (top left) are shown for the ensemble of downscalings of six GCM projections under RCP8.5.

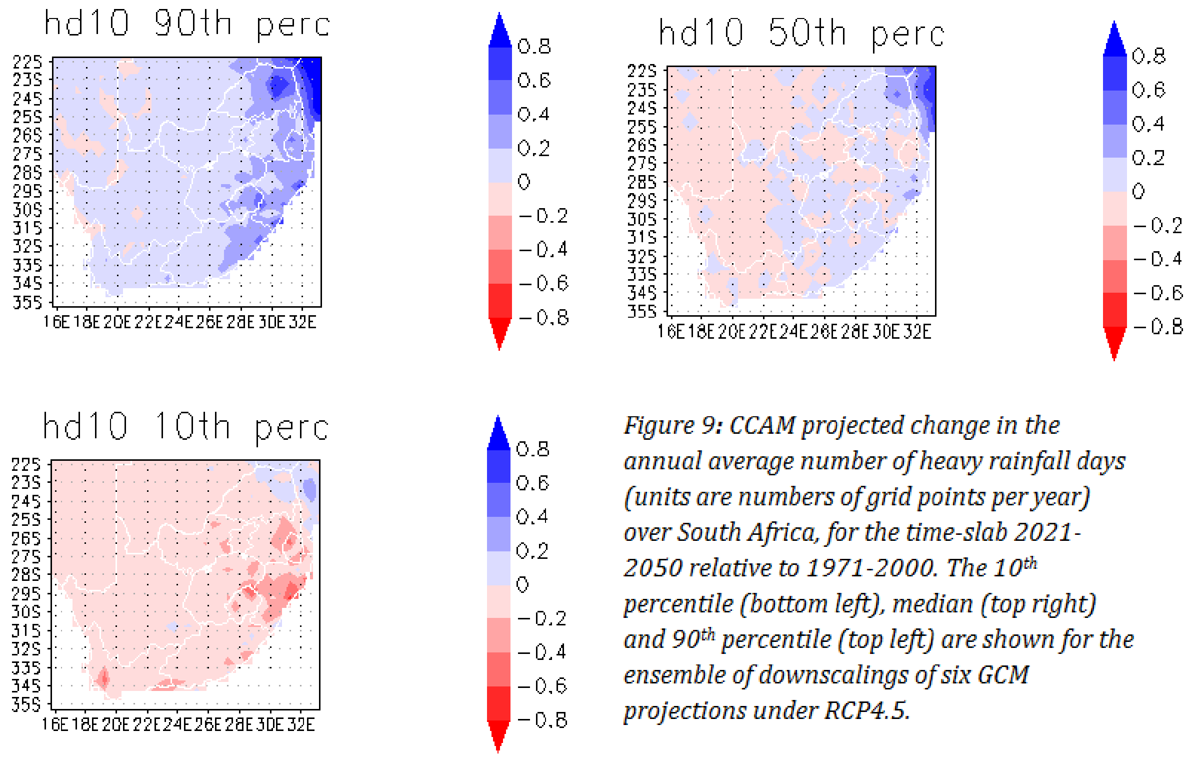


Figure 9: CCAM projected change in the annual average number of heavy rainfall days (units are numbers of grid points per year) over South Africa, for the time-slab 2021-2050 relative to 1971-2000. The 10th percentile (bottom left), median (top right) and 90th percentile (top left) are shown for the ensemble of downscalings of six GCM projections under RCP4.5.

5.1.3.3 Heat-waves

- The model-simulated and bias-corrected annual average numbers of heat-wave days (units are number of days per model grid point) are displayed in Figure 10, for the baseline period 1971-2000. Heat-waves are rare events in terms of southern Africa's present-day climate, with most regions experiencing less than five of these days per annum.
- In association with drastically rising maximum temperatures, the frequency of occurrence of heat-wave days is also projected to increase drastically under climate change.
- For the period 2021-2050 relative to 1961-1990, under low mitigation, heat-wave days are projected to increase with more than 8 days per year over large parts of the central interior of South Africa (Figure 11). More modest increases are projected for the coastal regions.
- Even under high mitigation, the increase in the number of heat-wave days may be 8 or more over the central interior regions of South Africa (Figure 12).
- Increases in the occurrence of heat-wave days occur in association with projected changes in the frequency of very hot days and high fire danger days (see section 3.4). Since heat-wave days are associated with prolonged periods of oppressive temperatures, these changes may impact on human and animal health through increased heat stress, are likely to impact negatively on crop yield and are plausible to be conducive to the occurrence of veld and forest fires.

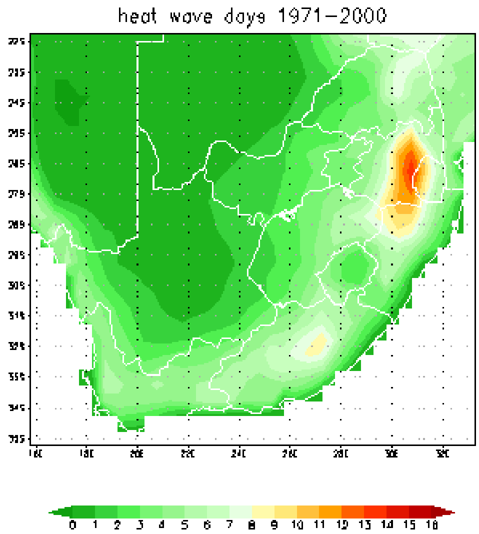
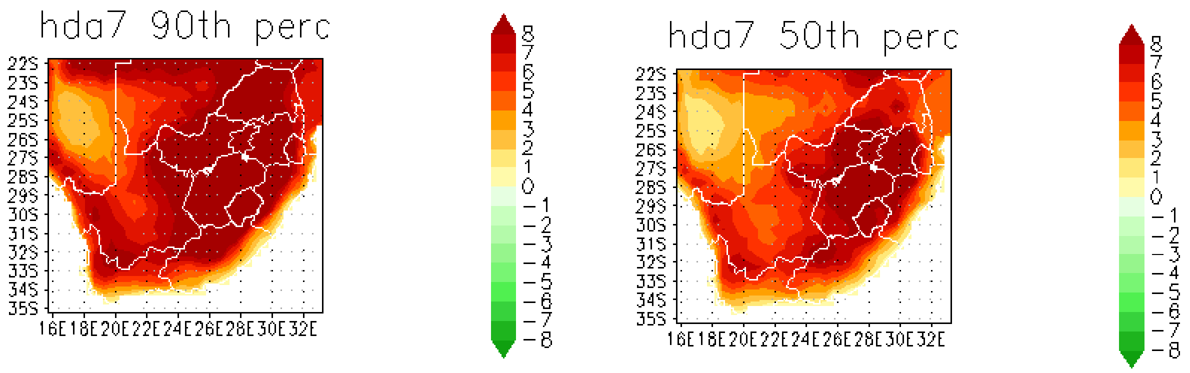


Figure 10: CCAM simulated annual average number of heat-wave days (units are number of days per grid point per year) over South Africa, for the baseline period 1971-2000. The median of simulations is shown for the ensemble of downscalings of six GCM simulations.



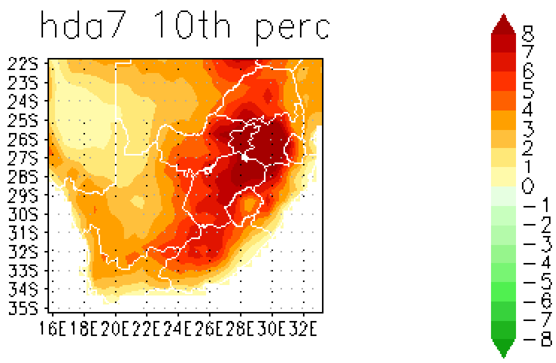
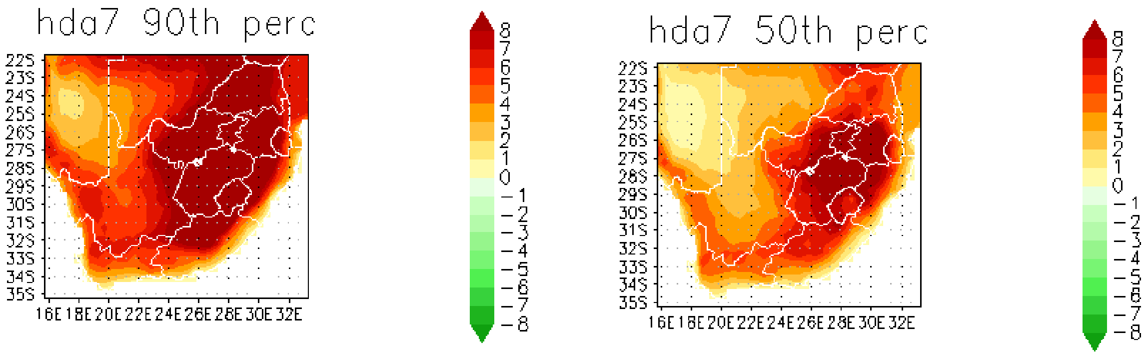


Figure 11: CCAM projected change in the annual average number of heat-wave days (units are number of days per grid point per year) over South Africa, for the time-slab 2021-2050 relative to 1971-2000. The 10th percentile (bottom left), median (top right) and 90th percentile (top left) are shown for the ensemble of downscalings of six GCM projections under RCP8.5.



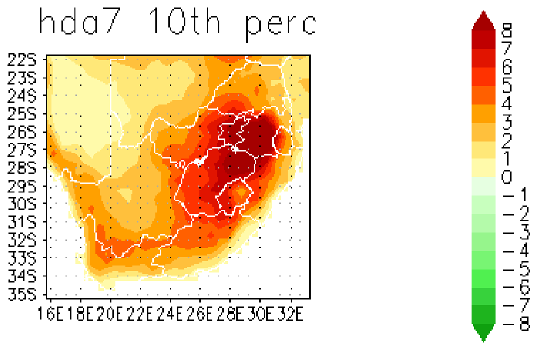


Figure 12: CCAM projected change in the annual average number of heat-wave days (units are number of days per grid point per year) over South Africa, for the time-slab 2021-2050 relative to 1971-2000. The 10th percentile (bottom left), median (top right) and 90th percentile (top left) are shown for the ensemble of downscalings of six GCM projections under RCP4.5.

5.1.3.4 High fire-danger days

- The model-simulated and bias-corrected annual average number of high fire-danger are displayed in Figure 13, for the baseline period 1971-2000. Over the northern parts of the Northern Cape, more than 160 of these days occur annually, on the average. However, drier regions effectively have a very low burning potential due to the sparse vegetation. More relevant are the eastern and southern parts of the country, which under present-day climate experiences less than 20 high fire-danger days per year.
- In association with drastically rising maximum temperatures, the frequency of occurrence of high fire-danger days is also projected to increase drastically under climate change.
- For the period 2021-2050 relative to 1961-1990, under low mitigation, high fire-danger days are projected to increase with as many as 10-30 days per year in the forested regions of Mpumalanga, Limpopo, the Western Cape and Eastern Cape. Smaller increases are projected for the coastal regions, with larger increases plausible over the Free State grasslands and the western interior (Figure 14).
- Even under high mitigation, the increase in the number of high fire-danger days may be as many as 10-30 over the southern and eastern interior, with larger increases plausible over the western interior (Figure 15).
- Increases in the occurrence of high fire-danger days occur in association with projected changes in the frequency of occurrence of heat-wave days (see sections 3.3).

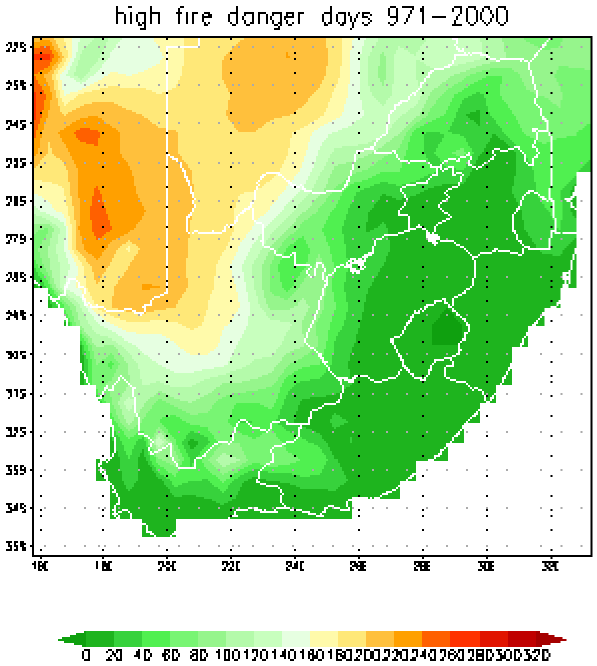


Figure 13: CCAM simulated annual average number of high fire-danger days (units are number of days per grid point per year) over South Africa, for the baseline period 1971-2000. The median of simulations is shown for the ensemble of downscalings of six GCM simulations

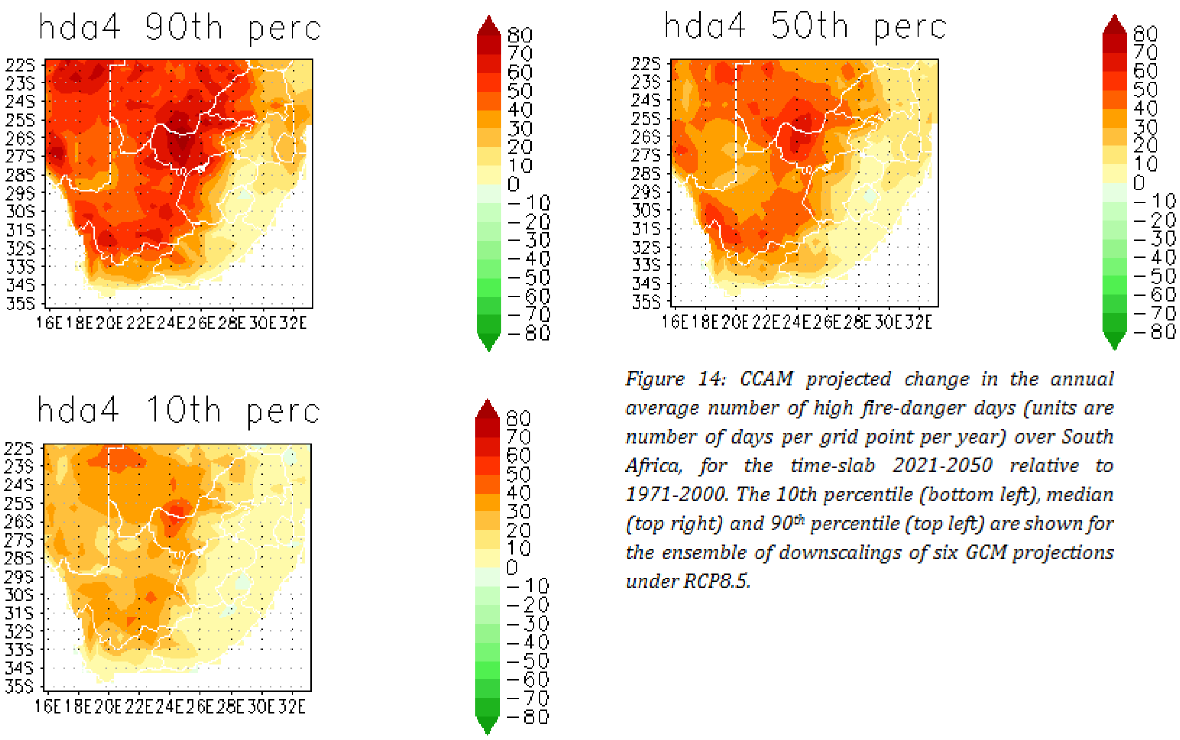
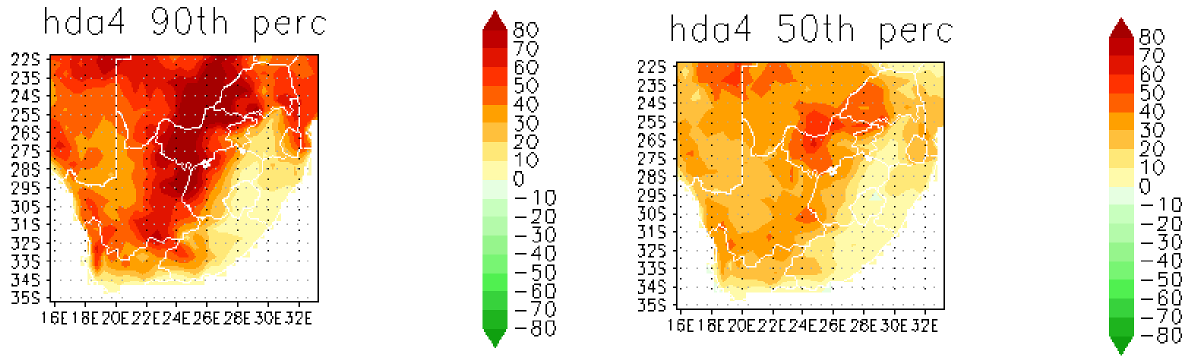


Figure 14: CCAM projected change in the annual average number of high fire-danger days (units are number of days per grid point per year) over South Africa, for the time-slab 2021-2050 relative to 1971-2000. The 10th percentile (bottom left), median (top right) and 90th percentile (top left) are shown for the ensemble of downscalings of six GCM projections under RCP8.5.



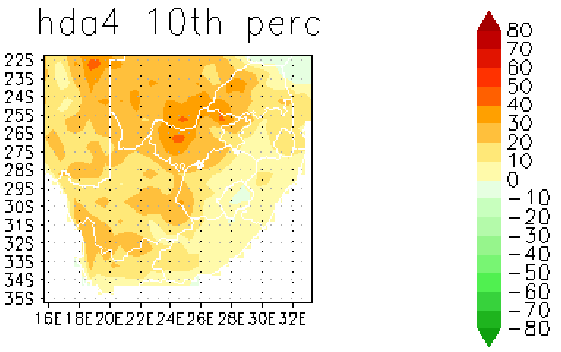


Figure 15: CCAM projected change in the annual average number of high fire-danger days (units are number of days per grid point per year) over South Africa, for the time-slab 2021-2050 relative to 1971-2000. The 10th percentile (bottom left), median (top right) and 90th percentile (top left) are shown for the ensemble of downscalings of six GCM projections under RCP4.5.

5.1.3.5 Intense thunderstorms

- The model-simulated and bias-corrected annual average intense thunderstorm event frequencies (units are number of events per model grid box per year) are displayed in Figure 16, for the baseline period 1971-2000. Over the east coast and eastern escarpment regions, and in the mountainous regions of the southwestern Cape, more than 10 intense thunderstorm events occur annually, on the average.
- Consistent with the projected decreases in rainfall, intense thunderstorm events are projected to decrease in frequency over most of South Africa under low mitigation, for the period 2021-2050 relative to 1971-2000, by most ensemble members (Figure 9.2 a to c). A minority of ensemble members project increases in intense thunderstorm events over most of eastern South Africa (Figure 17) and all ensemble members project an increase in intense thunderstorm events over northeastern South Africa.
- The projected changes in extreme rainfall events under high mitigation is very similar to the patterns projected under low mitigation (Figure 18).
- Intense thunderstorms are often also the cause of lightning, hail, damaging winds and flash floods. That is, the climate change projections analysed here are indicative that decreases in these hazardous rainfall events are plausible over most of South Africa, however, a minority of ensemble members are indicative of increases in such events over eastern South Africa. That is, adaptation policies need to take into account the possibility that intense thunderstorm events over eastern South Africa may increase in their frequency of occurrence.

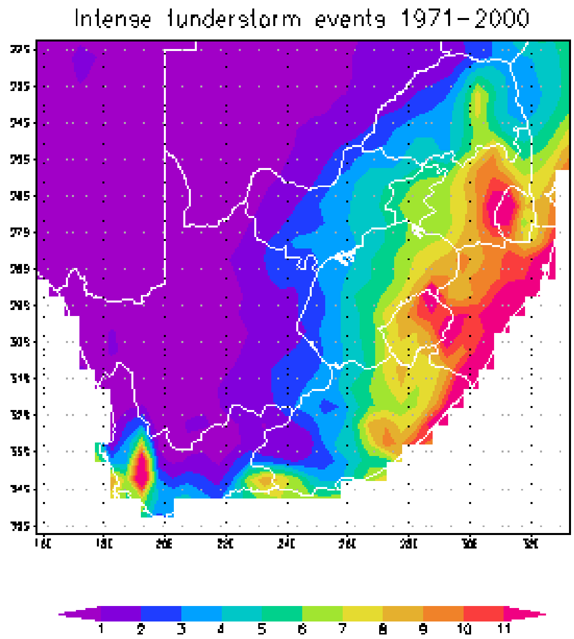
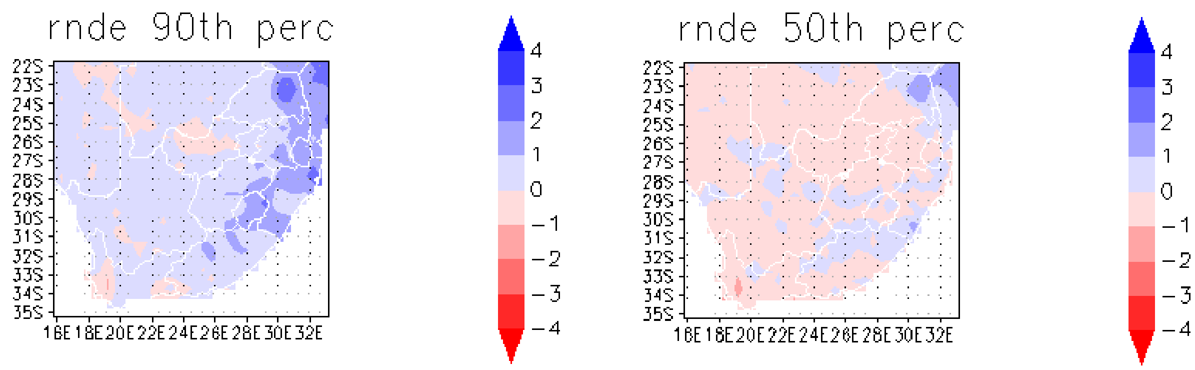


Figure 16: CCAM simulated annual average number of intense thunderstorms (units are number of days per grid point per year) over South Africa, for the baseline period 1971-2000. The median of simulations is shown for the ensemble of downscalings of six GCM simulations.



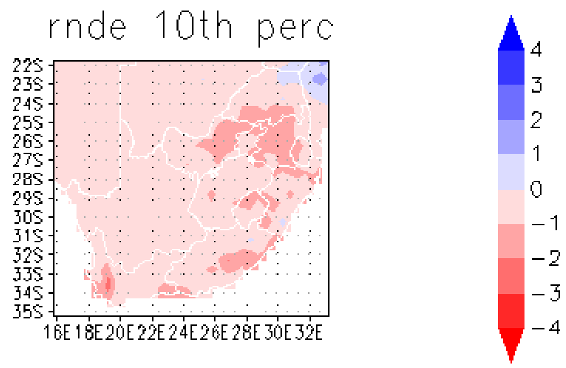
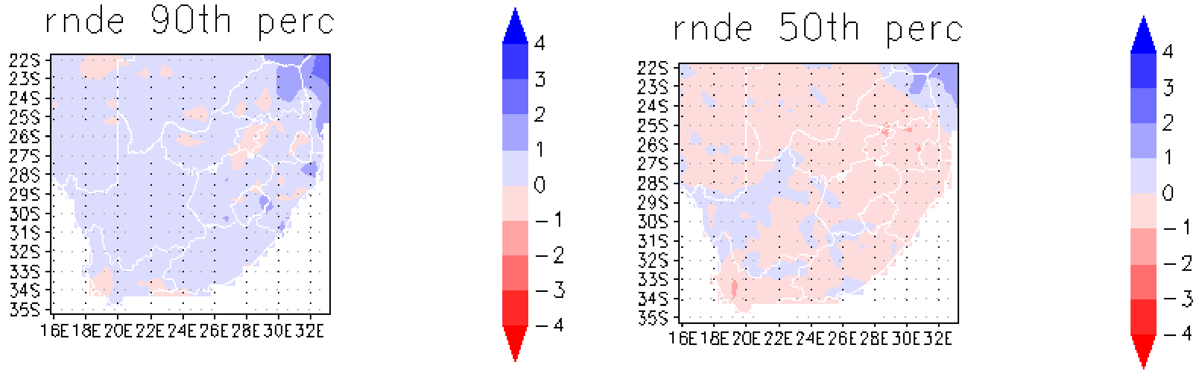


Figure 17: CCAM projected change in the annual average number of extreme precipitation days (units are numbers of grid points per year) over South Africa, for the time-slab 2021-2050 relative to 1971-2000. The 10th percentile (bottom left), median (top right) and 90th percentile (top left) are shown for the ensemble of downscalings of six GCM projections under RCP8.5.



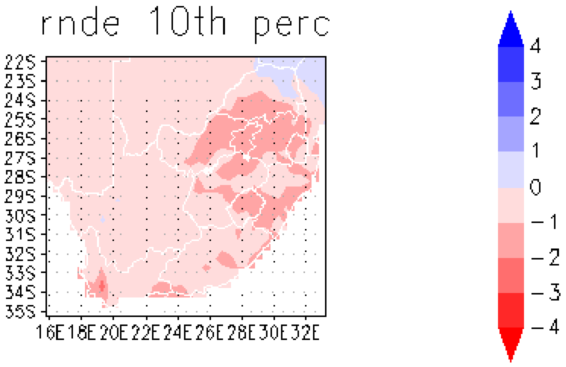


Figure 18: CCAM projected change in the annual average number of extreme precipitation days (units are numbers of grid points per year) over South Africa, for the time-slab 2021-2050 relative to 1971-2000. The 10th percentile (bottom left), median (top right) and 90th percentile (top left) are shown for the ensemble of downscalings of six GCM projections under RCP4.5.

5.1.3.6 Cold-snaps

- The model-simulated and bias-corrected annual average numbers of cold-snap days are displayed in Figure 19, for the baseline period 1971-2000. These events typically occur when a cold front moves deep into the interior of South Africa, transporting sub-Antarctic air inland. Strong mid-level high-pressure systems typically get well-established over the southern African interior after the intrusion of the cold front - it is in the subsident air underneath the high-pressure system, which lead to rapid heat loss through radiation after the passage of the cold front that minimum temperatures tend to drop to below 0 °C. Cold-snap days under present-day climatological conditions occur most frequently (about 5-8 days per year) over the central interior regions of South Africa.
- In association with drastically rising minimum temperatures (Figure 20), the frequency of occurrence of cold-snap days are projected to decrease drastically under climate change.
- For the period 2021-2050 relative to 1961-1990, under low mitigation, cold-snap days are projected to decrease with about 2-3 days per year over the central interior regions of South Africa (6.2).
- Even under high mitigation, the decrease in the number of cold-snap days is plausible to be in the order of 2-3 days per year over the central interior regions of South Africa (Figure 21).
- The decreases in cold-snap days may imply a decrease in the winter demand for warming within households and factories.

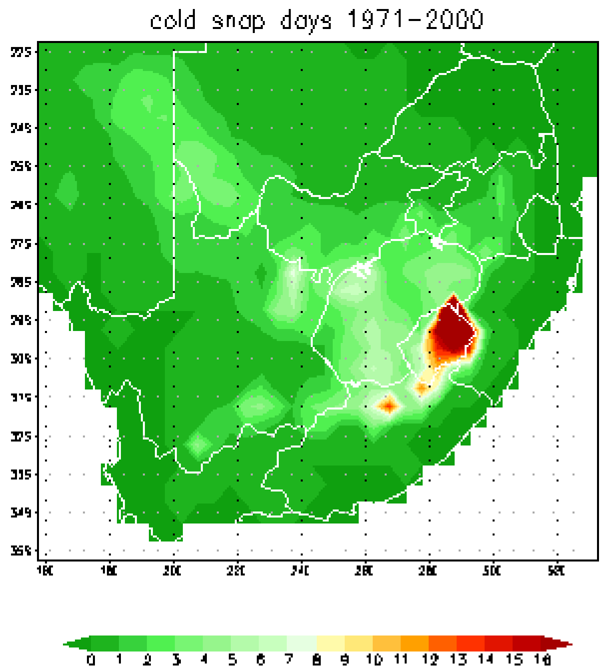
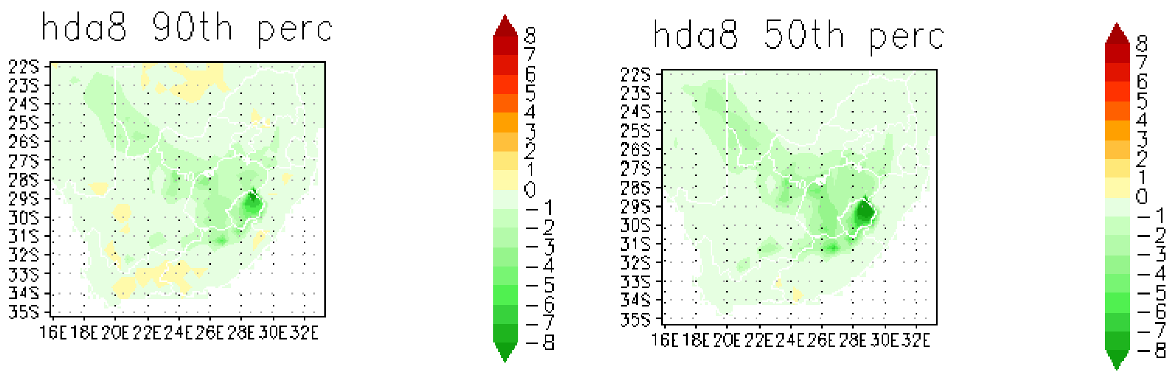


Figure 19: CCAM simulated annual average number of cold-snap days (units are number of days per grid point per year) over South Africa, for the baseline period 1971-2000. The median of simulations is shown for the ensemble of downscalings of six GCM simulations.



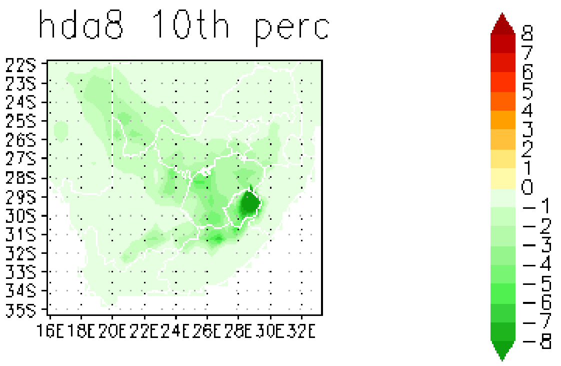


Figure 20: CCAM projected change in the annual average number of cold-snap days (units are number of days per grid point per year) over South Africa, for the time-slab 2021-2050 relative to 1971-2000. The 10th percentile (bottom left), median (top right) and 90th percentile (top left) are shown for the ensemble of downscalings of six GCM projections under RCP8.5.

5.1.4 Projected changes in adaptation costs

The annual-average costs associated with the occurrence of a number of extreme events in South Africa are estimated in this section, for both present-day and future climates. The extreme events considered in this draft report (analysis to be extended to more event-types in the final version) are veld and forest fires, droughts, floods and intense thunderstorms. For each of these events, the median of annual costs for the period 1979-2012 was calculated from the data on observed costs, presented in an earlier section of this report. These median values were then associated with the median frequency of occurrence of the relevant extreme event type. Calculation of the 10th and 90th percentiles of the event frequencies under present-day climate then made feasible estimations of the current (present-day) range in annual costs. Note that all observed costs over the period 1979-2012 were expressed in terms of the 2014 real-value costs. The estimations of future costs are similarly expressed in terms of the 2014 real-values. The future estimations are based on calculating the 10th percentile, median and 90th percentile of the future frequency of the relevant extreme event type, which is then linked to costs estimates using the present-day frequency-cost relationship. In this report, the range of projected costs, for both present-day and future periods obtained using this methodology is provided in tabular form (see Tables 1 to 4 below). Future costs are estimated for both low mitigation (RCP8.5) and high mitigation (RCP4.5) scenarios, and are presented for the period 2021-2050. The present-day cost estimates are for the period 1971-2000. The final version of the report cost estimates will be provided for a range of different climate futures, and will also include probability density functions as an additional method to describe the range of costs for both present-day and future climates.

The estimates of the present-day and future ranges of costs associated with veld and forest fires are displayed in Table 7. The costs of years with extreme costs (90th percentile) are significantly higher for the 2021-2050 period relative to the baseline costs. Costs are only marginally lower for the high mitigation scenario (RCP4.5) relative to the low mitigation case. The most significant benefits associated with high mitigation is only to be realised during the second half of the 21st century.

Table 7: Estimates of present-day and future costs associated with veld and forest fires (costs expressed in terms of 2014 millions of US$).

Period	10th percentile	Median	90th percentile
Present-day (1971-2000)	6.0	19.0	32.0
2021-2050 Low mitigation (RCP8.5)	3.3	22.9	53.2
2021-2050 High mitigation (RCP4.5)	3.2	21.6	50.7

The estimates of the present-day and future ranges of costs associated with droughts are displayed in Table 8. The costs of years with extreme costs (90th percentile) are significantly higher for the 2021-2050 period relative to the baseline costs. Costs are only marginally lower for the high mitigation scenario (RCP4.5) relative to the low mitigation case. The most significant benefits associated with high mitigation is only to be realised during the second half of the 21st century. Years with decreases costs associated with droughts are also projected to occur, consistent with a minority of climate models projecting increases in rainfall and decreases in drought-frequency over the central and eastern parts of the country.

Table 8: Estimates of present-day and future costs associated with droughts (costs expressed in terms of 2014 millions of US$).

Period	10th percentile	Median	90th percentile
Present-day (1971-			

2000)	3.3	15.9	69.0
2021-2050 Low mitigation (RCP8.5)	3.0	20.4	90.5
2021-2050 High mitigation (RCP4.5)	3.1	19.8	87.6

The estimates of the present-day and future ranges of costs associated with floods are displayed in Table 9. The costs of years with extreme costs (90th percentile) are significantly higher for the 2021-2050 period relative to the baseline costs, under both high and low mitigation futures. The most significant benefits associated with high mitigation are only to be realised during the second half of the 21st century. In the somewhat drier futures that are projected, the median of costs associated with flood events are projected to change only modestly under climate change, however, it is the years of extreme costs that may be of most significance to the South African economy.

Table 9: Estimates of present-day and future costs associated with floods (costs expressed in terms of 2014 millions of US$).

Period	10th percentile	Median	90th percentile
Present-day (1971-2000)	10.9	149.3	1812.4
2021-2050 Low mitigation (RCP8.5)	4.2	179.2	4531.0
2021-2050 High mitigation (RCP4.5)	3.9	161.1	4440.3

The estimates of the present-day and future ranges of costs associated with thunderstorms are displayed in Table 10. The costs of years with extreme costs (90th percentile) are higher for the 2021-2050 period relative to the baseline costs, under both high and low mitigation futures. The most significant benefits associated with high mitigation are only to be realised during the second half of the 21st century. In the somewhat drier futures that are projected, the median of costs associated with intense storms are projected to change only modestly under climate change, however, it is the years of extreme costs that may be of most significance to the South African economy.

[we must write up a section where all the costs are aggregated; then reduced to annual aggregate figures; discounted to future costs, adjustments for either costs based only on infrastructure, projected for 2020-2030] including the assumptions made in the aggregation process

6 Quantification of current and past adaptation investments

6.1 National capacity to facilitate climate change adaptation

Investment into national government capability to facilitate climate change adaptation in terms of human capacity and processes is considered in this section as investment into adaptation efforts. This is the responsibility of the Department of Environmental Affairs (DEA) and resides within the Climate Change and Air Quality Programme in the department. The purpose of the programme is to formulate policies, and administer legislation and implement systems to improve regulation, monitoring and compliance regarding climate change and air quality and its objectives are

6.2 Investments in programmes and projects

6.2.1 Water sector

As noted above, the climate change adaptation technologies for the water sector that are most commonly used are boreholes/tubewells as a drought intervention for domestic water supply, desalination, household and large scale waste water treatment, improved water safe storage, improving resilience of protected wells to flooding, increasing the use of water-efficient fixtures and appliances, leakage management, detection and repair in piped systems, post-construction support (PCS) for community-managed water systems, rainwater collection from ground surfaces-small reservoirs and micro-catchments, rainwater harvesting from roofs, water reclamation and reuse, and water safety plans (WSPs)[3].

Based on these technologies the water sector government programmes that have climate change adaptation components to them are

a. Water resource management which ensures that the country's resources water resources are used, developed, conserved and managed in sustainable and equitable manner to the benefit of all the people of South Africa. This is done through effective policies and strategies, integrated planning, water ecosystems knowledge base and procedures, water information management and institutional oversight.
b. Water infrastructure management that ensures a reliable supply of water from bulk water resources infrastructure to meet sustainable demand objectives for South Africa within acceptable risk parameters. The programme also solicits and source funding to implement, operate and maintain bulk raw water resources infrastructure in an efficient and effective manner by strategically managing risks and assets. This includes infrastructure development and rehabilitation to ensure the safety and functionality of dams and related infrastructure.
c. Regional implementation and support that coordinates the establishment of water resource management institutions and facilitates water conservation, demand management, and access to water infrastructure by communities. The integrated catchment management in this programme provides for the protection, development, use and management of the resources at water management area level.

Under these programmes, the Department of Water Affairs (now the Department of Water and Sanitation) has, during the period 2010 to 2015, commissioned a number projects that are listed in reports on national expenditure to the National Treasury. These are considered climate change adaptation projects as guided by the water sector climate change adaptation technologies outlined above. These include strategies that have been developed for water systems around the country during period 2010 to 2015. The results are also shown in Figure 20 relative to the total annual expenditure of the national department that are outlined above to give an indication of the history of how much the water sector has invested in projects that

[3] http://www.climatetechwiki.org/

might be considered to be climate change adaptation projects. These projects range from the development of new desalination plants around the country, through augmenting water resources by upgrading boreholes as well as constructing new waste water treatment plants and upgrading old ones.

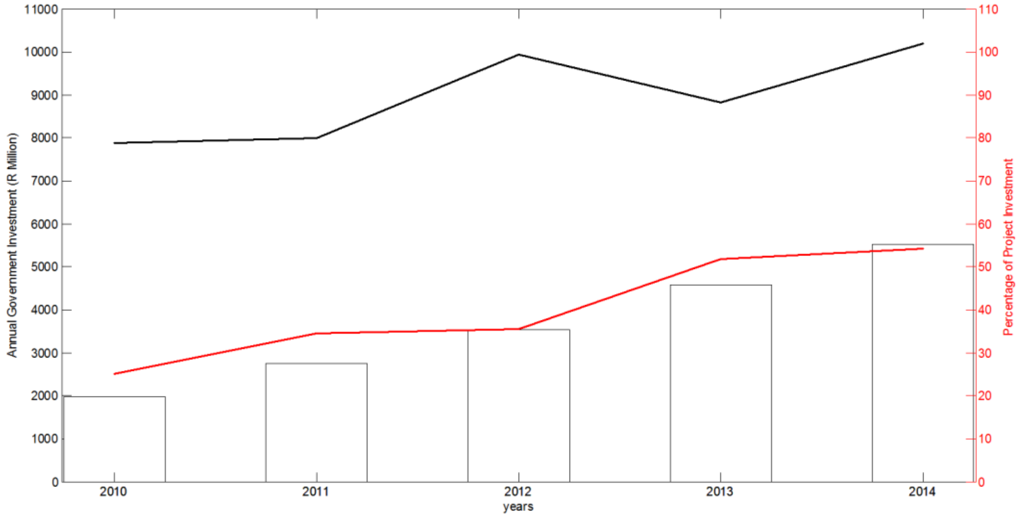


Figure 20: Combined graphs showing annual budget allocations to the Department of Water Affairs (Black line) and expenditure on projects that are deemed climate change adaptation initiatives (bar graph) as guided by climate adaptation technology definitions (Footnote 2) plotted as a function of month on the left y-axis in R Millions. On the right axis the percentage of percentage of project investment relative to total government allocation is shown (red graph).

It follows from Figure 20 above those investments into efforts to render the South African water sector more climate resilient has steadily been increasing over the last five years. Most of the investment went into the development of bulk water supply infrastructure and maintenance thereof, development of new desalination plants and upgrade of old ones, augmentation of water supply from boreholes which can also be used as a drought intervention for domestic water supply, large scale water treatment plants, the development of new water storage facilities and improving on the old ones by increasing their capacity as well as optimization of the water monitoring network.

6.3 Agricultural sector

Climate change adaptation technologies or the agricultural sector are planning for climate change and variability[4] (e.g. national climate change monitoring system, seasonal to inter-annual prediction, decentralised community-run early warning systems, climate insurance), sustainable water use and management (e.g. sprinkler and dripping irrigation, fog harvesting, rainwater harvesting), soil management (e.g. slow-forming terraces, conservation tillage, integrated soil nutrient management), sustainable crop management (e.g. crop diversification and new varieties, new varieties through biotechnology, ecological pest management, seed and grain storage), sustainable livestock management (e.g. selective breeding via controlled mating,

[4] Note that these technologies will be considered in section 6.1.3 as such activities fall under the responsibility of the Department of Environmental Affairs

livestock disease management), sustainable farming systems (e.g. mixed farming, agro-forestry), and capacity building and stakeholder organisation (e.g. farmer field schools, community extension agents, forest user groups, water user associations).[5]
Programmes having a climate change adaptation link to them are:

a. Agricultural production, health and food security which contributes activity to the water-energy-food nexus and its purpose is to manage the risks associated with animal diseases, plant pests, genetically modified organisms (GMOs) and registration of products used in agriculture; promote food safety; and create an enabling environment for increased and sustainable agricultural production. Its objective is to promote efficient production, handling and processing food, fibre and timber products, ensure protection of indigenous genetic resources, manage the level of risk associated with food, dieses, pest, natural disasters , and trade as well as establish and maintain effective early warning system and mitigation.
b. Food security and agrarian reform which contributes facilitating and promoting household food security and agrarian reform programmes and initiatives targeting subsistence and smallholder producers. This is done by coordinating the government's food security initiatives and providing leadership and support to research, training and extension in the sector.
c. Forestry and natural resources management which develops and facilitates the implementation of policies and targeted programmes to ensure management of forests, sustainable use and protection of land and water, as well as managing agricultural risks and disasters.
d. Fisheries management which promotes the development, management, monitoring and sustainable uses of marine living resources and the development of South Africa's fisheries sectors.

Following the same procedure as in Subsection 6.1.2, the adaptation technologies were used as a guide to identify investments made in the agricultural sector for climate change adaption. The series of those investments are shown in Figure 21 below.

[5] http://www.climatetechwiki.org/

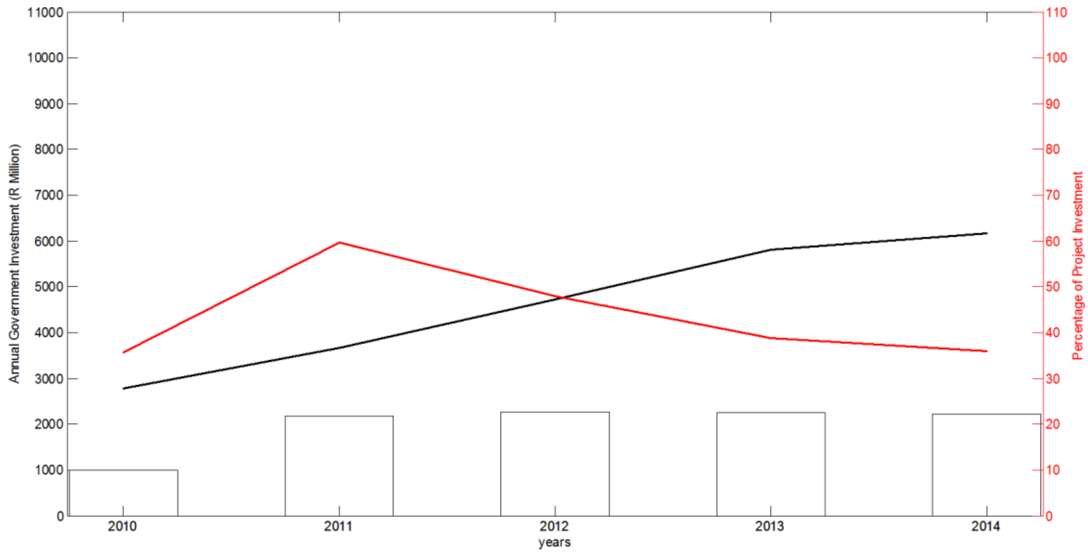


Figure 21: Same as in Figure 20 but for the agricultural sector

A key climate change adaptation technology that forms the basis of all adaptation efforts and strategies is operational climate monitoring and operational climate prediction. This is function of the South African Weather Service (SAWS) which is an entity of the Department of Environmental Affairs (DEA). Transfers to SAWS for the maintenance of these operational climate related activities are considered climate change adaptation, these are shown in the table below for the period 2010 to 2014.

Years	2010	2011	2012	2013	2014	2015
US$ Million						
Climate monitoring and prediction	13 535.7	14 861.4	13 820.5	15 058.1	16 294.3	15 248.9

In addition to the above, various funding initiatives have been undertaken that are relevant to climate change adaptation in this sector.

a. Environmental Protection and Infrastructure Programme identifies, plans and implements projects under the expanded public works programme through the use of labour intensive methods targeting the unemployed, youth, women and people with disabilities; and empowers small, medium and micro enterprises during project implementation processes. In 2012/13, 99 548 work opportunities were created, while 13 613 were created in the first half of 2013/14.
b. Working for water (WfW) the objective of which is to reduce the density of established, terrestrial, invasive alien plants, through labour intensive, mechanical and chemical control, by 22% per annum. Working on fire (WoF) which has the following objectives: To reduce the cost of clearing the invasive plants, to prevent and control wild fires, to implement integrated fire management; to contribute to the reduction of densely

invaded areas; and to reduce the risk of high biomass loads after clearing. These that South Africa addresses its responsibilities relating to water resource management, biological diversity and the functioning of natural systems; and ensures that meaningful livelihood opportunities are supported for those employed on these programmes. The Working for Wetlands programme, which is responsible for the rehabilitation, protection and sustainable use of wetlands, and the Working for Land programme, which addresses the rehabilitation and restoration of degraded land, are where this subprogramme's activities are focused. Working on Fire employs and trains young men and women from marginalised communities to be skilled, wild land fire fighters, in order to reduce the personal and economic harm caused by unwanted wildfire.

c. Green Fund invests in projects to protect the environment by working with the donor community and the private sector. The Development Bank of Southern Africa has been appointed as the implementing agent of the fund. In 2013/14, 22 projects were approved for implementation.

Years	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
US$ Million						
Environmental Protection	84 955.8	54 279.7	113 623.9	84 889.6	81 738.3	88 006.8
WfW and WoF	62 496.7	88 944.3	110 758.4	144 621.0	15 0645.4	183 175.3
Green fund	0	0	8 877.4	2 5000.0	2 5000.0	3 000.0

6.4 Biodiversity and ecosystems

The adaption of biodiversity and ecosystems is undertaken through the safeguarding of ecosystems, species and genetic diversity, and the minimising of threats to ecological sustainability, by increasing the percentage of land under conservation from 7.7 per cent in 2012/13 to 9.5 per cent in 2016/17. Furthermore these efforts promote and enhance livelihoods through access to, and fair and equitable sharing of, benefits arising from the use of biological resources. It is envisaged that a system for transformation of the biodiversity sector will be in place by 2016/17. The key interventions that can have aided climate change adaptation in the biodiversity sector are

a. The protection and conservation of the country's biological resources and ecosystems for human wellbeing and sustainable development; and development and implements programmes and processes aimed at the protection and mitigation of threats to biodiversity at the species and ecosystem levels. This entails developing, coordinating and implementing policies and decision support tools for conservation planning and biodiversity management. In 2012/13, the mining and biodiversity guideline was finalised and published, and risk assessment guidelines for alien and invasive species were developed. In 2013/14, the minimum requirements for biodiversity in land use planning and integrated environmental management were drafted.

b. Protected Areas Systems Management oversees the establishment and maintenance of comprehensive, effectively managed and ecologically representative national and cross border systems of protected areas. This entails ensuring the effective management of transfrontier conservation areas; developing and overseeing the implementation of protected area policies and legislation; and ensuring compliance with and enforcement of protected area legislation, while promoting the participation and beneficiation of local communities in the establishment, development and management of protected areas. In 2012/13, management plans for De Mond Nature Reserve, Seekoeivlei Nature Reserve, Langebaan Lagoon, uKhahlamba Drakensberg Park and De Hoop Nature Reserve were completed. In 2013/14, 5 management plans were evaluated. This subprogramme had a staff complement of 40 in 2013/14.

c. iSimangaliso Wetland Park Authority conserves and promotes the park. In 2012/13, 10 per cent of the park's former commercial forestry and other incompatible land use areas were rehabilitated. In 2013/14, 47 pre-site inspections were completed and 20 contractors were appointed regarding rehabilitation of degraded habitats and ecosystems.
d. South African National Parks conserves, protects, controls and manages national parks and other defined protected areas and their biological diversity. The total number of visitors to the parks grew by 5 per cent from 4 705 306 in 2012/13 to 4 941 697 in 2013/14.
e. The South African National Biodiversity Institute implements strategic activities as identified in the National Environmental Management: Biodiversity Act (2004), with a specific focus on biodiversity research and knowledge management in support of South Africa's biodiversity. In 2012/13, 30 publications were reviewed at the institute and in 2013/14, 33 publications were produced. The publications focused on trends, risks and benefits associated with emerging invasive, threatened species and the sustainable use of biological resources.
f. Biodiversity Monitoring and Evaluation is responsible for sector wide biodiversity monitoring and evaluation, and coordinating biodiversity related multilateral environmental agreements through the management of the science policy interface. In 2012/13, the fifth national report to the Convention on Biological Diversity was compiled. In 2013/14, the international expert and stakeholder workshop on the conceptual framework for the intergovernmental science policy platform on biodiversity and ecosystem services was hosted.

The expenditure for this programme for the past five years within the DEA is:

Years	**2010**	**2011**	**2012**	**2013**	**2014**
US$ Million					
Biodiversity and conservation	36 885.2	44 259.8	47 952.7	56 841.2	57 672.9

At the end of every fiscal year all departments of the South African government are required to issue annual reports on expenditure. From these it is possible to estimate how much the government has invested on activities that may be related to climate change adaption. Whilst some of these investments are not flagged as direct adaptation components, if the methods used in implementing them meet the criteria or definitions of adaptation technologies, they may be regarded as such. These activities may also be regarded as a measure of technology transfer for the adaptation sector in South Africa. As a guide, the adaptation technologies themselves for various sectors were used (Table 10) were used to extract the investments made by the country in climate change adaptation related activities. It should be noted that not all these technologies will be applicable

When up scaled with by the range[6] 5% - 15% increase per annum to the years 2020, 2025 and 2030, the adaptation investments respectively increase to ranges R15.3m – R24.1m, US$1.96m – R48.6m and R25m – R97.7m for building national capacity in the coordinating ministry. For the same years, the total investments increase to R29.5 bn- R46.5 bn, R37.6 bn – R93.5 bn and R48.0 bn – R188.0 bn. When broken down into sectors the increases translate into sectoral range of estimates as follows

	2020 (US$ bn)	2020 (US$ bn)	2030 (US$ bn)
Agriculture and Fisheries	0.75 - 1.19	0.96 – 2.39	1.22 – 4.8
Energy	0.46 - 0.72	0.59 – 1.46	0.75 – 2.93
Human settlements	0.0.3 - 0.04	0.03 – 0.08	0.04 – 0.16
Biodiversity	0.06 - 0.1	0.08 – 0.20	0.10 – 0.41
Water	0.75 - 1.19	0.96 – 2.39	1.22 – 4.8
disaster risk reduction	0.89 - 1.41	1.14 – 2.83	1.45 – 5.7

Some of the key programmes requiring scaling-up going forward, particularly beyond 2020 include,

1. Working for Water (WfW) and Working on Fire (WoF) estimated at US$ 1.2 bn
2. Working on Wetlands estimated at US$ 0.12 bn
3. Water Conservation and Water Demand Management estimated at US$ 5.3 bn
4. LandCare estimated at US$ 0.07 bn

7 Concluding remarks

7.1 South Africa's adaptation commitments for the period 2020 - 2030

The purpose of preparing Intended Nationally Determined Contributions (INDCs) by all Parties to the United Nations Framework Convention on Climate Change is to inform the outcomes on the 2015 agreement under the United Nations Framework Convention on Climate Change (UNFCCC). The Parties envisage signing this new agreement at the 21st Conference of the Parties (COP) that will be held in Paris towards the end of 2015. The INDCs should be communicated to UNFCCC during the course of the year, but before COP 21 in accordance with provisions agreed in Lima in respect of upfront information to be communicated by Parties, as well as the aggregation of INDCs by October 2015.

[6] The range represents uncertainty in the estimates

The South African government currently responds to infrastructure vulnerable to extreme weather and climate event through rehabilitation and enhancing resilience in the sectors that may be affected. Scenarios of extreme events however, show that the associated costs to continue doing this will be exacerbated by increasing greenhouse concentrations. As guided by the National Development Plan, the National Climate Change Response Policy (NCCRP) – to be supported by a National Climate Change Adaptation Plan in 2017 – and sectoral plans, the South African government's adaptation goals and aspirations for the period 2020 – 2030 may be articulated as follows:

Goal 1: Development of a vulnerability assessment and adaptation needs framework by 2020
Aspiration: To provide information relevant to potential climate change impacts and adaptation responses at an appropriate scale that can be embedded at key junctions of decision-making and regulatory processes

Goal 2: Mainstreaming of policies, sectoral plans and programmes to incorporate climate change considerations by 2020
Aspiration: To ensure that there is alignment between sectoral plans, economic growth and potential climate change impacts

Goal 3: Strengthening capacity at institutions and institutionalisation to climate change by 2025/2030
Aspiration: To strengthen government's capacity to respond to climate change and educate the public on climate change

Goal 4: Development of an early warning and reporting system for all climate adaptation sectors by 2025/2030
Aspiration: To use information on vulnerability and risk to enhance early warning systems and report on progress and implementation of adaptation plans

Goal 5: Plan to adapt to the impacts of climate change
Aspiration: Consider adaptation to the impacts of climate change and means to increase resilience in sectoral plans and National Adaptation Plan, revised after each five-year implementation period.

Goal 6: Invest in adaptation and gain recognition for past investment
Aspiration: The government of South Africa will invest in adaptation to ensure its citizens – and particularly poor communities – are less negatively impacted by climate change. It will seek recognition of such efforts in the UNFCCC.

7.2 Means of implementation

7.2.1 Technology development, transfer and deployment

For implementation of key climate change adaptation projects, South Africa's technology development - transfer and deployment (TTD) initiatives - should link with the technology needs assessment (TNA) and technology action plan (TAP), which is currently being updated to the second phase.

The South African government identified an innovation chasm, which also exists in the climate change adaptation area. As a means of implementation domestic technology transfer needs to be enhanced, thus linking South African technology development research with adaptation outcomes. The technology needs of the country will also be satisfied by the acceleration of international technology transfer. The South African government, in response to the TNA and TAP will stimulate the development of technology assistance to the Climate Technology Centre and Network (CTCN). Through the CTCN facility, technology transfer efforts matchmaking with international donors technology transfer will link to sub-section 4.2 below.

7.2.2 Additional, reliable and adequate financing

With South Africa's current adaptation costs plausibly affected through climate change and related extreme events, it is important that estimates of these costs are projected timeously and reliably. Cost estimations inform climate change adaption investments, which in turn increase resilience, and reduce future damage costs from high impact climate events. Adaptation investments should be made and informed by the following procedure

- Continued systematic refinement of cost calculations and planning through enhanced interaction with the different sectors;
- Increase national investment into climate change adaptation;
- Identify the adaptation gap between South Africa's national investments in adaptation and the total investments needed to be more resilient to climate change;
- Materialise international investment to fill the adaptation gap through UNFCCC regulations and negotiations; and
- Enhanced international investment in adaptation in South Africa through the adaptation fund and other international investment instruments.

7.2.3 Capacity building – Research, data collection and use

Establish a National Adaptation Planning Commission (NADC) that will develop a National Framework for climate change adaptation according to the NCCRP with continuous modification thereof and aligned with National Development objectives. The NADC will work increasingly with different sectors towards incorporating adaptation needs in the NDP. The NADC should link with academic institutions to align training programmes to the adaptation needs of the country. This should create targeted research that will make use of data collected through various designated entities to inform the implementation of climate change adaptation programmes.

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