Embedding climate change & disaster risk reduction within the Tsitsa Project

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List of Acronyms

ARC	Agricultural Research Council
ARC-ISCW	Agricultural Research Council Institute for Soil, Climate and Water
ANDM	Alfred Nzo District Municipality
AWARD	Association for Water and Rural Development
CCA	Adaptation to climate change
CCAFS	Climate Change, Agriculture and Food Security
CGIR	Consortium of International Agricultural Research Centres
CSA	Climate Smart Agriculture
CPO	Community of Practice
CA	Conservation Agriculture
CSIR	Council for Scientific and Industrial Research
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CWP	Community Works Programme
DEA	Department of Environmental Affairs
DAFF	Department of Agriculture, Forestry and Fisheries
DWS	Department of Water and Sanitation
DICLAD	Dialogues for Climate Change Literacy and Adaptation
DDR	Disaster risk reduction
EbA	Ecosystem Based Adaptation
EMG	Environmental Monitoring Group
EPWP	Extended Public Works Programme
FANRPAN	Food, Agriculture and Natural Resources Policy Analysis Network
FAO	Food and Agricultural Organization of the United Nations
FFS	Farmer Field School
DAO	Desired Adaptation Option
GCM	Global Change Model
GHG	Greenhouse gas
$GtCO_2eq$	Gigatonnes of equivalent carbon dioxide
IDP	Integrated Development Plan
IPCC	Intergovernmental Panel on Climate Change
M-INDC	Mitigation Nationally Determined Contribution
$MtCO_2e$	Metric tons of carbon dioxide equivalent

NAP	National Action Programme
NBRES	National Biodiversity Research & Evidence Strategy
NCCRP	National Climate Change Response Policy
NDVI	Normal deviation vegetation index
NGO	Non government organisation
OAC	Objective Adaptive Capacity
PAC	Perceived Adaptive Capacity
PMERL	Participatory Monitoring, Evaluation, Reflection and Learning
RCM	Regional Climate Models
RCP	Relative concentration pathways
RESILIM-O	Resilience in the Limpopo Basin Programme - Olifants
RSA	Republic of South Africa
SAWS	South African Weather Service
SAEON	South African Environmental Observation Network
SANBI	South African National Biodiversity Institute
SARVA	South African Risk and Vulnerability Atlas
SDG	Sustainable Development Goal
SPI	Standardised Precipitation Index
SPEI	Standardised Precipitation-Evapotranspiration Index
USAID	United States Agency for International Aid
WRC	Water Research Commission

1. Introduction

There is irrefutable evidence that global warming is happening. According to the IPCC (2018) current predictions indicate that global mean temperature is likely to reach 1.5ºC above pre industrial level between 2030 and 2052 if it increases at the current rate and 2ºC by 2100 unless there are serious attempts globally to mitigate greenhouse gas emissions. The IPCC (2018) report looks at the implications of a 1.5ºC warming against a 2ºC warming. The general conclusion is that there is high confidence that a 2ºC warming will have major impacts on the world's socio-ecological systems while a 1.5ºC change will have more moderate impacts that will be easier to adapt to.

The IPCC (2018) report suggest that the current nationally stated mitigation ambitions as submitted under the Paris Agreement (December 2015) (52–58 $GtCO_2eq\ yr^{-1}$ by 2030) would not be sufficient to limit global warming to 1.5ºC. Global CO_2 emissions need to decline well before 2030 if the effects of global arming are to be limited to a manageable level. A reduction in atmospheric carbon lags behind a reduction in GHG emissions as CO_2 will remain in the atmosphere indefinitely if not actively sequestered. van Vuuren et al. (2011) warn that it may be technically feasible to keep long-term warming to below 2ºC but whether or not this is achieved depends on overcoming political and social inertia. This presents a warning that the world and South Africa could see significant shifts in the frequency and intensity of climate related hazards over the next ten years and beyond.

South Africa is developing a number of Flagship programmes to address mitigation of and adaption to climate change (DEA 2017). One of these is the Land, Biodiversity and Ecosystems Flagship that promotes large scale investment in, and expansion of, the restoration and rehabilitation of South Africa's natural resources. There are clearly synergies between this Flagship Programme and the Tsitsa Project. How climate change and disaster risk management can be embedded into the Tsitsa Project is explored in this report.

The report starts with an overview of observed and projected global climatic change with particular reference to South Africa and the Tsitsa area. Mitigation and adaptation options are considered in relation to their application to the Tsitsa Project. Current South African policy is reviewed in order to examine the context of options for the Tsitsa Project.

In May 2019 many South Africa's ministries were reconfigured, with the Department of the Environmental Affairs (DEA) becoming the Department of Environment, Forestry and Fisheries. the Department of Agriculture, Forestry and Fisheries (DAFF) becoming the Department of Agriculture, Land Reform and Rural Development and the Department of Water and Sanitation becoming the Department of Water and Human Settlement. At the time of writing the websites for these departments still use the former acronyms and government publications cited in this report all come under the former names. To avoid confusion over name changes the pre-May 2019 names are used.

2. Global scale climate change - pre-industrial to the present

2.1. GHG emissions

CO_2 is the most important GHG responsible for global warming, contributing more than 60% of total radiative forcing by long-lived GHGs. Other important GHGs are methane, nitrous oxide, chlofluorocarbons (CFCs) and water vapour. Figure 1 presents data on CO_2 concentrations measured at Cape Point in South Africa, showing the steady increase over the period 1993 to 2017.

The rate of increase is similar to those measured globally (Joubert 2018). CO_2 levels measured at Mauno Loa, Hawai, have increased from 315 ppm in 1958 to over 410 ppm at the start of 2019 (Scripps CO_2 Programme accessed on line 23 February 2019 http://scrippsco2.ucsd.edu). Ice core records indicate a relatively stable CO_2 concentration of under 280 ppm in the late 18th Century (Scripps CO_2 Programme accessed on line 23 February 2019 http://scrippsco2.ucsd.edu).

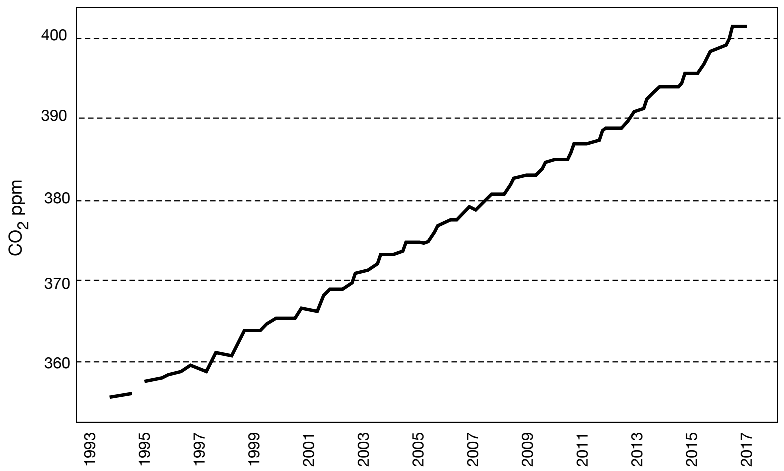


Figure 1. Measured CO_2 concentrations at Cape Point. Source: redrawn from WeatherSmart August 2018

Global carbon emissions have increased tenfold from around 1 000 metric tonnes of carbon per year in the early 20 Century to nearly 10 000 metric tonnes of carbon per year in 2015 (United States Environmental Protection Agency no date). Burning fossil fuels and industrial processes contributed about 78% of this between 1970-2011. Agriculture, deforestation and other land use changes make the second largest contribution to GHG emissions.

South Africa's GHG emissions are currently growing at a rate of about 7 $MtCO_2e$ per annum, from 434 $MtCO_2e$ in 2000 to 529 $MtCO_2e$ in 2010, after which emissions decreased to 518 MtCO2e in 2012 (DEA 2017). The decline can be attributed to a combination of mitigation actions and economic decline. A cumulative total of 779.4 $MtCO_2e$ of emission reduction was achieved by 2014. The Kusile and Medupi coal-fired power plants will offset some of this achievement, contributing between 55 and 60 $MtCO_2e$ per annum to the national GHG inventory. According to USAID (2016) in 2012 84% of South Africa's GHG emissions came from the energy sector, 7% from agriculture, 5% from industrial processes, 4% from waste and 0.2% from land use change and forestry.

2.2. Climate change indicators

(1) Temperature

According to the IPCC (2018), global mean temperature has increased by 0.87ºC for the period between 2006-2015 compared to1850-1900 (pre-industrial). Current warming is around 0.2ºC per decade. There has been a 0.5ºC increase between 1960-1979 and 1991-2010. The global mean temperature increase relative to pre-industrial reached 1ºC in 2017.

There is considerable variation in temperature increases over the world; in general they are greater over land than the oceans. The greatest temperature increases have been observed over the Arctic. There has also been intensification of extremes with maximum temperatures increasing by 1ºC and minimum temperatures by 2.5ºC over the last half century. Increases in mean temperatures bring greater increases in extremes (maximum and minimum) and duration of hot spells.

Figure 2 indicates that temperatures over South Africa have risen by an average of 0.16ºC per decade or 1.08ºC over the 67 year period since 1951. Pearce and Huasfather (2018) indicates a warming since 1985 of 0.08ºC per decade or 1.28ºC over the 160 year period since 1850 for the Tsitsa area (Figure 3).

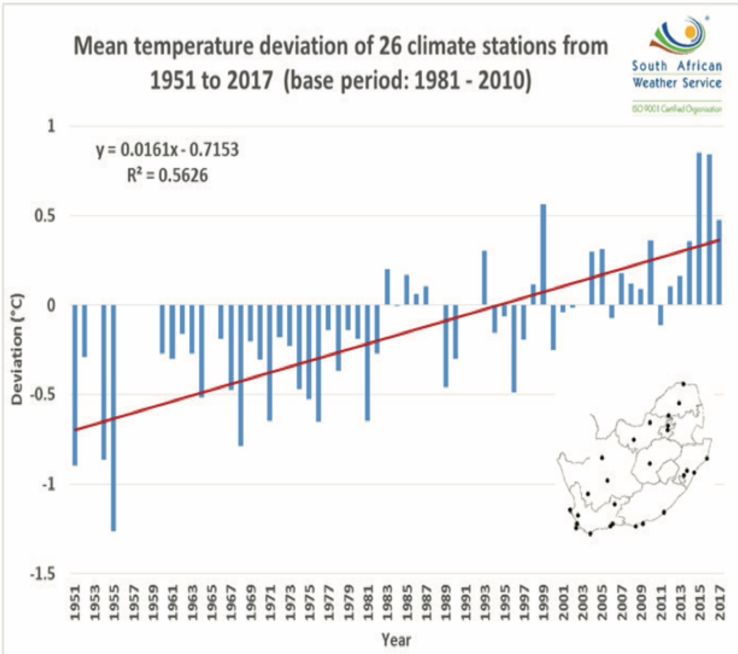


Figure 2. Temperature trend in South Africa, 1951-2017 (Source: Kruger et al. (2018) p. 2

During the 2015-16 drought, South Africa experienced prolonged heatwaves (defined as at least three consecutive days with maximum temperature more or equal to 5ºC higher than the average maximum of the hottest month for a particular station) (DEA 2017).

(2) Precipitation

Evidence for changes to precipitation is less clear than for temperature and varies regionally. Mean precipitation over mid-latitude land areas in the Northern Hemisphere has increased since 1951 but no clear trends are observed elsewhere (partly due to poor quality data) (IPCC 2018). There is global scale evidence that there has been an increase in the intensification of heavy precipitation over the second half of twentieth century with an increase in frequency, intensity and/or amount of heavy rain (IPCC 2018). There is medium confidence that anthropogenic forcing has contributed to more intense rainfall since the 1950s. The IPCC (2018) identifies increased risk of drought in the Mediterranean region.

The IPCC (2018) reports that streamflow trends since 1950 are not significant for the world's largest rivers and it is difficult to ascribe any observed changes to global warming due to other catchment impacts. There is some evidence for increased frequency of flooding and more extreme events.

Precipitation trend in South Africa are regionally variable but no clear upward or downward trend has been identified. New et al. (2006) found that a decrease in regionally averaged precipitation was accompanied by an increase in the duration of dry spells, rainfall intensity and the annual maximum one-day rainfall. Kusangaya et al. (2014) note significant regional and temporal differences.

Figure 4 illustrates observed rainfall for Mtata Dam, a station that lies just outside the lower Tsitsa catchment and which should be a fair indicator of regional trends. Mean rainfall for Mtata is given as 681 mm with a standard deviation of +/- 219 mm. This gives a variability of 32%. The maximum rainfall was for the water year 1999/2000 when 1472 mm was recorded. The driest water year was 1992/1993 when 231 mm was recorded. There has been no clear trend in rainfall over the period of record.

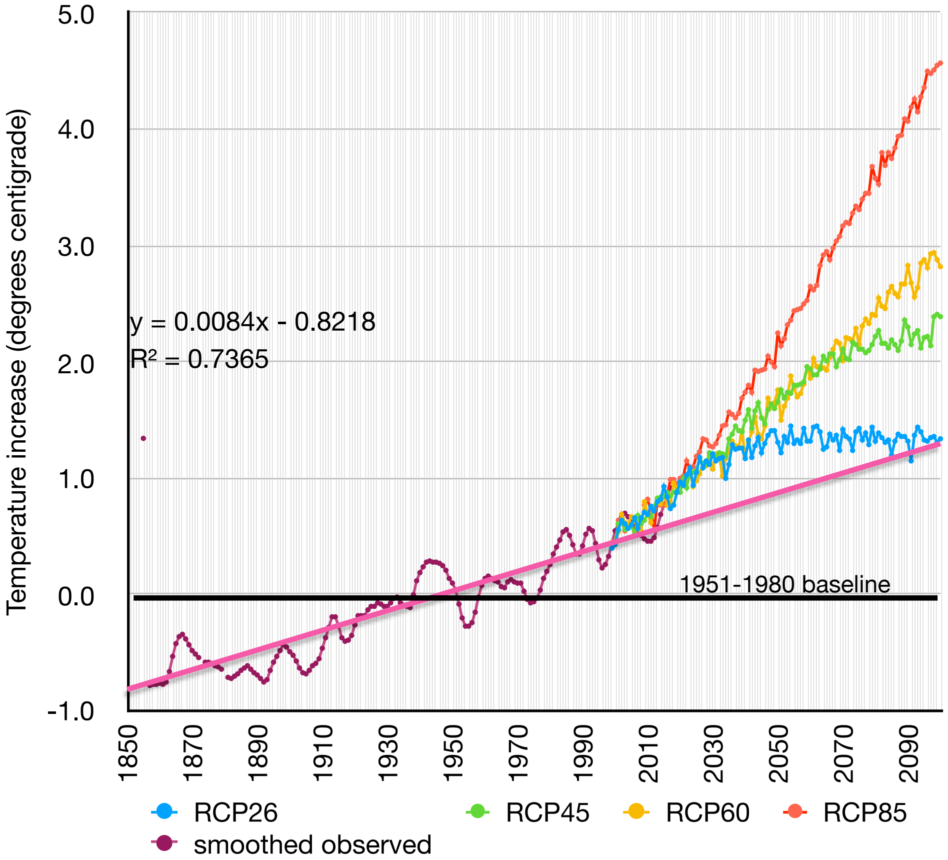


Figure 3. Observed and modelled temperature trends in the Tsitsa Catchment (Data source: Pearce & Hausefather 2018. Carbon Brief online February 2019)

Periods of higher rainfall and drought can be seen from Figure 4B. Two periods of prolonged drought can be seen for 1980-1984 and 1990-1995. Wetter periods occurred from 1985-1990, 1999-2002 and 2010-2013. Since 1995 there have been no severe meteorological droughts recorded at an annual resolution although 2006-2010 was a 4-year dry period. The DEA (2017) report indicates multi-year droughts in the winter rainfall region in the late 1920s, late 1960s-early 1970s, less severe events late 1930s, 1940s, 1950s, 1970s, 1990s, early 2000. The summer rainfall region suffered major droughts in the late 1920s to early 1930s, late 1940s to early 1950s, mid 1960s to early 1970s, early to mid 1980s, early 1990s, early to mid 2000s. The post 1980 drought periods tie in with those observed in the Mtata record.

The DEA (2017) reported extensively on the drought of 2015-16 when there was a drastic reduction in water resources: decrease in dam levels, streamflow, boreholes, drying up of natural springs. There were widespread agricultural crop losses, livestock deaths and escalating food prices across the country. Ecological impacts were observed in the mortality of perennial plants, especially in second year of the drought. A switch from perennial to annual grasses has been observed in arid and semi-arid rangelands. The effect is exacerbated by heavy grazing after drought ends. The drought resulted in many herbivore deaths.

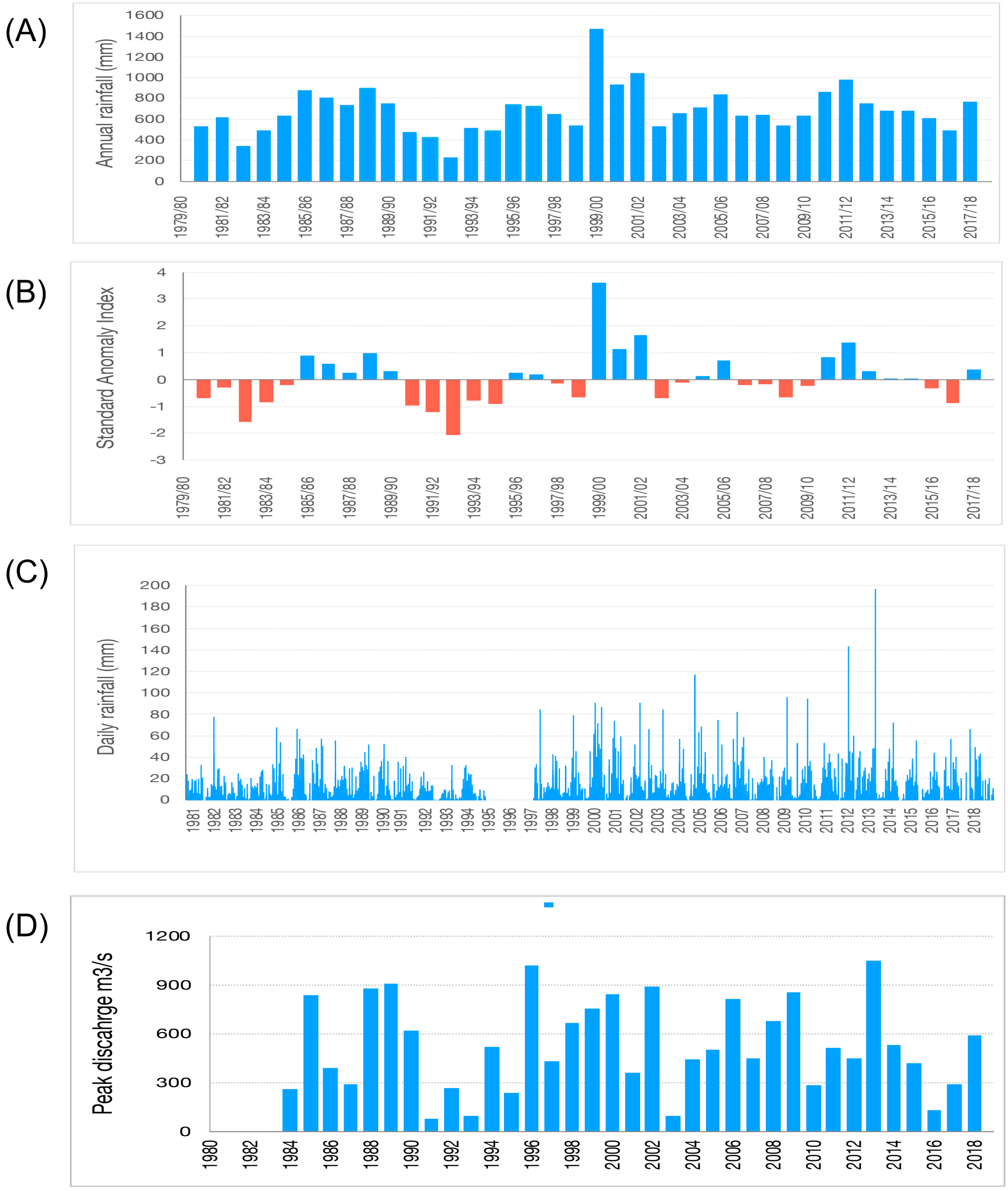


Figure 4. Rainfall time series for Mtata Dam 1980-2018: A) annual; B) Standard Anomaly Index C) daily rainfall D); Flood time series for the gauge at Xonkonxa (N2 road bridge) 1984-2018. Data source DWS online February 2019

There is some indication that the frequency of extreme daily rainfall has increased in the Tsitsa catchment. (Figure 4C). There has been a steady increase in maximum daily rainfall from 1997 to 2013 but thereafter daily maximum have been lower. The number of days receiving more than 20 mm has increased from 7 per year up to the end of 1994 to 10 per year from early 1997. This rainfall threshold can be considered to indicate rainfall that is highly likely to cause significant surface runoff, erosion and flooding.There is no apparent relationship between annual rainfall and the maximum daily rainfall.

Figure 5 illustrates the variability of monthly rainfall over the summer wet season (October to March). All months exhibit a high variability but there is a recent tendency for early summer rainfall (October to December) to decrease whereas late summer (January to March) has either been maintained or increased. There was very low rainfall in December from 2016 to 2018, aggravated in 2018 by low October rainfall, a situation that delayed planting of grain crops to the point where they might not have time to reach maturity before winter. This recent shift to late summer rainfall may be indicative of an increase in autumn rainfall projected by some climate change models (see Figure 10).

The flood record for the Tsitsa River does not indicate a clear trend to date (Figure 4D and 6). The highest flood peaks since 1960 have been in 1972, '76 and '77 and 2013 (Figure 6). All four floods exceeded 1000 m^3s^{-1} and had a flood stage exceeding 3 m at the gauge.

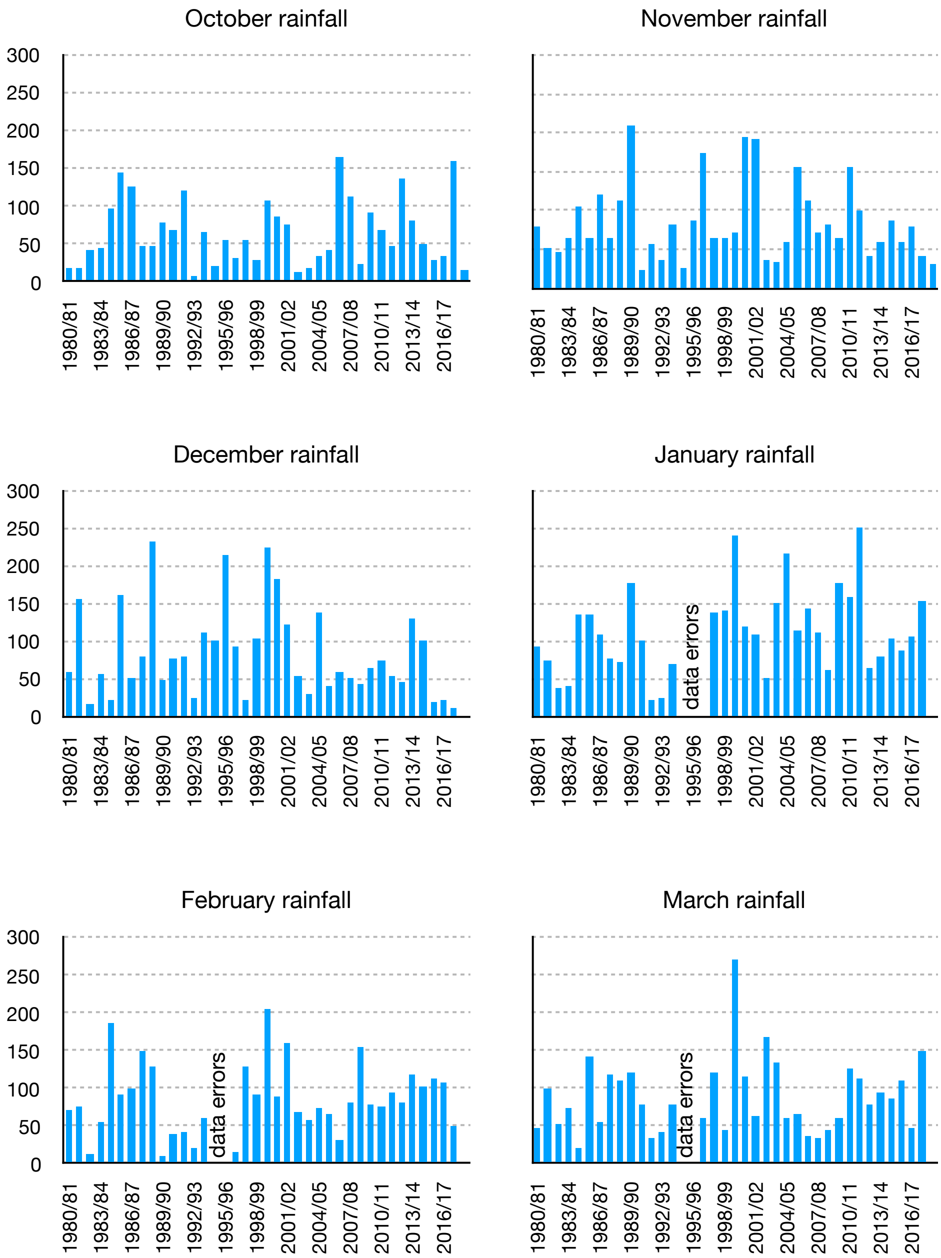


Figure 5. Time series of monthly rainfall at Mtata Dam. Date indicate water years, starting in October. Data source DWS online February 2019

2.3. Projections of future change

(1) Models

There is a wide range of models that have been used to project future climate change, collectively known as Global Change Models (GCMs) or, downscaled, as Regional Climate Models (RCMs). The South African Weather Service (SAWS) (2017) used nine downscaled models to derive an integrated projection of future climate for South Africa. The South African Environmental Observation Network's (SAEON) Risk and Vulnerability Atlas (SAEON 2017) presents climate projections based on six models performed by the Council for Scientific and Industrial Research (CSIR) of South Africa.

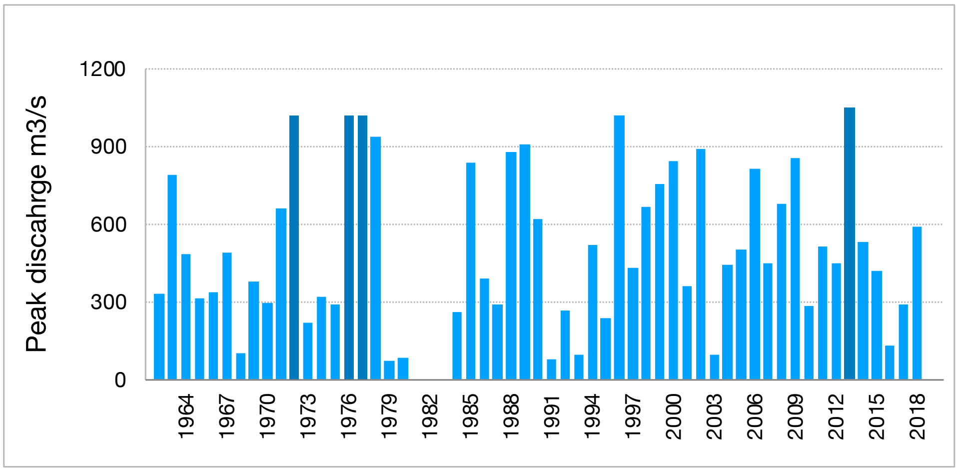


Figure 6. Annual flood series for the Tsitsa at Xonkonxa (N2 road bridge) 1962-2018. Darker columns indicate years when the gauge was overtopped. Data source DWS online February 2019

Global Change Models have been applied under a number of different Greenhouse Gas concentration trajectories, termed Relative Concentration Pathways (RCPs). Four RCPs were considered by the IPCC in the fifth Assessment Report of 2013. These are RCP2.6, RCP4.5, RCP6.0 and RCP8.5. They are defined according to their contribution to atmospheric radiative forcing in the year 2100, relative to pre-industrial values. For example, RCP2.6 indicates an increase of 2.6W/m2. RCP4.5 represents GHG concentrations that can reasonably be achieved by active mitigation whereas RCP8.5 represents 'business as usual"

Model outputs are variable depending on both the model structure and assumptions and the RCP being considered. They show a range of possible outcomes and as such should be treated with due caution. Temperature projections tend to be more consistent than precipitation and model observed trends well.

(2) Temperature

According to the IPCC 2018 report, global mean temperature is likely to reach 1.5ºC above pre industrial level between 2030 and 2052 if the current rate of increase is maintained. Locally the temperature increase is likely to be greater. Even if GHG emissions are strictly curtailed, warming will continue due to current levels of CO_2 in the atmosphere but past emissions on their own are unlikely to cause warming past 1.5ºC. An increase in mean temperature means that it is very likely that there will be an increase in the number of warm days and nights and a decrease in cold days and nights on land. The impacts related to increased global temperatures have already been observed, indicating significant impacts due to a 1.5ºC or 2ºC rise.

When looking at the long term impact of mitigating warming trends it is important to consider overshoot periods. These are periods when global warming exceeds the target value before returning to a lower temperature. They may cause irreversible changes depending on length and strength of the overshoot.

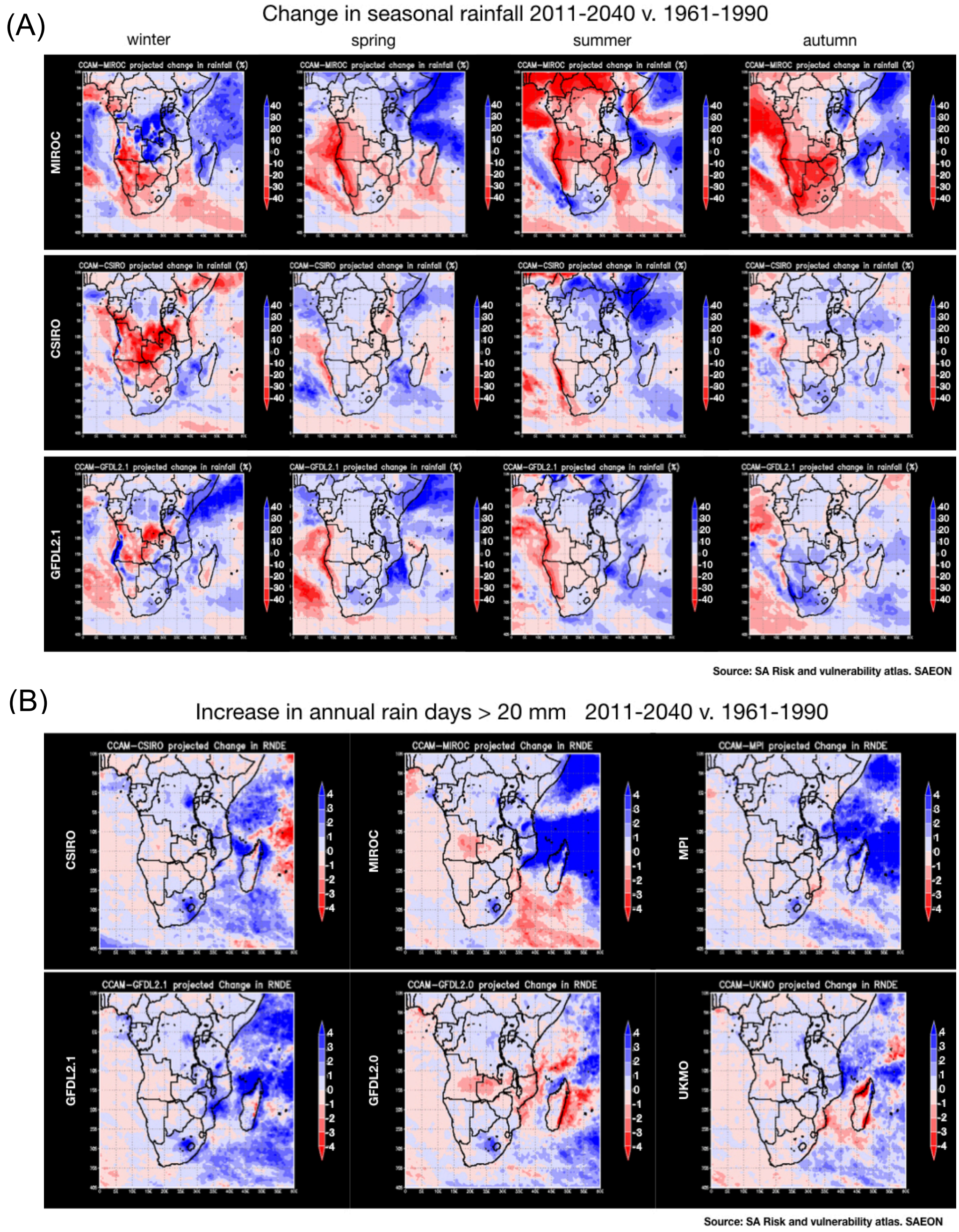


Figure 7. Projections of temperature changes under global warming. (A) output from SAEON's Risk and vulnerability Atlas; (B) output from SAWS Climate Change Reference Atlas (2017).

According to the IPCC (2018), southern Africa is one of the regions expected to show the greatest response in terms of temperature extremes, in part due to low soil moisture and lack of temperature amelioration due to evaporation. They predict that some of the strongest increases in hot extremes will be in this region and may be up to 3ºC for a 1.5ºC rise in global mean temperature. From maps published by the IPCC (2018) it can be deduced that average temperature in the Tsitsa area is likely to increase by 1.5-2ºC for a 1.5ºC global increase and by 2-3ºC for a 2ºC global increase. Carbon Brief projections indicate a temperature rise by 2100 of 1.3-4.3ºC relative to a 1950-1980 baseline depending on the modelled representative carbon pathway (RCP) (Figure 3). Maps of southern Africa in Figure 7A, from the SA Risk and Vulnerability Atlas (SAEON online February 2019), indicate a temperature rise for South Africa of up to 2ºC by 2040, regardless of the model used, and an increase of up to 5 hot days per year. SAWS (2017) predict an increase in median annual temperature in the Tsitsa catchment of between 1.5-2ºC for the period 2036 to 2065 and 2-2.5ºC for 2066 to 2095 (Figure 7B). Their results integrate the output from a number of different models.

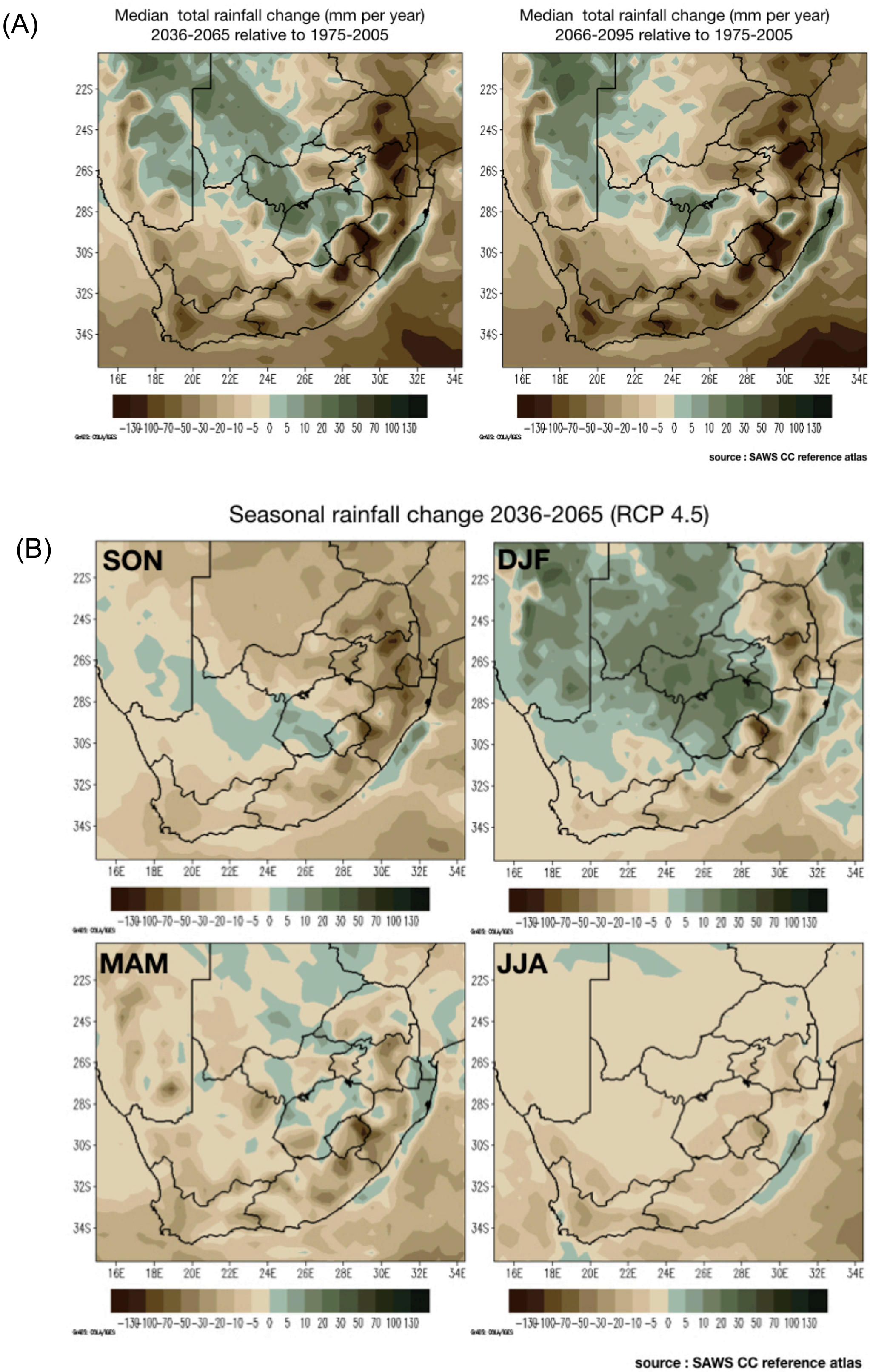
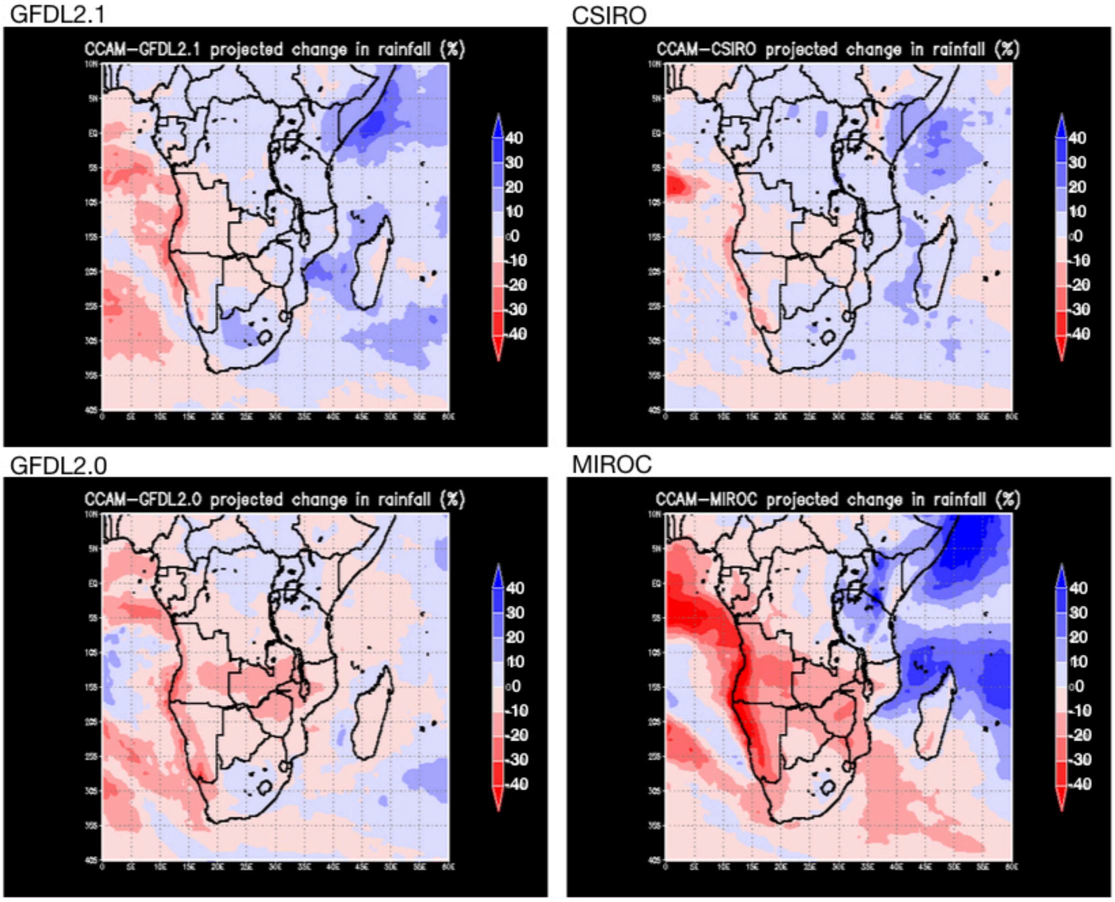


Figure 8. Projections of precipitation changes under global warming. (A) Annual change for 2036-2065 and 2066-2095 (B) Seasonal change for 2036-2065. Output from SAWS Climate Change Reference Atlas.

(3) Precipitation

(A)

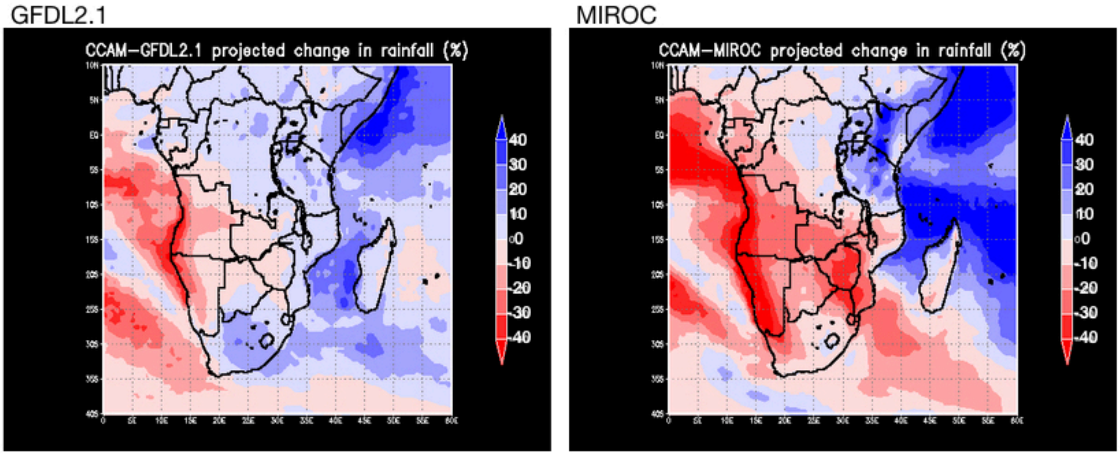
Change in annual rainfall 2011-2040 v. 1961-1990



Source: SA Risk and vulnerability atlas. SAEON

(B)

Change in annual rainfall 2041 - 2070 v. 1961-1990



Source: SA Risk and vulnerability atlas. SAEON

Figure 9. Projections of precipitation changes under global warming. (A) Annual change for 2011-2040 as projected by four climate change models (B) Annual change for 2041-2070 as projected by two climate change models. Output from SA Risk and Vulnerability Atlas, SAEON

There is greater uncertainty regarding the response of precipitation to global warming. It is likely to vary regionally, with some areas experiencing an increase in annual precipitation and others a reduction. There is a consensus that the maximum annual precipitation and consecutive 5-day precipitation will increase in many areas. Most models indicate a general reduction in rainfall over southern Africa, though some predict an increased rainfall in the north-eastern region. The general consensus is that there will be decreased rainfall over the growing season, increased variability, more extreme events, and longer dry spells (Kusangaya et al., 2014).

The IPCC (2018) report concludes that there is likely to be a decrease in the number of cyclonic storms but an increase in the frequency of intense storms with a southward shift in storm tracks. This could bring more cyclonic storms to South Africa.

Southern Africa is not among the regions where heavy rainfall events are expected to increase significantly. Modelled outputs vary significantly. The IPCC (2018) report indicates a decrease in rainfall of up to 5% for the Tsitsa catchment area but other projections indicate a small increase. The SAWS projections (Figure 8) generally agree with those from the IPCC (2018) whereas the maps in Figure 9 and 10, derived from the SA Vulnerability and Risk Atlas, shows considerable variation between modelled outputs, with most indicating an increase in both annual and seasonal precipitation. Two of the models illustrated indicate a shift towards autumn rainfall in this area. It can be noted that much greater changes are projected to the west and north west of the country, with up to a 20% decrease in rainfall.

There is more agreement in the frequency of days of heavy rainfall (Figure 10B), with all models showing some increase in the number of days with more than 20 mm. The CSIRO model indicates an increase of between 3-4 days. This would be a 30%-40% increase in the current pattern of heavy falls in the Tsitsa area.

Research on the impact of climate change on water resources of southern Africa is reviewed by Kusangaya et al. (2014). Streamflow responses to climate change are highly variable and, in part, depend on local catchment conditions. According to Kusangaya et al. (2014), modelled projections indicate a general decrease in streamflow. Graham et al. (2011) applied ten regionally downscaled future climate projections to assess the future hydrology of the Thukela River Basin, an area that is geographically similar to the Mzimvubu Basin. Despite a consistent increase in temperature shown by all models, there was less consensus regarding streamflow. The predominant outcome, however, was for increased runoff with intermittent dry periods. Schulze et al. (2011) showed the Mzimvubu to be outside the hotspots of climatic change-related water stressed areas. These were given as the south-west, the west coast and the extreme north. They noted increased (and often a high increase) year-to-year variability of the future hydrological response. This variability was related to rainfall, stormflows, accumulated streamflows and sediment yields. The most sensitive components to change were baseflows and hydrological droughts. Hydrological droughts are more sensitive to change than meteorological drought.

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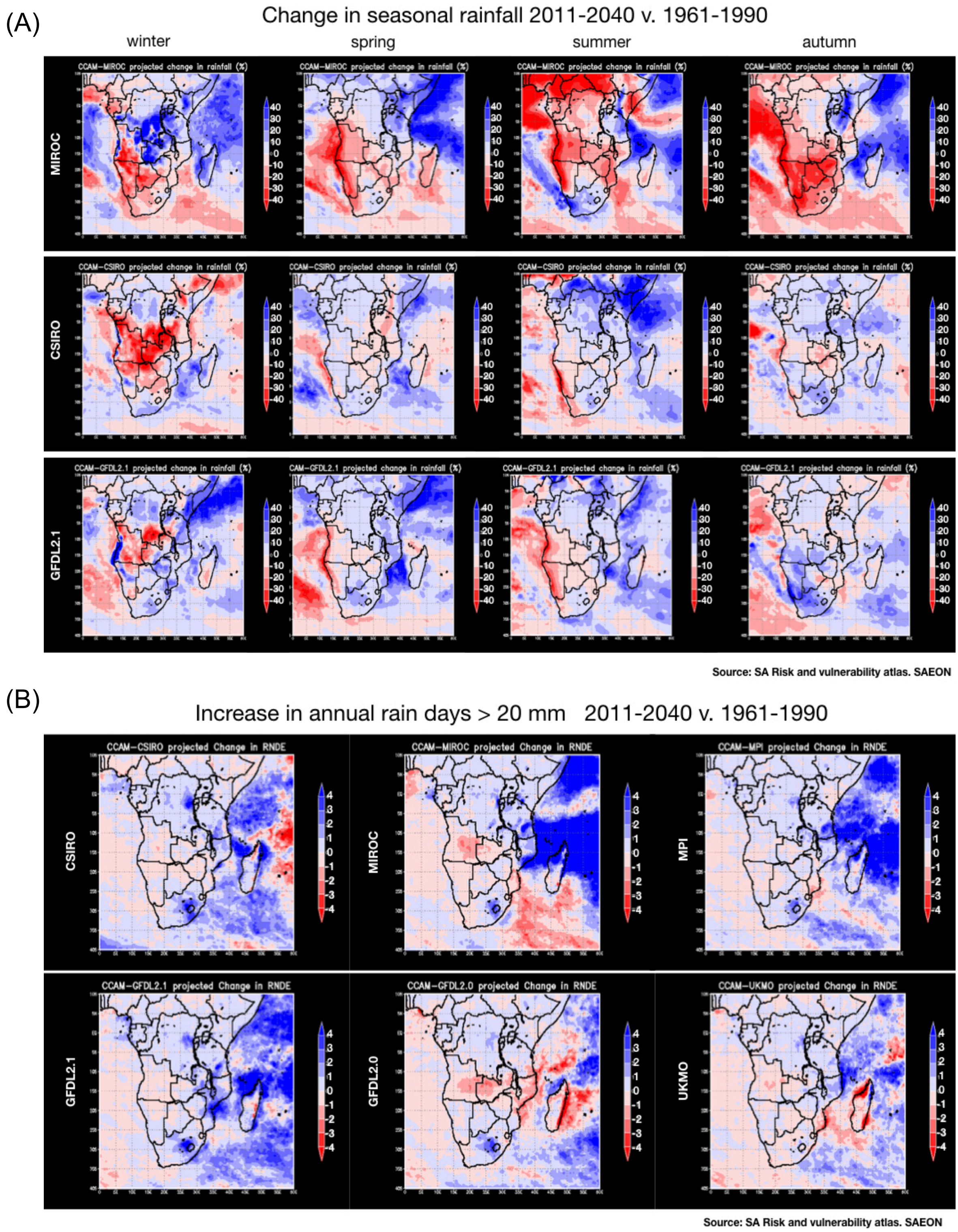


Figure 10. Projections of precipitation changes under global warming. (A) Seasonal change for 2011-2040 as projected by three climate change models (B) Increase in annual raindays>20 mm for 2041-2070 as projected by six climate change models. Output from SA Risk and Vulnerability Atlas, SAEON.

(4) Drought and dryness

IPCC (2018) reports that there is uncertainty over drought response globally. The likelihood of drought depends on the balance between precipitation and evaporation, which is linked to temperature. The only region for which there is confidence in a link between anthropogenic greenhouse forcing and observed increased drying is in the Mediterranean region. The report warns, however, of a significant increase in drought risk in South Africa if global mean temperatures increase by 2ºC rise. Southern Africa is one of the 'hot spots' identified as at risk to drying due to

changes in at least one of the following: increases in consecutive dry days (CDD); decreases in precipitation - evaporation (P-E). The areas most likely to be affected by drying are in the west of the region; the area within which the Tsitsa catchment lies has a much lower risk of drying.

(5) Summary

Climate change due to global warming has already resulted in increased temperatures and is likely to have as yet unpredictable impacts on precipitation. Likely changes and their hydrological impact are summarised in Figure 11. Table 1 summarises the likely changes to the climate in the Tsitsa catchment under to the two scenarios of warming by 1.5ºC and 2ºC according to the IPCC (2018).

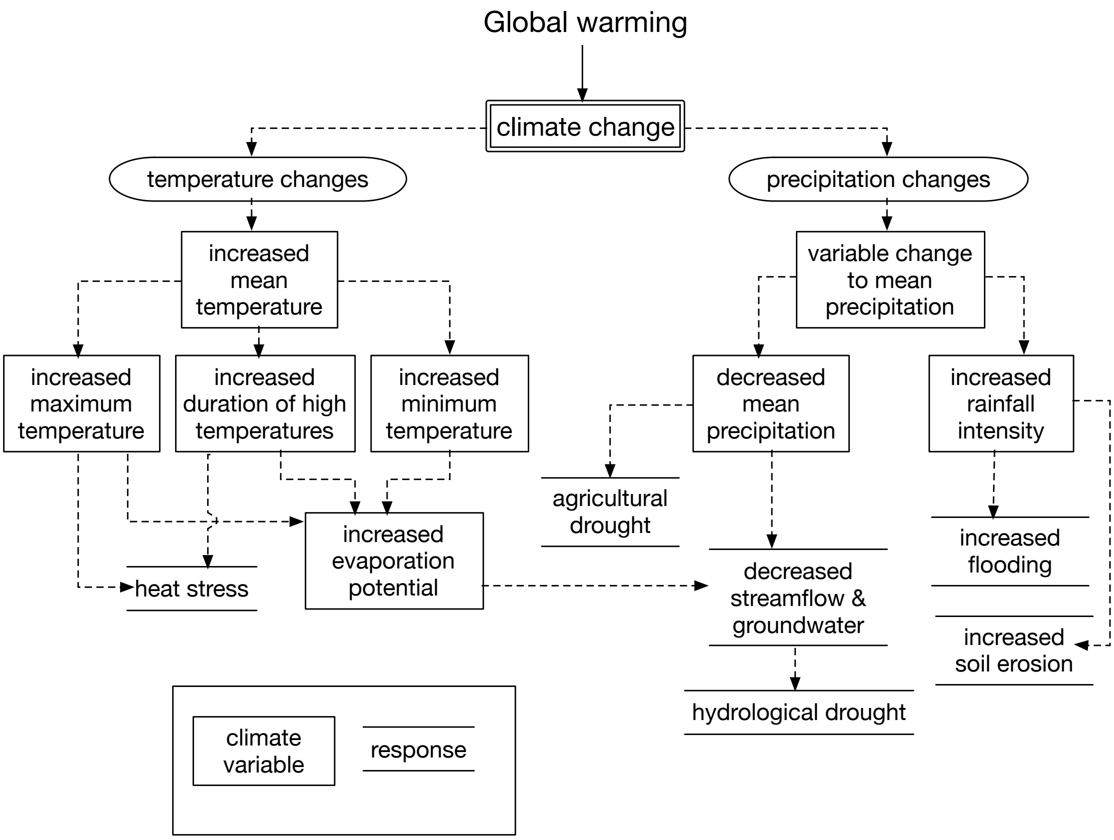


Figure 11. Hydrological response to projected changes of climate change on temperature and precipitation characteristics.

Table 1. Projected changes to the climate of the Tsitsa catchment (IPCC 2018)

Tsitsa catchment (Eastern Escaprment)	1.5ºC global increase	2ºC global increase	direction of change
Mean temperature (ºC change)	1.5 - 2.0	2.0 - 3.0	increase
Annual Max. temp (ºC change)	2.0 - 3.0	3.0 - 4.0	increase
Annual Min temp (ºC change)	2.0	2.0 - 3.0	increase
Mean precipitation (% change)	0% - -5%	0% - -5%	decrease
Precipitation extremes (annual max. 5-day rainfall)	0 - 5%	5 (-10)%	increase

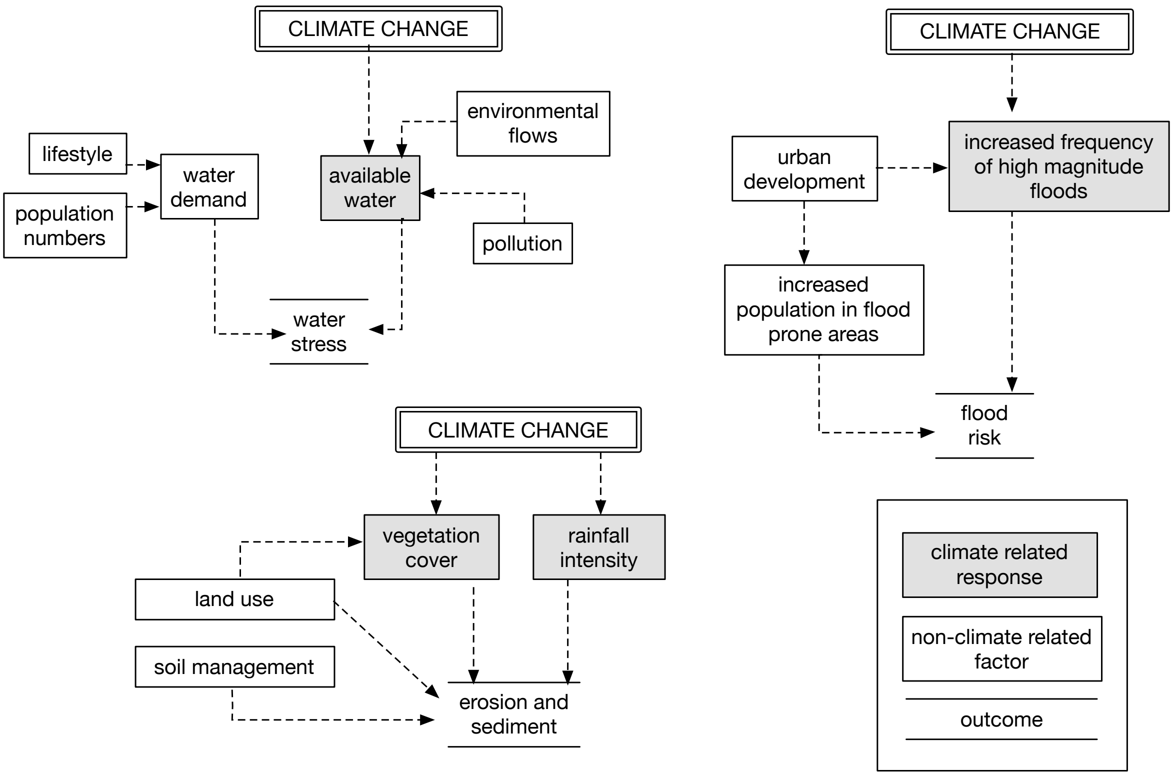


Figure 12. Interaction of climate change impacts with social factors affecting risk to water stress, flooding and soil erosion.

2.4. Implications of climate change for ecosystems and livelihoods

It is anticipated that climate change will have serious negative impacts on ecosystems, livelihoods and human health and wellbeing. Some of these are already being experienced. The direction and extent of these impacts also depends on non-climate related factors that are important when considering mitigation and adaptation. Three examples relating to the risk of water stress, flooding and soil erosion are illustrated in Figure 12.

(1) Ecosystem transformation

The IPCC (2018) highlight a number of implications for ecosystems and livelihoods under a 1ºC and 2ºC increase in global mean temperature. In nearly all cases a 1.5ºC increase will give rise to changes that will not greatly impact our lives but a 2ºC increase may cause the crossing of thresholds that cause irreversible negative changes. Some of these are difficult to predict due to multiple and compound climate-related risks with overlapping risks across energy, food and water sectors exacerbating risk ad vulnerability.

In terms of biodiversity there will be a loss of species due to change in their geographic range, the projection for 1.5ºC is a 6% loss of insect species, 8 % of plants species, and 4% of vertebrates. The loss would be greater at 2ºC with a doubling or more for insects. In addition to the direct effects of temperature increase and moisture stress, other biodiversity related factors include forest fires, extreme weather events, spread of invasive species, pests and diseases. The projected increase in terrestrial and wetland ecosystem transformation given by the IPCC (2018) is 4% at 1.5ºC and 13% at 2ºC. The impacts are expected to be greatest at higher latitudes.

Rutherford et al. (2000) mapped projected changes for South African species. The area suitable for many of the country's biomes can be expected to shrink in response to warming and increased aridity, especially in the western, central and northern parts of the country. The species composition of individual biomes is also likely to change. The main changes in the Tsitsa catchment would be a spread of the savannah biome into the grassland biome, which could become restricted to the high altitude refugia in the Drakensberg. Species that are projected to become more widespread in the area include *Aloe marlothii subsp.marlothii* (mountain aloe), *Erythrina lysistemon* (coral tree) and *Pentizia incana* (marginal) (karoo bush), whereas there could be a loss of the cold-adapted grass *Catalepis gracilis*. *Themeda trianda* (red grass) is likely to maintain its present distribution. The area of the woody plant *Leucosidea sericea* could contract and move to higher altitudes.

There is an increased risk of erosion and sediment movement under climate change due to increased rainfall intensity and a reduction in vegetation cover following increased drought. Land use change and poor soil management increase this risk (Figure 12)

(2) Livelihood impacts

Livelihood impacts can be reviewed under those which affect agriculture and food security and those which affect health and wellbeing. Agricultural production and viable crop types are strongly affected by temperature and moisture availability, the latter directly affected by temperature (evapotranspiration rates) and rainfall total and seasonal distribution. Pests are likely to increase under warmer, wetter conditions. The available water resources for agriculture also depend on socio-economic conditions, demand by other sectors and national capacity to store and distribute water sustainably (Figure 12). Global projections (IPCC, 2018) indicate reduced yields of rice, wheat and maize and a loss of rangeland for livestock. Where soil moisture is not a constraint, cereal yields may respond positively to elevated CO_2 levels but at the expense of protein levels (IPCC, 2018). This points to reduced food availability in several regions including southern Africa. Inter-regional trade will be an important adaptation option.

(3) Human health, well-being, cities and poverty

There are a number of ways in which human health and well-being can be affected by global warming. The higher maximum temperatures and longer duration of hot spells will lead to heat related morbidity and mortality. This will be especially so in extensive urban areas due to the urban heat island effect. Ozone formation is temperature related so increased ozone levels are also likely to lead to ozone related mortality.

There is concern that the area affected by vector borne diseases will spread, for example malaria, bilharzia, dengue fever, tick borne disease (Meyers et al. 2011). The range of the malaria-linked mosquito depends on both temperature and moisture so it is not easy to project its spread into the Eastern Cape with any confidence. Behera (2018) found that, historically, malaria in Vhembe was reduced during dry decades. Therefore if global warming brings drier conditions malaria might be contained even with warming. Others have found malaria incidences more closely linked to temperature. By 2050 malaria could spread to isolated areas along the East Cape coast or more widely (Tonnang et al. (2010). Warming can increase the vector's altitude limits.

Schistosomiasis (bilharzia) is already present in parts of the Eastern Cape (Kiker 2000) and could spread with climate change. Water borne diseases such as cholera are also likely to spread if dry season flows are reduced and floods carry pathogens into rivers that are used for household water or recreation (Meyers et al. (2011).

Undernutrition linked to food security and price increases is foreseen as a consequence of global warming, especially in poor and vulnerable communities.

Flood risk is projected to increase due to higher intensity rainfall resulting in an increased frequency of high magnitude floods. The extent of the risk will also depend on the extend to which urban development and agriculture encroaches onto flood plains (Figure 12).

Reductions in economic growth due to climate change are predicted to be greatest in Africa and the southern Hemisphere sub-tropics, among other areas (IPCC 2018). The report cites evidence for outmigration of agriculturally dependent communities due to current warming. Tourism is identified as one area of economic activity that is likely to be affected by climate change but the main risk areas are coastal areas (sea level rise and loss of coral reef) and snow sports area. The Tsitsa catchment could promote tourism and thus benefit from constraints in the industry elsewhere.

2.5. Implications for sustainable development

The IPCC (2018) report notes that it will be easier to reach the Sustainable Development Goals (SDGs) if temperature increase is limited to 1.5ºC but there will still be risks to eradicating poverty, reducing inequalities and ensuring human and ecosystem wellbeing. If temperature rises by 2ºC the chance of achieving the SDGs becomes limited. The impacts that affect vulnerable people in particular if temperature increase is kept below 1.5ºC include food insecurity, higher food prices, income losses, lost livelihood opportunities, adverse health effects and population displacements. Those most vulnerable are agricultural communities, indigenous people, children and elderly (among others) (IPCC 2018)

The SDGs are in line with proposed climate change adaptations, "providing attention is paid to reducing poverty in all its forms and to promoting equity and participation in decision making" (IPCC 2018 p. 447). There is a risk of trade-offs between SDGs, for example the use of biofuels for energy production can have a negative impact on food security due to competition over land. The IPCC (2018) report concludes that it is possible to achieve synergy between SDGs and adaptation/mitigation strategies in a 1.5ºC warmer world. The report stresses that "Social justice and equity are core aspects of climate-resilient development pathways for transformational social change." (IPCC 2018 p.448). The most effective way to reduce global warming is to reduce energy demand; given the current rate of warming there is a clear need to act now.

2.6. Implications for the Tsitsa social-ecological system

The following responses to and impacts of global warming are projected as being likely in the Tsitsa catchment. If the global mean temperature rise is kept to within 1.5ºC the impacts will be moderate and mitigation of impacts and adaptation to changes are feasible. If global mean temperature rise to 2ºC conditions become more serious and will be much harder to mitigate against or adapt to.

Climate change and biophysical response

- Average temperatures are projected to increase by 1.5ºC - 2ºC within the next ten to thirty years and a further 2ºC - 3ºC thereafter if there is not immediate action to mitigate global warming.
- Extreme temperatures will increase by a further 2ºC - 3ºC (max. temp) within the next ten to thirty years and 3ºC - 4ºC thereafter and the duration of hot spells will increase. Minimum extremes will increase by 2ºC - 3ºC.
- Projections concerning precipitation are uncertain and vary depending on what model is used. It is not likely that there will be significant changes to mean annual precipitation but there may be seasonal shifts. Some models predict an increase in autumn rainfall. It is likely that the intensity of rainfall will increase, indicating increased length of dry spells if annual rainfall remains the same.
- The incidence of drought is likely to increase due to higher temperatures, increased evaporation potential and longer dry spells.
- Dry season flows will decrease and springs may dry up. Groundwater levels drop.
- Flash flooding may increase due to higher rainfall intensity. Hydrological connectivity imparted by gully networks will exacerbate this.
- Winter snow cover is likely to decrease in spatial extent and duration; this will impact negatively on groundwater.
- Erosion potential is likely to increase due to lower vegetation cover (drought) and higher rainfall intensities.
- Fluvial sediment and the rate of reservoir infilling are likely to increase.
- Woody vegetation encroaches into high altitude grassland. Lower areas become more Xeric with spread of aloes and other dryland species.
- May be loss of critical species of fauna and flora.

Impact on livelihoods

- Agricultural productivity will decrease due to drought, delayed start to the rain season, heat stress, further soil loss and increase in pests.
- Livestock will suffer from heat stress, reduced forage and reduced water supply as springs and streams dry up for longer periods.
- An increase in autumn rainfall together with higher temperatures may extend the growing season; reduction in frost damage.
- Heat stress becomes a serious health issue, especially in poorly insulated houses. Manual labour outdoors is restricted during hot periods.
- Disease outbreaks result from poor water quality and lack of domestic water for drinking and sanitary purposes. There is an increase in bilharzia and possibly malaria appears in the area.

- Migration to urban areas increases due to difficulty of making a living in a rural setting.

External factors

- Food prices rise due to reduced agricultural production within southern Africa.

3. Mitigation and adaptation pathways

3.1. Mitigation

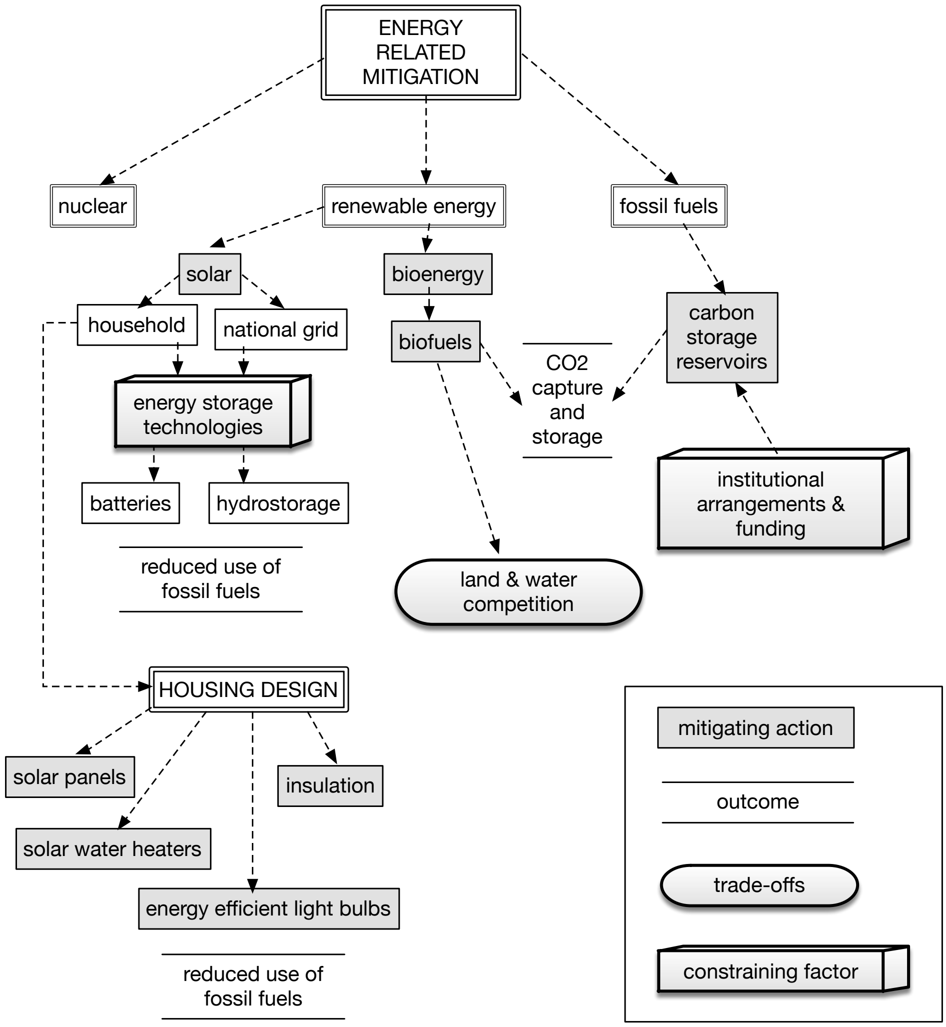


Figure 13. Energy related mitigation

Mitigation measures aim to reduce the rate of warming either by reducing the input of carbon into the atmosphere or increasing the rate of carbon capture and storage - removing carbon from the atmosphere. The measures cover a wide range of activities that include the energy sector, household design, land and ecosystem transitions, soil carbon sequestration and biochar. Figures 13 and 14 capture some of these mechanisms. They can include measures that limit the demand on land, energy and material resources including lifestyle and dietary changes.

Fossil fuels contribute approximately 75% of greenhouse gas emissions. It is possible to capture and store CO_2 emissions from power plants but the institutional capacity and funding to do this is often lacking. Bioenergy using biofuels is an alternative source of fuel but this can mean competition with food production. Nuclear energy and renewable energy avoid CO_2 emissions. Renewable energy

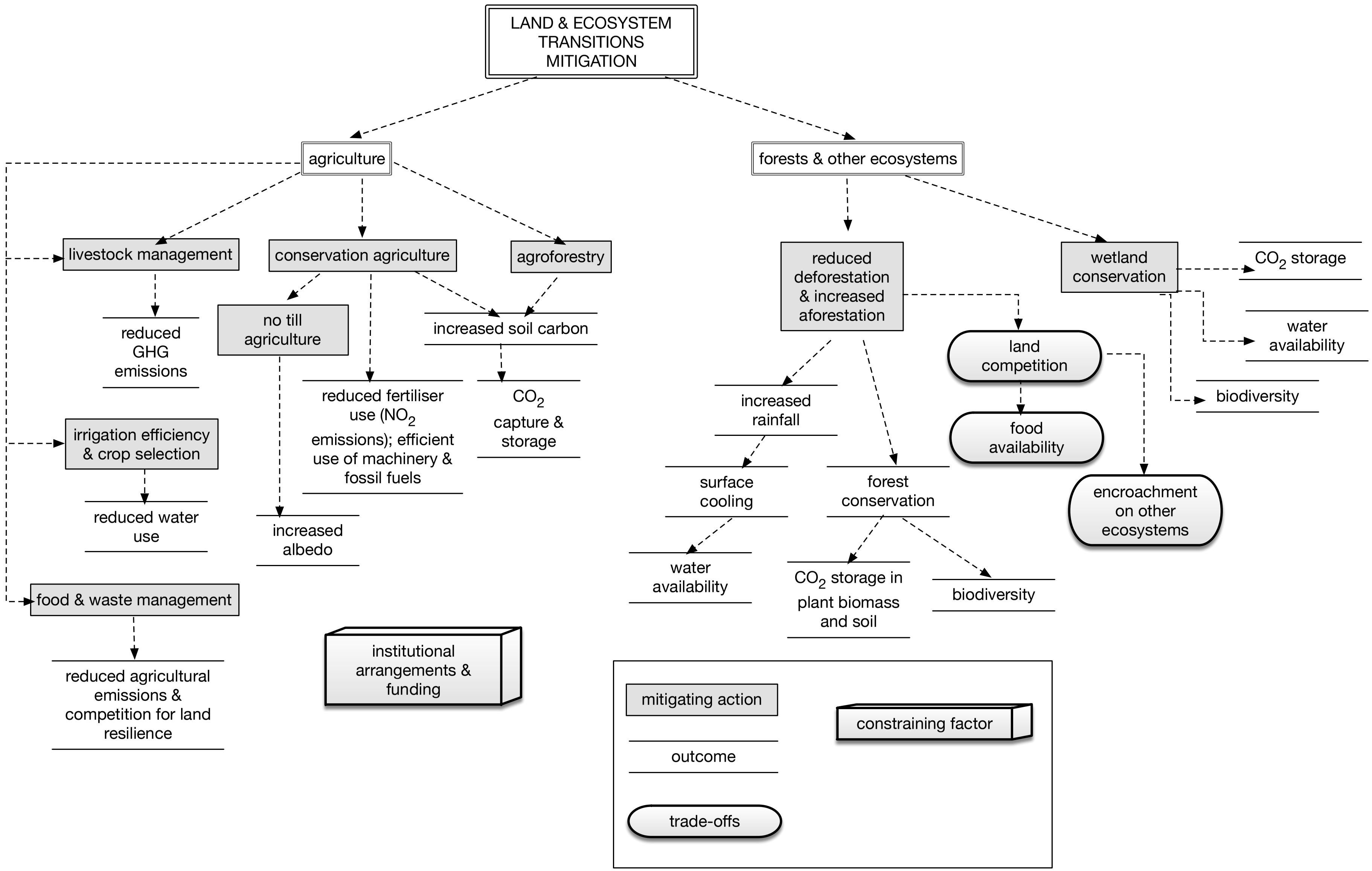


Figure 14. Mitigating global warming through land and ecosystem transformation

can also be promoted at the household level. Housing design is also a way of integrating renewable technology and reducing energy use.

Agriculture is estimated to account for much of the remaining greenhouse gas emissions. Livestock are a significant source of methane whereas fertiliser use contributes to NO_2. Loss of vegetation cover following ploughing also reduces albedo so contributes to warming.

There are a number of ways in which modified agricultural practice can mitigate against global warming. Reduced numbers of livestock would reduce methane emissions; this requires a lifestyle change with respect to diet and tradition. Conservation agriculture includes the adoption of the practice of no tillage, agroforestry and incorporation of crop residues into the soil, thus aiding carbon capture. Increased soil organic matter reduces the need for fertiliser. The efficient use of fossil fuels and farm machinery is an important aspect to consider. Globally, much of the food that is produced is wasted so better food and waste management would reduce pressure on land to produce food and allow other uses such as biofuel production or forestry. This wastage is more pronounced in developed countries and is not likely to be a major issue in the Tsitsa catchment. It is important to have an integrated plan for land use change that enhances carbon storage without impacting negatively on biodiversity and food production.

Forests and other ecosystems offer much potential for carbon mitigation. Increasing and maintaining forest cover brings a number of benefits as shown in Figure 14, especially where the forest is indigenous. Forestry as a land use is often in competition with agriculture and afforestation with non-native species results in encroachment in to other ecosystems. Wetland conservation is also important for sustaining water resources, storing carbon and for biodiversity.

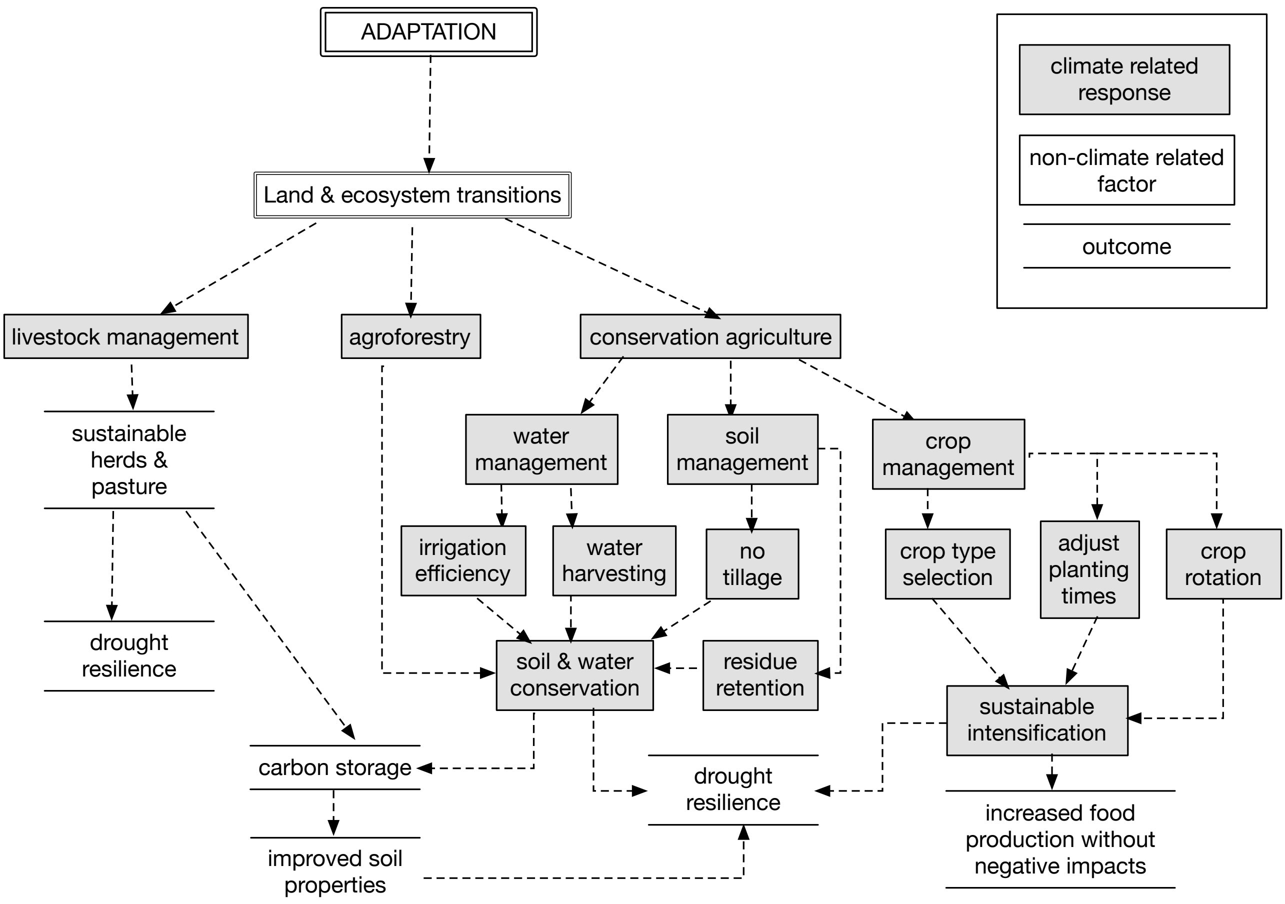


Figure 15. Adaptation measures related to land and ecosystem transitions

3.2. Adaptation

Adaptation measures that relate specifically to land and ecosystem transitions are outlined in Figure 15. Many of these are designed to increase drought resilience as well as improving soil condition and thereby increasing crop yields. There is clear synergy with mitigation measures that aim to increase soil carbon and reduce water stress. Two approaches advocated by the DAFF are Climate Smart Agriculture (CSA) and Conservation Agriculture (CA), described in more detail in sections 5.4 and 5.5. At the household level, heat stress can be alleviated through improved housing - better insulation - which also results in lower energy use and is therefore also a mitigating measure.

Effective adaptation requires institutional support through for example climate services, education and integrating local knowledge. Migration either within a country or between countries can also be considered as an adaptation measure, though not necessarily one that is promoted or supported by government.

4. South African climate change policy

The Department of Environmental Affairs (DEA) is mandated by the National Climate Change Response Policy (NCCRP) of South Africa to oversee and coordinate the implementation of this policy. The responsible branch of the DEA responsible for climate change policy is Climate Change, Air Quality and Sustainable Development. Following the Paris Agreement of 2015, the DEA produced the second annual climate change report (DEA 2017). Key findings from the report, emphasising those that have implications for the Tsitsa Project, are summarised here. An important change incorporated into the Paris Agreement is that it includes an obligation not only to mitigate against climate change but also to act on adaptation. Whilst potential mitigation activities are limited at the local scale, the need for adaptation at the household scale upwards is paramount. South Africa's contribution to combatting global warming is summarised in Figure 16.

4.1. Mitigation

Under the Paris Agreement of 2015 South Africa agreed to a Nationally Determined Contribution (NDC) (Figure 16). The aim of mitigation actions is to achieve a peak, plateau and decline trajectory. Carbon emissions depend not only on direct mitigation but also on economic activity. According to DEA (2017) some of the recent decline in emissions can be attributed to a decline in the economy and a decrease in energy intensive operations such as mining over the last 11 years. From 2000 to 2012 the contribution of renewable energy to the country's energy mix increased from 6% to 11% (DEA 2017). The largest contribution to GHG emission reductions has come from energy efficiency measures (85% in 2014, DEA 2017). Other measures such as green transport, waste management and agriculture, forestry and other land uses (AFOLU) have so far had little impact on GHG emissions though it must be born in mind that these sectors contribute a low percentage to South Africa's emission total (see section 2.1).

When assessing the effectiveness of mitigation measures the following impacts are taken into account: mitigating climate change, job creation, other sustainable development indicators (DEA 2017).

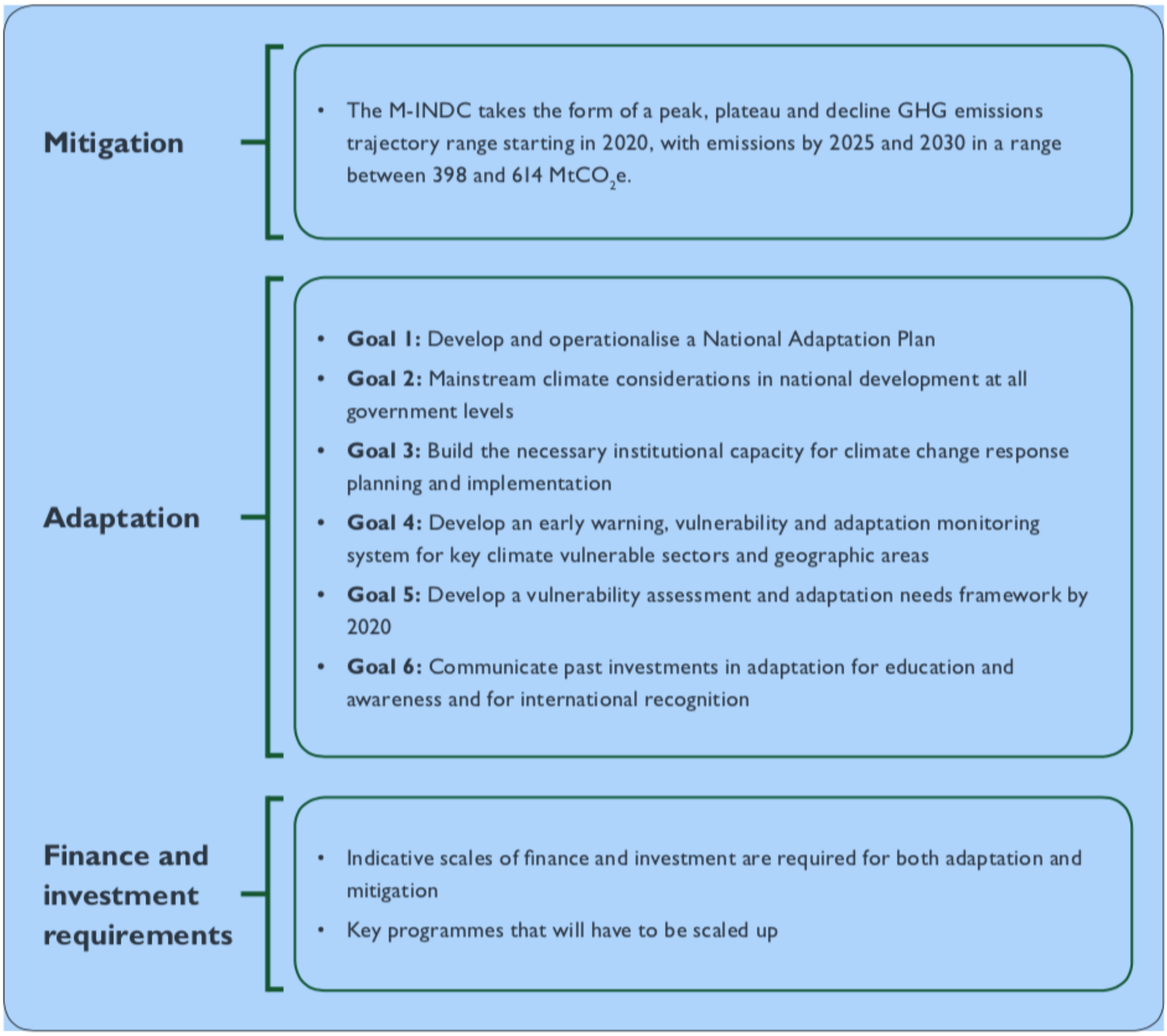


Figure 2: South Africa's Nationally Determined Contribution

Figure 16. South Africa's Nationally Determined Contribution to combat climate change as delivered to the Paris Agreement, December 2015. M-INDC = Mitigation Nationally Determined Contribution. Source: DEA 2017.

4.2. Adaptation

South Africa has developed a the National Adaptation Strategy that aims "to provide a framework for systematic and coordinated adaptation planning and response across various sectors of the country" (DEA 2017:60). The DEA (2017) report lists eight generic Desired Adaptation Options (DAOs) as presented in Table 2 taken directly from the report. DAOs have also been developed for different sectors vulnerable to climate change. The water sector (Table 3) is seen as being most seriously impacted by climate change, with an increased risk of drought, water restrictions, crop losses and general impacts on food and water security. One chapter of the report is given over to looking at drought impacts based on experience from the national drought of 2015-16.

As noted above, forest protection and expansion is an important component of climate change mitigation. Forests are also threatened by climate change. In South Africa there have already been observed changes including increased number and spread of pests and pathogens, and increased forest fires. Desired adaptation outcomes for forestry are given in Table 4.

Table 2. Desired Adaptation Options (DEA 2017 p.33)

DAO	Description
G1	Robust / integrated plans, policies and actions for climate change adaptation, together with resources and capacity (e.g. financial, human, legal and regulatory) for effective delivery (with monitoring, evaluation and review over the short, medium and longer-term).
G2	Appropriate processes and mechanisms for coordinating climate change adaptation (i.e. institutional and governance structures).
G3	Reliable climate information, including seasonal predictions and future projections, and effective early warning systems for extreme weather and other climate-related events (i.e. to inform adaptation planning and disaster risk reduction / management).
G4	Capacity development, education and awareness programmes (formal and informal) for climate change adaptation (e.g. informed by adaptation research and with tools to utilise data / outputs).
G5	New and adapted technologies / knowledge and other cost-effective measures (e.g. nature-based solutions) used in climate change adaptation.
G6	Systems, infrastructure, communities and sectors less vulnerable to climate change impacts (e.g. through effectiveness of adaptation interventions / response measures).
G7	Non-climate pressures and threats to human and natural systems reduced (particularly where these compound climate change impacts).
G8	Secure food, water and energy supplies for all citizens (within the context of sustainable development).

Table 3. Desired Adaptation Outcomes for the water sector (DEA 2017) (G1-G9 refer to the DAOs in Table 2)

1	Climate change adaptation fully integrated into planning processes in water-dependent sectors (e.g. agriculture, industry, economic development, health, spatial planning, and science and technology) [G1 & G3].
2	Capacity development programmes in water-dependent sectors informed by water-related adaptation research (e.g. high quality data and tools to analyse data) [G4].
3	Regional (international) adaptation policies and programmes established for South Africa's trans-boundary river systems [G1].
4	Water security and resource protection enhanced by adaptation of catchment and water management practices (e.g. investment in water conservation and water demand management) [G8].
5	New and unused water resources utilised sustainably in areas of water stress (e.g. groundwater, effluent re-use, and desalination – with cost-benefit and maladaptation risk assessments undertaken) [G5].
6	Vulnerable communities, sectors and infrastructure more resilient to water-related climate change impacts [G6].
7	Water sector has resources (i.e. human, legal, regulatory, institutional, governance, and financial) and capacity to properly address climate change challenges [G1].
8	Efficiency and effectiveness of water-related climate change adaptation policies and programmes monitored and evaluated over short, medium and longer-term time scales [G1 & G2].
9	Non-climate pressures and threats to water quality and availability reduced (particularly where these compound climate change impacts) [G7].

Table 4. Desired Adaptation Outcomes for the forestry sector (DEA 2017) (G1-G9 refer to the DAOs in Table 2)

	Desired Adaptation Outcome
1	Climate resilience integrated into forestry development plans (adaptation measures/interventions incorporated into national, provincial and local management plans, and resources and capacity available to address climate change challenges) [G1 & G2].
2	New opportunities, areas and crops utilised sustainably by forestry sector and negative impacts of existing practices reduced (development and implementation of new technologies and knowledge, vulnerability to climate and non- climate pressures and threats reduced, and security of supply of forest products and resources increased) [G5, G6, G7 & G8].
3	Stakeholders in forestry sector better understand climate change and need for adaptation (capacity development programmes informed by forestry-related adaptation research) [G4].
4	Foresters alerted to adverse weather conditions by early warning systems, and provided with up-to-date climate information and decision-support tools to assess vulnerabilities and inform management decisions [G3].

DAOs can also be developed at the provincial level. To date these have been developed for KwaZulu-Natal as given in Appendix A. No information on DAOs for the Eastern Cape were available.

Adaptation to drought

Drought has serious impacts on South Africa's ecosystems, water resources, economy and health, in turn South Africa has a relatively robust drought disaster declaration and response system. At a national level drought management is institutionalised through the Disaster Management Centre, the Disaster Management Framework, Disaster Management Act. The Act stipulates that all three layers of governance (national, provincial, municipal) can contribute to drought relief but the lowest level must use all resources before the next level can contribute. Other national and local legislation can support drought relief and civil society and the private sector is often active in providing drought relief.

DEA (2017) notes that there is a need for a more flexible operational systems for effective drought risk reduction. On the one hand there is a need for further scientific studies to enable drought forecasting; on the other there is a need for better communication to affected parties.

Further to the National Adaptation Strategy, the DEA and the South African Biodiversity Institute (SANBI) have developed a set of guidelines for Ecosystem Based Adaptation (EbA) (DEA & SANBI 2017) as part of their proposed strategy for adapting to climate change. EbA is seen as especially relevant for poor and vulnerable communities who are in part dependent on ecosystem goods and services in support of their livelihoods. Bourne et al. (2016) have developed a mapping approach to identify a socio-ecological approach for identifying spatial EbA priorities at the sub-national level. The Tsitsa Project is well aligned with EbA. Specific recommendations will be reviewed in more detail in section 5.3 below.

Flagship Programmes

Since 2011, South Africa has promoted a number of Climate Change Flagship Programmes (DEA 2017). Those most relevant to the Tsitsa Project are outlined in Table 5.

Table 5. Climate Change Flagship programmes 2011 (DEA 2017)

Programme	Sub programme
1. The Climate Change Response Public Works Flagship Programme	• Working for: Water, Wetlands, Land, Fire, Energy, Ecosystems
2. The Water Conservation and Demand Flagship Programme	• Comprehensive Agricultural Support Programme
3. The Renewable Energy Flagship Programme	• LandCare
4. The Energy Efficiency and Energy Demand Management Flagship Programme	• Residential energy efficiency programmes • Biofuels
5. The Waste Management Flagship Programme	• Municipal waste management
6. The Carbon Capture and Sequestration Flagship Programme	
7. Long-term Adaptation Scenarios Flagship Research Programme	• Development of adaptation scenarios for future climate conditions

In 2016 three core programmes were proposed, as detailed below. The Climate Change Flagship Programmes provide a focal point for attracting and leveraging investment from both the private and public sectors at the scale required to enable meaningful climate action. They fall under the DEA.

The three 2016 programmes are:

- Low carbon, climate resilient built environment, communities and human settlements
- Agriculture, food systems and food security
- Land, biodiversity and ecosystems

Low Carbon, Climate Resilient Built Environment, Communities and Human Settlements Climate Change Flagship

This programme aims to integrate mitigation and adaptation measure into the build environment. Measures indicated under Housing Design in Figure 13 should be considered. Other measures would include flood mitigation measures such as pervious paving, urban wetlands and avoiding building settlements on flood plains. Municipalities should be encouraged to adopt improved waste management and conversion of waste to biofuels. There has been little development of this flagship to date.

Agriculture, Food systems and Food Security Climate Change Flagship

This flagship programme aims to promote climate smart agriculture, enhancing agricultural productivity and climate resilience at all scales of production. Proposed interventions relate to infrastructure investment and technology, agricultural/production inputs, enhanced access to finance and technology, skills and capacity building and education and awareness. The core focus will be on establishing demonstration projects.

Land, Biodiversity and Ecosystems Climate Change Flagship

This flagship programme is concerned with restoration/rehabilitation of South Africa's natural resource base through, among other things, management of invasive species, enhancing ecosystem integrity and resilience, creating and enhancing carbon sinks and ecosystem-based adaptation approaches. The Flagship builds on the various 'Working For' projects that come under the DEA.

Working on Fire is seen as a mitigation action whereas other ‘Working For’ programmes are seen as adaptation responses.

“The aim is to demonstrate the mitigation–adaptation nexus characteristic of land-based climate change response measures. This work package will develop mechanisms to support a sustainable land management regime that enhances ecological infrastructure and resilience, and reduces GHG emissions from the land sector” (DEA 2017). The core focus is a “demonstration scale implementation of integrated approaches to rehabilitation and management of grasslands, sub-tropical thicket, forests and woodlands” (DEA 2017). The Tsitsa Project should clearly be considered to be one such demonstration.

4.3. Combatting desertification, land degradation and drought impacts

The DEA has recently revised their National Action Programme (NAP) for South Africa to combat desertification, land degradation and the effects of drought (2018-2030) (DEA 2018). This programme is seen to be contributing to South Africa’s obligations under the Paris Agreement of 2015. The envisaged outcomes are as follows.

- By 2020, national strategy for communication and coordination programme to mitigate desertification / degradation and drought is delivered.
- By 2020, policy and institutional frameworks are effectively implemented and strengthened to minimise desertification, reverse land degradation and mitigate effects of drought.
- By 2025, support and encourage research by academic and scientific institutions on science, knowledge and technology on desertification, land degradation and drought, as well as climate change mitigation and adaptation.
- By 2019, the capacity of government institutions, non-governmental organisations (NGOs) and civil society to support efforts / initiatives aimed at mitigating desertification, land degradation and drought has been built.
- By 2019, funding mechanisms to support land owners, communities and conservation entities to implement sustainable land use management have been established and are functioning.
- By 2030, South Africa is to ensure that degraded ecosystems are restored whilst contributing to ecosystem services delivery, climate change adaptation and mitigation.
- By 2020, South Africa’s national voluntary targets to ensure a land degradation neutral world have been identified, formulated and implemented. (DEA 2018)

4.4. Research and communication

Three key government institutions responsible for documenting, analysing and communicating weather impacts, including drought, are the South African Weather Service (SAWS), the Agricultural Research Council (ARC) and the South African Environmental Observation Network (SAEON). SAWS provides climate summaries, weather reports and forecasts through their web site. They publish a biannual digital newsletter - WeatherSmart - and have developed a climate change reference atlas, available from their website. The Agricultural Research Council Institute for Soil, Climate and Water (ARC-ISCW) monitors rainfall from a network of stations together with Earth Observation rainfall estimates and vegetation activity products (e.g. NDVI). They publishes a monthly newsletter, Umlindi, also available from their website. Together with Rain4Africa (https://www.rain4africa.org) they have developed a mobile app, AgriCloud, that can be used in the field to forecast weather and get advice on aspects of crop management such as planting, spraying, irrigation and harvesting. The app has been developed specifically for extension officers and small-holder farmers and is available in several South African languages. SAEON maintains longterm records of temperature, rainfall and streamflow for selected stations as well as soil moisture probes and flux towers in some of these. They are involved in modelling to examine hydrological response to rainfall and changes in vegetation cover. SAEON is developing the online South African Risk and Vulnerability Atlas (SARVA). Dams and water levels are monitored and reported on by DWS.

Other government funded research organisations that undertake climate change research include the CSIR and the WRC. The CSIR engages in developing climate models for seasonal forecasting and undertakes research into the carbon cycle, carbon-climate feedbacks and the role of seasonality in driving ecosystem dynamics. A WRC funded project is projecting future drought scenarios using the SPI (Standardised Precipitation Index) and SPEI (standardised Precipitation-Evapotranspiration Index). The projection shown by SPEI analysis indicates that large areas of SA will be affected by drought by 2100. The SPI shows a much lower increase (more or less stable).

It is apparent that South Africa has a well developed research capacity (Ziervogel et al. 2014) and effective digital communication portals for communicating information on climate change related topics but communication on the ground is less satisfactory. Do municipal officials acquaint themselves with the information available through web portals? How can this information be made accessible to small-holder farmers? There is a pressing need to build capacity on the ground for understanding and relaying climate information that can be used to build climate resilience through adaptation. The RESILIM-O Programme implemented the Association for Water and Rural Development (AWARD) and the Suid Bokkevled project provide useful pointers as to how this can be achieved in a rural catchment. This is taken further in section 6 below.

4.5. Monitoring effectiveness of climate change adaptation

Increased climate resilience is proposed by DEA (2017) as a good indicator of the effectiveness of adopting adaptation interventions. The report stresses that any monitoring tool needs a local context that includes current and anticipated climate impacts, current state of capacity for action and current state of vulnerability. An example of such an assessment was carried out by Conservation South Africa for Alfred Nzo District Municipality (Conservation South Africa 2015a&b). Another example given is the Rhodes University Community Based Adaptation Project (Cundilll et al. 2013; Hamer at al. 2014) which used social learning as a key approach for both communicating and monitoring climate change adaptation interventions in the rural area of Willowmore. Their approach included tools ranging from quantitative data collection at household level to social learning using a number of participatory techniques including drama to develop capacity and agency among community members. Two examples from urban areas come from EThekwini Municipality and the City of Cape Town.

4.6. Funding

Climate change adaptation is unlikely to take place without sufficient accessible funding to promote adaptation projects. South Africa's Green Climate Fund is an investment fund that has been set up with the purpose of supporting national climate change response priorities. The Adaptation Fund is a global fund that specifically targets developing countries that are vulnerable to negative impacts of climate change. The South African National Biodiversity Institute (SANBI) is South Africa's National Implementing Entity for the Adaptation Fund. As of 2016 this fund had supported the uMngeni Resilience Project (KwaZulu-Natal) and the Community Adaptation Small Grants Facility (Limpopo Province and Northern Cape) (DEA 2017).

The Climate Change Flagship Programmes provide a focal point for attracting and leveraging investment from both the private and public sectors at the scale required to enable meaningful climate action.

The DEA is mandated by the NCCRP to oversee and coordinate the implementation of the policy, including the Climate Change Flagship Programmes.

A list of potential funders from the Alfred Nzo report (Conservation South Africa 2015) is given in Appendix B.

5. Adaptation to climate change and disaster risk reduction

5.1. Introduction

Adaptation to climate change (CCA) and disaster risk reduction (DDR) are closely related. Both target the reduction of risk and the impact of shock through building resilience (Mathew et al. 2018). Mathew et al. (2018) suggest that climate change adaptation is more general and is applicable at a range of scales from the household to the nation in its application and response whereas DRR is a structured approach that is dependent on the development of appropriate policies and strategies for adaptation. The responsibility for DRR therefore applies at the municipal level or higher.

As the focus of the Tsitsa Project is primarily land-based livelihoods linked to rehabilitation this report will address climate change adaptation in the rural area of the catchment, in line with the South African Climate Change Response White Paper that highlights the agriculture sector as a priority in terms of addressing climate change (DEA 2018). In the Tsitsa river catchment the main land uses are commercial agriculture, forestry and communal land. However, although the Tsitsa catchment is largely rural with small urban centres of Maclear, Ugie and Tsolo, the urban sector accounts for a significant proportion of the population and a climate adaptation policy for the catchment must include the urban areas. In 2011 the population of the upper Tsitsa catchment was 45 043 (Hodgson 2018) of which 23% were living in Maclear (Census 2011 - https://census2011.adrianfrith.com). 80% of Maclear's population were living in township-type settlements, with 10% of the Maclear population living close to the river but mostly above the likely extent of flooding. The population of the catchment has declined by 19% since 2001 while Maclear's population increased by 10% (http://www.citypopulation.de/php/southafrica-easterncape.php?cityid=286180001) and the urban percent increased from 17% to 23%. Google Earth imagery indicates that there had been expansion of 'formal' township areas between 2002 and 2011 with further development since. These areas lack shade and there is much exposed soil around houses and along roads, several of which run up and down slopes (from Google Earth Feb 2019). In Mhlonto District less than 10% of the population live in the two urban areas of Tsolo and Qumbu (2011 Census 2011 https://census2011.adrianfrith.com).

5.2. Approaches to climate change adaptation

The present reality and future threat of climate change has given rise to a plethora of adaptation policies and strategies worldwide that have the goal of increasing the resilience of society to climate related shocks and, in particular, to address food security, with a strong focus of adaptation in agriculture. Given the largely rural nature of the Tsitsa catchment, this review will also focus on agriculture and natural ecosystems. Three approaches will be considered in detail: Ecosystem Based Adaptation (EbA), Climate Smart Agriculture (CSA)and Conservation Agriculture (CA) and.

Ecosystem Based Adaptation (EbA) is promoted by the DEA and SANBI as a climate change adaptation strategy, adopting earlier recommendations by Conservation South Africa (Midgley et al. 2012; Bourne et al. 2012). Its central principle is that society's resilience to climate change can be supported by biodiversity and ecosystem services. Its strategy focuses on the sustainable management, conservation and restoration of ecosystems. EbA integrates the three corner stones of benefits for people, services from biodiversity and ecosystems and climate change adaptation responses, contextualised within the paradigm of Sustainable Development (REF). EbA is explicitly linked to climate change adaptation but the DEA (2017) report does not mention any specific livelihood practices.

The FAO define Climate Smart Agriculture (CSA) as "agriculture that sustainably increases productivity, enhances resilience (adaptation), reduces/removes GHGs (mitigation) where possible, and enhances achievement of national food security and development goals". (from CSA website - FAO 2010) CSA is an approach that is being promoted world wide by organisations that include the World Bank and the CGIR (Consortium of International Agricultural Research Centres) which touts itself as the world's largest global agricultural innovation network. It has recently been adopted by the South African DAFF; in August 2018 the DAFF published a Draft Climate Smart Agriculture Strategic Framework for Agriculture, Forestry and Fisheries (RSA Government Gazette no 41811). The World Wild Fund for Nature (WWF) also promotes CSA in South Africa as a means to address climate change adaptation; CSA is one of the approaches advocated through the RESLIM-O project in Limpopo Province. CSA has an explicit focus on addressing climate change, it considers the synergies and tradeoffs between the three pillars of productivity, adaptation and mitigation and is well positioned to capture new funding opportunities.

Conservation Agriculture addresses some of the concerns of CSA without the explicit focus on climate change adaptation. It is actively promoted in South Africa by various bodies including the DAFF and GrainSA. The DAFF published their Draft Conservation Agriculture Policy in March 2017 but as yet it does not appear among policy documents in the government's website. The aim of CA is to improve soil health, increase yields and profits and lead to more sustainable farming practices; it includes carbon sequestration as a goal but does not explicitly address climate change adaptation. CA is based on three principles: minimum mechanical disturbance, organic soil cover throughout the year and use of crop diversity (rotations and associations). It is thus more limited in its approach than is CSA.

5.3. Ecosystem Based Adaptation

Ecosystem-based Adaptation (EbA) is defined as "the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people adapt to the adverse effects of climate change." (Vignola et al., 2015 page 128; DEA-SANBI 2017 page 4). It has been adopted by the DEA as part of South Africa's climate change adaptation strategy and is based on the "sustainable management conservation and restoration of ecosystems taking into account anticipated climate change impact trends to reduce vulnerability and improve the resilience of ecosystems and communities." According to the DEA-SANBI (2017), EbA is an integration of benefits for people, services from biodiversity and ecosystems and climate change adaptation responses, contextualised within the paradigm of Sustainable Development (p. 5). EbA is promoted by Conservation South Africa and is strongly advocated in the Alfred Nzo District Municipal Climate Change Response Strategy (Conservation South African 2015) (section 8) and in the Namakwa District Municipality (Bourne et al. 2012).

The DEA-SANBI guidelines for EbA published in 2017 are structured according to cornerstones, principles, criteria and safeguards, against which proposals for an EbA project should be evaluated. Guidelines set out the steps that different user groups can take to comply with EbA. User groups include project managers and programme managers, policy makers and influencers, funders and researchers.

The following definitions are from DEA-SANBI (2017) (page 7)

"**Cornerstones:** Conceptual framing describing the fundamental values and functional ideals that underpin the EbA approach at the highest level. EbA practice is anchored within these overarching assertions, with EbA the result of the synergy between the [cornerstone] set.

Principles: Deconstruct the overarching cornerstones into high-level standards that govern and guide the behaviour of EbA practice. Principles set out the expectation for EbA practice, articulating the ideals of the cornerstones into more specific achievement qualities.

Criteria: Requirements that must be met to achieve Principles. Criteria define the core characteristics of each Principle with high specificity, further articulating the ideals of the cornerstones into practical attributes to be captured during project design and implementation.

Safeguards: Measure taken to protect/prevent/mitigate undesirable outcomes that may result from [inappropriate] EbA implementation."

The DEA's environmental programmes, the working for/on programmes, are given as examples that could be considered to be EbA if given further consideration of 'future proofing' and climate change thinking was integrated at the highest levels of the programmes. The programmes need to be linked more explicitly to the four EbA cornerstones of climate change adaptation responses, services from biodiversity and ecosystems and benefits for people within the context of sustainable development.

"It requires more explicitly guiding programme effort towards (i) those most vulnerable to climate change impacts, (ii) areas most at risk and/or critical in terms of supporting an ecosystem's ability to adapt to climate change, and (iii) demonstrating tangible benefits to people, that go beyond only economic employment opportunities." (DEA-SANBI 2017 p. 17)

The EbA guidelines listed in Table 1 demonstrates how the Tsitsa Project can be aligned to the principles and criteria of EbA as set out by DEA-SANBI (2017). It can be seen that while many of Tsitsa Project objectives and practices can be considered as falling within EbA, there is further scope to make climate change adaptation more explicit in the programme. There is also considerable scope for EbA related research. According to the DEA-SANBI guidelines, research should support an evidence approach to policy and decision making and should be aligned with the National Biodiversity Research & Evidence Strategy 2015-2025 (NBRES) in order to attract national funding. The following core research areas are highlighted, many of which fall directly under the Tsitsa Project and would therefore be eligible for support from the NBRES:

- Slowing the rate of habitat loss and habitat degradation
- Reducing the threat status of South Africa's indigenous species
- Reducing land degradation and desertification
- Reducing and reversing declines in ecosystem health
- Rehabilitation and restoration of ecosystems
- Improving the status of freshwater and marine ecosystems, including transformed wetlands and estuaries

- Decreasing the spread of invasive alien species
- Minimising over-harvesting of indigenous species (DEA-SANBI 2017 p. 23-24)

Gaps and areas to strengthen are given by DEA-SANBI (2017) as:

- Lack of an effective monitoring system
- Find ways that can EbA contribute to sustainable development
- Strengthen connections between professional 'experts' and non-professional participants
- Encourage citizen science and indigenous knowledge
- Improve communication, encourage peer learning, capacity building and policy relevance
- Use a transdisciplinary approach to bring together the three key EbA research areas: biodiversity benefits for people, climate change adaptation strategies for people, and biodiversity resilience to climate change.

The Tsitsa Project is already addressing these gaps but could be more explicit in its consideration of climate change adaptation.

Vignola et al. (2915) make the point that many EbA initiatives focus on natural ecosystems such as wetlands, forests and riparian zones. They advocate the extension of EbA thinking to agricultural systems. They define Ecosystem-based Adaptation in agricultural systems as "agricultural management practices which use or take advantage of biodiversity or ecosystem services or processes (either at the plot, farm or landscape level) to help increase the ability of crops or livestock to adapt to climate change and variability" (Vignola et al. 2015 p. 128) and provide a framework for identifying EbA agricultural practices suitable for small holder farmers. EbA practices are those that improve crops and livestock to adapt to climate change and variability and include agroforestry, mulching, use of local species as cover crops and conservation of riparian vegetation. These would also fall under the umbrella of Conservation Agriculture and clearly the various different approaches are based on similar principles of conservation, restoration or management of biodiversity and ecosystem processes and services in either managed or natural systems.

Table 6. Present and potential alignment of the Tsitsa Project to the principles and criteria of EbA according to the DEA-SANBI guidelines (DEA-SANBI 2017)

EbA Guidelines	Tsitsa Project
Principle 1: EbA interventions support resilient and functional ecosystems that ensure and enhance ecosystem services.	
• Criterion 1.1 EbA interventions must maintain or improve ecosystem functioning and integrity with the understanding that healthy, intact ecosystems are better able to maintain functional integrity under a range of climate futures.	Key objective is to improve ecosystem functioning through the restoration of ecological infrastructure.
• Criterion 1.2 EbA interventions must leverage resilience in natural, near-natural, transformed or restored ecosystems without impacting adversely on biodiversity or compromising the ecological integrity of the broader ecosystem.	Restoration of ecological infrastructure should seek to increase resilience.
Principle 2: EbA interventions support people in adapting to climate change and climate variability.	

EbA Guidelines	Tsitsa Project
• Criterion 2.1. EbA interventions must result in tangible benefits to people within the context of climate change adaptation.	Focus on livelihoods can be orientated towards climate change adaptation.
• Criterion 2.2. EbA interventions support socio-economic benefits that go beyond improving adaptive capacity.	Aligned to Tsitsa Project objectives.
Principle 3: EbA interventions are participatory, inclusive, and transparent.	
• Criterion 3.1 EbA interventions must be designed to be inclusive and to consider the needs of and impacts of climate change on marginalised groups.	Aligned to Tsitsa Project objectives.
• Criterion 3.2 EbA interventions are cognisant of the disproportionate impacts of climate change on women and are designed with this in mind	Tsitsa Project objectives can be aligned to achieve this.
• Criterion 3.3 EbA interventions are designed, developed and implemented through participatory processes.	Approach used in the Tsitsa Project is designed to be participatory.
• Criterion 3.4 EbA interventions are supported by capacity building processes	The Tsitsa Project could develop the capacity building aspect further.
Principle 4: EbA interventions are knowledge and evidence-based as informed by the best available science and robust indigenous and local knowledge.	
• Criterion 4.1 EbA interventions must use credible, scale relevant climate scenarios.	CoPs need to embed climate change scenarios into their thinking.
• Criterion 4.2 EbA interventions are based upon credible, locally relevant impact and vulnerability scenarios.	More research needs to be done to look at impact and vulnerability of local social-ecological systems to climate change.
• Criterion 4.3 EbA interventions support learning networks, communities of practice and the co-generation of knowledge.	These are being developed through the Tsitsa Project
• Criterion 4.4 EbA interventions support robust M&E and learning processes.	PMERL is aimed at this criterion.
• Criterion 4.5 EbA project cycles assess and evaluate thresholds and trade-offs.	Probably needs to be developed.
• Criterion 4.6 EbA project cycles permit flexible adjustment of interventions as informed by the best available information.	The underlying philosophy of the Tsitsa Project is strategic adaptive management (SAM)
Principle 5: EbA interventions are contextualised within broader national and regional policy and landscape processes and are designed to be scalable and replicable.	
• Criterion 5.1 EbA interventions are cognisant of broader landscape processes and ecosystem services, and recognise that some EbA service benefits may only become apparent at larger scales such as watersheds or biomes.	The scale of the Tsitsa Project is from household up to catchment.

EbA Guidelines	Tsitsa Project
• Criterion 5.2 EbA interventions are implemented as part of integrated climate change adaptation strategies. As such, they are aligned with national and sub-national enabling frameworks and mainstreamed into relevant plans, polices and practice at multiple scales.	The Tsitsa Project is closely aligned to the DEA's climate change adaptation policy but the links could be made clearer.
• Criterion 5.3 Scalability and sustainability is explicitly considered in EbA interventions.	Aligned to Tsitsa Project objectives.
Principle 6: EbA interventions strive to be integrative and to promote transdisciplinarity and multi-sectorality throughout the project lifecycle.	
• Criterion 6.1 EbA interventions are sectorally cross-cutting and require the collaboration, coordination, co-operation of multi-stakeholder groups and operational role-players, including that of institutional stakeholders.	Closely aligned to Tsitsa Project practice.
• Criterion 6.2 EbA interventions support cross-sectoral adaptation and governance across scales.	Closely aligned to Tsitsa Project practice.
• Criterion 6.3 Where relevant, EbA interventions make use of complementary natural, engineered, social and systemic solutions	Closely aligned to Tsitsa Project practice.
Principle 7: EbA strives to achieve co-benefits and synergistic outcomes.	
Synergies between adaptation and mitigation outcomes have long been sought and incentivised where feasible. EbA generally revolves around ecosystem management and thus may be relevant to carbon sequestration and related local changes in climate forcing such as albedo changes, especially where restoration or reforestation interventions are being considered.	
Criterion 7.1 EbA interventions promote positive co-benefit synergies, e.g. job creation, income generation, climate change mitigation (Box 3).	Closely aligned to Tsitsa Project practice.

5.4. Climate Smart Agriculture

A valuable resource explaining the philosophy and practice of Climate Smart Agriculture (CSA) is available for the online guide to CSA developed by the CGIAR Research Programme on Climate Change, Agriculture and Food Security (CCAFS) for the World Bank. [https://csa.guide/csa/what-is-climate-smart-agriculture#chapter-1]. The key characteristics of CSA are closely aligned with the goals of the Tsitsa Project and are given as:

- CSA addresses climate change
- CSA integrates multiple goals and manages trade-offs:
- CSA maintains ecosystems services:
- CSA has multiple entry points at different levels:
- CSA is context specific:
- CSA engages women and marginalised groups.

CSA addresses food security, misdistribution and malnutrition, improving food security for the poor and marginalised while reducing food waste; it reduces rural poverty by developing agriculture and mitigates carbon emissions and increases adaptation to climate change. CSA covers a range of practices including soil management, crop production, water management, livestock management, forestry and agroforestry, capture fisheries and aquaculture and energy management. It is compatible with a landscape management approach (Scherr et al. 2012, Harvey et al. 2014, Minang et al. (eds) 2015) and stresses the importance of considering the broader value chain such as links to urban supply chains and marketing of produce.

To provide an enabling environment for CSA the following should be put in place: index-based insurance, climate information services, infrastructure, policy engagement, institutional arrangements, gender and social inclusion. These help to build institutional capacity for adaptation and reduce risk to farmers.

Developing a CSA plan follows four steps: Situation analysis, Targeting and prioritisation, Programme support and Monitoring evaluation and learning. The context specific nature of CSA is stressed, highlighting the importance of understanding the local biophysical and social environment. Full details of how to develop and CSA plan are given in the online guidelines.

The last section of the guidelines considers finance. Climate change mitigation and adaptation activities attract funding from global and national sources. An overview or resources and funding opportunities is available from the guidelines.

FANRPAN (Food, Agriculture and Natural Resources Policy Analysis Network) reviewed the potential for CSA in South Africa (FANRPAN 2017). Their key recommendations are given in Box 1. The importance of an enabling policy environment and access to funding are clear recommendations from their policy brief. Educational materials for schools and extension workers is another aspect highlighted.

Climate Smart Agriculture has been adopted as an appropriate response to climate change by the DAFF (RSA 2018). The Climate Smart Agriculture (CSA) Framework as envisioned by the DAFF is illustrated in Figure 17. It can be seen that this framework covers a complex set of strategic objectives, guiding principles and strategic actions/ priority areas. To achieve the objectives as set out here requires commitment, capacity and resources at all levels.

The Strategic Framework of 2018 (DAFF 2018) identifies the following CSA actions as being important: “reducing vulnerability, increasing adaptive capacity, addressing specific risks related to climate variability and climate change, exploring sector-specific opportunities in the context of a changing climate and promoting communication and research”. (DAFF 2018 exec, Summary p. 5). It points to adaptation practices such as planting early maturing crops and adoption of hardy crop varieties and adapting livestock husbandry to lower rainfall. Mitigation measures include carbon capture, forest protection and replanting trees and use of renewable energy. The role of a supporting environment is emphasised.

DAFF (2018) gives five core objectives of the Framework that are closely aligned to those of the World Bank. They are:

- To guide actions at all levels of government, investors and development partners on mainstreaming CSA into agriculture, forestry and fisheries plans, programmes and projects.
- Contribute to increasing productivity and growth of agricultural, forestry and fisheries related value chains with nutrition and gender considerations.
- Enhance resilience to climatic and weather shocks on the social, environmental, and economic aspects of agriculture, forestry and fisheries production and food systems.

BOX 1

Climate smart agriculture in South Africa

FANRPAN Policy Brief 15/2017 page 1.

KEY RECOMMENDATIONS

1: Moving forward, policy efforts should focus on integrating CSA priorities into cross-sectoral mechanisms, and should ensure that plans for CSA are filtered down from national to the provincial and local level.

2: Identify appropriate strategies and mechanisms to address landlessness and poverty among smallholder farmers, and thereby also increase the uptake of CSA practices.

3: It is recommended that an appropriate mechanism for coordinating CSA in South Africa be identified and mandated.

4: For maximum impact, CSA should be integrated into educational curriculum across institutions, and materials related to CSA provided for extension workers and farmers.

5: There is a lack of prioritization of funding to implement CSA approaches in South Africa. Agriculture-related policies should also look at the role of development finance institutions and commercial banks in strengthening climate change adaptation in the agricultural sector.

- Contribute to low carbon development through efficient use of agricultural, agribusiness, forestry and fisheries resources to reduce national emission intensity in the AFF production and food systems.
- Strengthen governance and institutional coordination for effective implementation of the Climate Smart Agriculture Framework Programme at the National, Provincial and local levels. (RSA 2018 Exec summary page 5)

The Tsitsa Project can give effective support to this framework through working with subsistence farmers to improve their farming practices in line with CSA, to raise awareness of the commercial farming sector to the importance of adopting CSA and to work with the local municipalities and provincial government to strengthen governance and institutional coordination. It will be important to get the support of national and provincial DAFF.

Kruger et al. (2018) researched the potential for adopting CSA in the North West Province. Although farmers acknowledged that they were at risk to drought, heat waves and shifting seasonality of rainfall, they also indicated that high costs of equipment and agricultural inputs and market accessibility were constraining factors on productivity and willingness to change their farming system. The authors recommend supporting national policies that enable famers to change to CSA.

5.5. Conservation Agriculture

Conservation agriculture (CA) can be considered to be a component of CSA as it relates to farming practices that are designed to conserve water and retain organic matter in the soil. CA is based on three principles: minimum mechanical disturbance, organic soil cover throughout the year, use of crop diversity (rotations and associations) (Swanepoel et al. 2018). CA has a number of perceived advantages over commonly practiced farming methods. Minimising soil disturbance and increasing soil organic cover together increase the soil's organic content and therefore increases carbon sequestration, an important mitigation activity. Increased organic matter improves soil structure and enhances water use efficiency through improved infiltration and water holding capacity, thus reducing climate related risks. Multi-cropping and crop rotations promotes biodiversity, increases biological regulation functions and reduces nutrient losses. It can also reduce weed and pest problems. An important aspect of CA is that farmers are less reliant on external inputs which leads to greater profit margins, especially if accompanied by a yield increase.Swanepoel et al. (2018) reviewed conservation agriculture research in South Africa. The outcome of their review supported many of the positive responses listed above. They suggested that where CA did not produce a positive response it was likely that all three principles were not applied. Where farmers adopt minimum tillage without a good organic soil cover /mulch and crop diversification, weeds become a problem, with spraying being the favoured solution. Roundup is commonly used on maize crops, using Roundup-Ready maize promoted by Bayer who have strong links to Grain-SA. Mixed cropping cannot be practiced under this system and there is little potential to build up carbon reserves in the soil. This presents a real danger of unsustainable farming practices if the three principles of CA are not adopted.

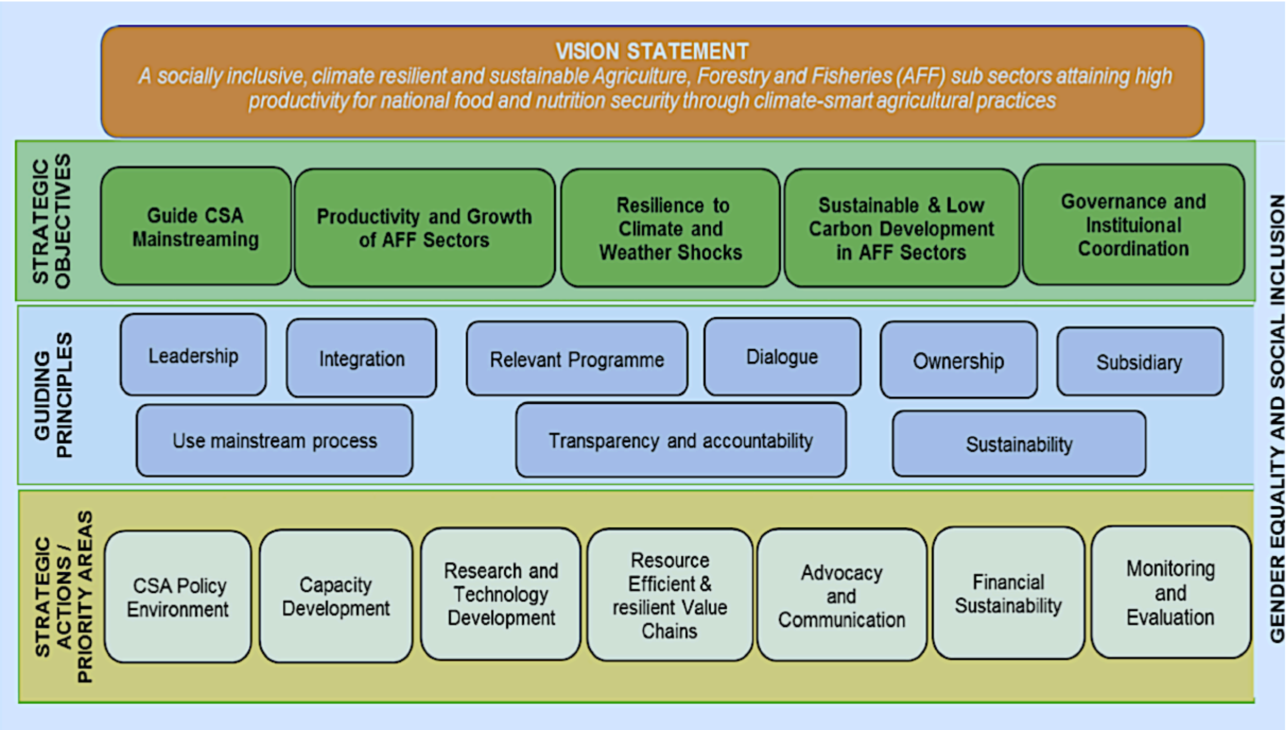


Figure 17. DAFF's Climate Smart Agriculture Framework (Source: DAFF 2018)

According to DAFF's draft CA policy of 2017 (RSA:DAFF 2107), commercial farmers were already adopting CA but it was not part of government policy. They state that 20-30% of grain farmers had adopted some sort of CA but the rate was lower than in other countries such as the USA or Brazil. Adoption by smallholders was constrained by land tenure issues, lack of resources and infrastructure. The draft policy sets out to provide support to this sector. Priority issues that should be supported by the state include restoration of degraded land, sustainable grazing management and enhanced forage production and cover. These are all important issues in the Tsitsa river catchment. The national LandCare Programme is given an examples of activities that should be promoted.

In addition to on-ground support of CA practices, DAFF's draft policy recommends that the government's mechanisation programmes should support specialised CA equipment such as no-till planters and sprayers, investment should be made in public and private sector training initiatives, extension officers should be trained in CA methods and the educational curricula should be adapted to promote CA. Possible incentives include Payment for Ecosystem Services, carbon markets, tax rebates for companies manufacturing CA equipment, a reduction of import duties on CA equipment and a carbon tax on farmers using external inputs associated with GHG emissions beyond agreed amounts. The draft policy also calls for further investment in research on CA.

An effective agricultural extension service is essential to the widespread promotion and adoption of CA (and CSA) within South Africa, especially by small-holder and subsistence farmers. Many studies have shown that a bottom-up approach is necessary to support farmer innovation. The conventional extension method of imparting expert knowledge in a short visit does little to build capacity to innovate. Therefore new approaches to extension need to be developed and extension officers trained in appropriate methods. One method that is proposed in the DAFF's draft CA policy is to establish Farmer Field Schools (FFS), which aim to train groups of farmers through the use of demonstration plots in an experiential process that brings about social learning. This model has been used globally, with 10-15 million farmers in 90 counties attending FFSs (Waddington 2014). Further discussion of the FFS model is given below (section 5.6).

Other components of the draft policy include a communication plan and a monitoring and evaluation plan. Examples of currently available outlets for communication of CA policy and practice are given in Appendix C. The policy recommends the use of participatory monitoring and evaluation in order to "enable organizations and groups to track progress, build on successes, and enhance capacities for learning". The PMERL initiative of the Tsitsa Project is closely aligned to this approach.

DAFF's draft CA policy is a brave attempt to put a comprehensive plan in place to promote and support Conservation Agriculture. As with the CSA framework, the policy highlights the need for an enabling framework that supports initiatives on the ground. Without a strong and clear commitment from government to support both CSA and CA as fundamental to the country's climate change adaptation policy their widespread adoption is unlikely. Two case studies described below (section 6) illustrate how these policies can be implemented in local communities but only with facilitation through the dedicated NGOs.

The Department of Planning, Monitoring and Evaluation (RSA: Department of Planning, Monitoring and Evaluation 2017) review the impact of implementing Conservation Agriculture in South Africa, looking at benefits and costs to different groups and the need for behaviour change. Due to the reduced inputs implied by CA, this will impact on those who currently supply commercial farmers with inputs such as herbicides, fertilisers and machinery.

Drimie (2016) critiques South Africa's agricultural policy and points to a lack of coherence between different policies relating to agriculture and food. As an example, RSA-DAFF (2017) point to the contradiction between the CA policy and the government's Illima/Letsema programme that seeks a reduction in poverty through increased intensification of production, mechanised agriculture and food 'massification'. Drimie (2016) suggests that there had to date been a focus on large scale black commercial farmers rather than smallholder farmers while urban food security and the value chain beyond production had been largely ignored. He sees developing and implementing policies for food security as a wicked problem that is hard to solve.

5.6. Farmer Field Schools

The widespread adoption of climate adapted agricultural practices such as CSA and CA requires an effective extension service. This is especially true in the case of smallholder farmers, who to date have received less support than commercial farmers. The conventional method of a top down approach, what Simpson and Owen (2002) refer to as the Training and Visit method, fails to bring about deep learning for adaptation among farmers. Farmer Field Schools (FFSs) provide a model based on experiential and social learning through a sustained participatory approach that aims to provide farmers with a deeper understanding of the agro-ecology of the farming system. They are based on principles that are well aligned to those of the Tsitsa Project.

Farmer Field Schools were pioneered in Asia in the 1960s by the FAO as a method to teach farmers about integrated pest control (Tomlinson and Rhiney 2018). The earliest application in Africa was in Ghana and Mali in the 1990s (Simpson and Owen 2002). Tomlinson and Rhiney (2018) investigated the extent to which Farmer Field Schools had built farmers's capacity for climate change adaptation in Jamaica.

The construct of a Farmer Field School is based on the idea of bringing farmers together to learn about the underlying ecological principles driving the agro-ecological system, to be exposed to different farming practices and to design, carry out and interpret field experiments comparing sustainable versus conventional practice. This is normally done at a demonstration site that is accessible to the group of participants. A season-long series of weekly meetings focus on biology, agronomic and management issues with input from farmers on their experience (Simpson and Owen 2002). Open days and exchange visits that involve all stakeholders (farmers, other community members, government officials, unions, schools, traditional leadership) were found by Chemura et al. (2013) to be a successful way of promoting learning and sharing knowledge. In this way FFSs lead to increased social cohesion (Chemura et al. 2013). Simpson and Owen (2002) found that FFSs led to increased trust between farmers and extension officers and better collaboration with other government departments or projects. The curriculum of a FFS is context specific and must be adapted to local circumstances. For example, Waddington (2014) suggests that women might have different priorities to men, focussing on subsistence crops rather than cash crops.

Waddington (2914) undertook a comprehensive review of literature on Farmer Field Schools, reviewing 460 publications and 337 project documents. The main focus of the publications were on integrated pest management. His findings indicted that the FFS model leads to increased knowledge and the adoption of beneficial practices by those participating in the schools. A statistical analysis of available quantitative date found that on average there was a 17% reduction in pesticide use and an associated 39% reduction in the estimated environmental impact quotient. Agricultural yields increased by around 13% and net revenue by 19%. Clearly there were direct benefits to farmers who attended the schools.

The long term aim is for participants to share knowledge of new practices within their communities. Evidence from Waddington (2014) shows that this is seldom achieved, with participants keeping the knowledge to themselves. Simpson and Owen (2002) were more positive, indicating that there was some degree of knowledge exchange between participants and neighbours. This tended to be related to new practices rather than ecological knowledge. These authors mentioned that one constraint was that village elders might discourage farmers from telling others what to do.

Several authors mention the challenge of effective extension. The facilitator plays an important role in maximising benefits of a bottom-up approach. Facilitators require appropriate training in participatory methods and, as Waddington (2014) points out, recruiting extension officers previously trained in top-down methods may be problematic. He recommends that recruitment is based on the following attributes: personal attitude, maturity, literacy, leadership skills, knowledge of the local language, experience wth farming and gender. He suggests that the ability to communicate may be more important than education or literacy levels but that facilitators need to be supported by supervisors and technical experts, backed up by regular monitoring. Facilitation should also encompass building the capacity of local FFS participants to train other farmers as part of an outreach programme. As noted above, lack of adoption of new practices by non participants has been a weakness of FFSs. The FFS is also a relatively expensive approach to extension so costs could be reduced if farmer facilitators are used (Simpson and Owen 2002). This could also extend participation by an increased number of farmers (Tomlinson and Riley 2018)

Although FFSs were initially developed to teach farmers about integrated pest control, they have been adapted for a range of situations. Of particular relevance here is their use to build capacity for climate change adaptation, as was described by Tomlinson and Riley (2018) for Jamaica. They compared the adaptive capacity of farmers who had participated in a FFS with non participants, surveying 51 individuals in each group. The FFS modules ran for an average of eight months. Tomlinson and Riley (2018) developed two measures for comparison. The first was Objective Adaptive Capacity (OAC) linked to educational level, access to remittances, savings and livestock, access to irrigation and membership of farmers' groups and other social networks. The second they call the Perceived Adaptive Capacity (PAC), based on farmer's responses to questions about, firstly, whether there are overall actions that can reduce the impact of climate change and, secondly, whether individual farmers can reduce the effect of climate change on their own farms. They found that the OAC index was slightly higher for the participant famers but the PAC was significantly higher, pointing to the conclusion that attendance at a FFS did increase adaptive capacity. Their findings showed that FFS participants were more likely to adopt sustainable farming practices such as intercropping with legumes and pest control plants or use trash barriers for soil and water conservation. They were also likely to engage in some sort of entrepreneurial initiative after the end of the school, another form of climate change adaptation. The risk perception of FFS participants increased and they were more accepting of formal weather information whereas non-participants were more reliant on traditional methods such as observing clouds or insect activity. FFS participants who saw public action on climate change as important were also more likely to take individual action on their own farms.

The Farmer Field School model is one that could be adapted to build capacity for climate change adaptation in the Tsitsa river catchment. A similar approach is being used by AWARD through the RESILIM-O project and the Suid Bokkeveld wild rooibos tea project as described below (section 6). Common elements include:

- a bottom up approach using experiential and social learning
- bringing groups of famers together from a wider areas for shared learning
- learning over an extended period
- inclusion of experimentation by farmers
- training of local facilitators

Waddington (2014) identified a number of enablers and barriers to effective FFFs. These are summarised in Table 7 and provide a useful check-list for evaluating a learning programme.

Table 7. Enablers and barriers of Farmer Field Schools. Compiled from Waddington (2014)

Knowledge acquisition	Adoption of FFS practices	Effective-ness and sustainability	Diffusion	Enablers	Barriers
Social factors					
	✓	✓	✓	High levels of social capital and tradition of collective action; FFS groups with consistent membership, good leadership, collective goals and a supportive group environment	Low levels of social capital & cohesion
✓				Farmers motivated to learn and improve livelihoods	High drop out rates due to incorrect expectations, lack of interest, access or time issues
	✓				Farmers lack access to inputs, capital and/or markets (i.e. lack of a supporting environment
✓					Farmers excluded through targeting procedures; exclusion due to gender, cultural norms or poverty
			✓		Socio-economic differences between FFS and non-FSS farmers
Curriculum					
✓	✓	✓		Bottom-up approach to learning	Top-down training, transfer of knowledge approach
✓	✓			Curriculum relevant to the local context	Curriculum not relevant
	✓		✓	Concrete and relatively easy to practice	Practices too complicated
	✓		✓	Farmers observed benefits	Farmers do not observe benefits
✓					Lack of resources for the schools
Facilitation					
✓				Facilitators are mature, have a positive personal attitude and leadership skills	Imbalance in relation between facilitators and particapnts
✓				Facilitators use the local language and metaphors	Not using the local language
✓				Facilitators have farming experience	Facilitators lack farming experience
✓					Lack of training of facilitators
✓				Gender of facilitator acceptable	
		✓	✓	Active follow up and continued support; active promotion of FSS practices	Lack of technical assistance and backstopping from researchers and extensionists
External factors					
		✓			Diverging institutional incentives and objectives & conflicting agricultural policies
		✓			Power of pesticide industry and continued links with the extension service

6. Case studies of climate change adaptation - NGO activity

6.1. Introduction

Two South African case studies provide useful models for climate change adaptation strategies in the Tsitsa catchment. The first is the USAID funded RESILM-O project managed by the non profit organisation Association for Water and Rural Development (AWARD) that has the overarching goal of reducing vulnerability to climate change in the Olifants river basin. The second is a climate change adaptation project in Suid Bokkeveld, Namaqualand, supported by the non profit organisations Environmental Monitoring Group (EMG) and Indigo development and change. Both projects have a number of common elements that contribute to their success: long term sustained engagement, location in proximity to the project area, bottom-up approaches using participatory and action research methodologies for social learning and empowerment, frequent interaction, support for farming practices that support adaptation, farmer experimentation, support with marketing produce, training of local people to become facilitators or mentors and production of appropriate training materials. Information on RESILIM-O was obtained from the AWARD-RESILIM-O Annual Report 2017-18 (AWARD 2018a) and the Resilim-O phase 2 milestone 4: progress report (AWARD 2018b). Information on the Suid Bokkeveld project was obtained from the report by Oettle (2012): Adaptation with a human face, Adaptation Case Study. More recent information is available from an article on the dry-net website (EMG 2015). These two projects are described and compared in more detail below.

6.2. Key learning

<u>Long-term sustained engagement</u>

The Suid Bokkeveld project has been running for 20 years having started in 1998 when the Department of Agriculture approached the EMG, asking for assistance in developing a bottom-up approach to development in the area. Likewise, AWARD has had an active presence in the lower Olifants since the early 1990s; the RESILIM-O project has been ongoing for four years. Thus in both areas there has been sufficient time to acquire a deep knowledge of the human and physical landscape, build trust between partners, learn from mistakes and to make a meaningful contribution to local development.

<u>Location of the NGOs</u>

In both projects there is a continued presence close to the area where activities take place. AWARD is based in the small town of Hoedspruit in the lower Olifants. Indigo development and change is based in Nieuwoudtville, close to the project area. EMG is based in Cape Town but has an office in Nieuwoudtville, with one staff member. This geographic proximity helps to build rapport between the service providers and the local community, makes it easier to respond to issues and allows frequent contact and meetings due to reduced travel time and cost.

<u>Project philosophy and methods</u>

Both projects are based on bottom-up approaches using participatory and action research methodologies for social learning and empowerment. AWARD partners with the Mahlathini Development Foundation (MDF), which specialises in participatory learning and action processes. Collective action and learning and sharing experiences are seen as important pathways to empowerment in both projects.

Oettle (2012) describes in some detail the principles behind the research in the Suid Bokkeveld. This project used Participatory Action Research (PAR) and Human Scale Development (HSD). Through PAR the researcher is also a practitioner and works with the community to bring about change through opening up space for empowerment. PAR should be participatory, action-orientated and research should develop knowledge, increase ability to solve problems, and critically review theory on an ongoing basis (Oettle 2012). HSD is based on the notion that a development project must satisfy a number of different human needs. According to Max Neff (1991) these include subsistence, protection, affection, understanding, participation, idleness, creation, identity, freedom. In its PAR activities the Suid Bokkeveld project worked towards achieving a synergic satisfier that fully satisfies one need while also contributing to others (Oettle (2012).

The first step in working with the Suid Bokkeveld community was to develop an agreed set or working principles. Later, as more external researchers started to become involved, a research protocol was also established.

PAR methods used in the Suid Bokkeveld included visioning through pictures, story telling, drama, role play, game playing, participatory video (allows sharing within and outside community, enhances sense of self worth), participatory GIS. Two methods mentioned as being used in the RESILM-O project are the five finger categories and the traffic light system. The five fingers are water management, soil management, crop management, soil fertility and soil health, natural resources. Presumably this provides participants with a check-list for evaluating actions. The traffic light system is a way of assessing and coding a specific intervention: green - good implementation, yellow can be improved, red - none or very little.

Frequent interaction

Project implementers in both areas meet frequently with participants. According to RESILIM-O (2018) over the two months at the start of the 2017/2018 summer season a 2-day learning and mentoring session was held in six villages in the lower Olifants, training sessions for monitoring in seven villages, a 3-day networking workshop and a 30 day cross-visit to a learning site. This is an intensive programme of 60 days of work or 140 person days involving three people. In the Suid Bokkeveld, quarterly climate change preparedness workshops have been held since 2004. These workshops bring people together from across the area to share information on weather events, reflect on how these have affected their farming enterprises and receive a weather forecast for the next quarter. The different communities across the area have been given rain gauges and max-min thermometers so that they can monitor weather variations. These data and weather diaries are shared at the workshops.

Support for farming practices that facilitate climate change adaptation

Farmer support is the key activity in building resilience to climate change and both projects actively promote sound agro-ecological farming in line with Climate Smart Agriculture. The Agricultural Support Initiative of RESILIM-O aims to support increased adaptive capacity and resilience to the effects of climate change through improved soil and water conservation and agro-ecological practices. Increasing food security and livelihood diversification and supplementation through alternative climate resistant production are important objectives. Methods that are supported include: shade cloth tunnels, mulching, composting, trench beds, raised beds, eco-circle gardens, tower gardens, crop diversification, seed saving, growing organic produce, livestock husbandry including poultry, natural pest control, tree propagation for fruit trees, pruning, mixed cropping, erosion control measures, irrigation methods (e.g drip irrigation; timing), cell phone-based weather forecasts.

The main crop harvested in the Suid Bokkeveld is wild rooibos tea. The region is arid with high water and wind erosion potential and drought is a pervasive threat. Specific support has been given to implementing soil conservation measures and research into seedling propagation.

Farmer experimentation

Experimentation by farmers is an activity supported by both projects. In the Suid Bokkeveld, for example, farmers have experimented with fire regimes to encourage seedling propagation. In the RESILIM-O project participants experimented to investigate the effects of trench beds inside and outside tunnels and furrows and ridges outside the tunnel.

Support with marketing produce

Being able to derive an income through marketing produce is necessary if livelihood support is to extend beyond subsistence farming. This is especially true in the Suid Bokkeveld where the main product is wild rooibos tea. The Heiveld Co-operative was established in 2001 by the local community; it has played a pivotal role in increasing farmers' resilience to climate change. Its primary function is to market the tea, using Fair Trade outlets. In addition to its marketing role, the co-operative helps to mobilise donor funds to provide targeted incentives and has provided drought relief in the form of seeds and seedlings. It has played a key role in information sharing and implementing adaptation responses. Most important, it will still be there in the long term, leading to sustainability.

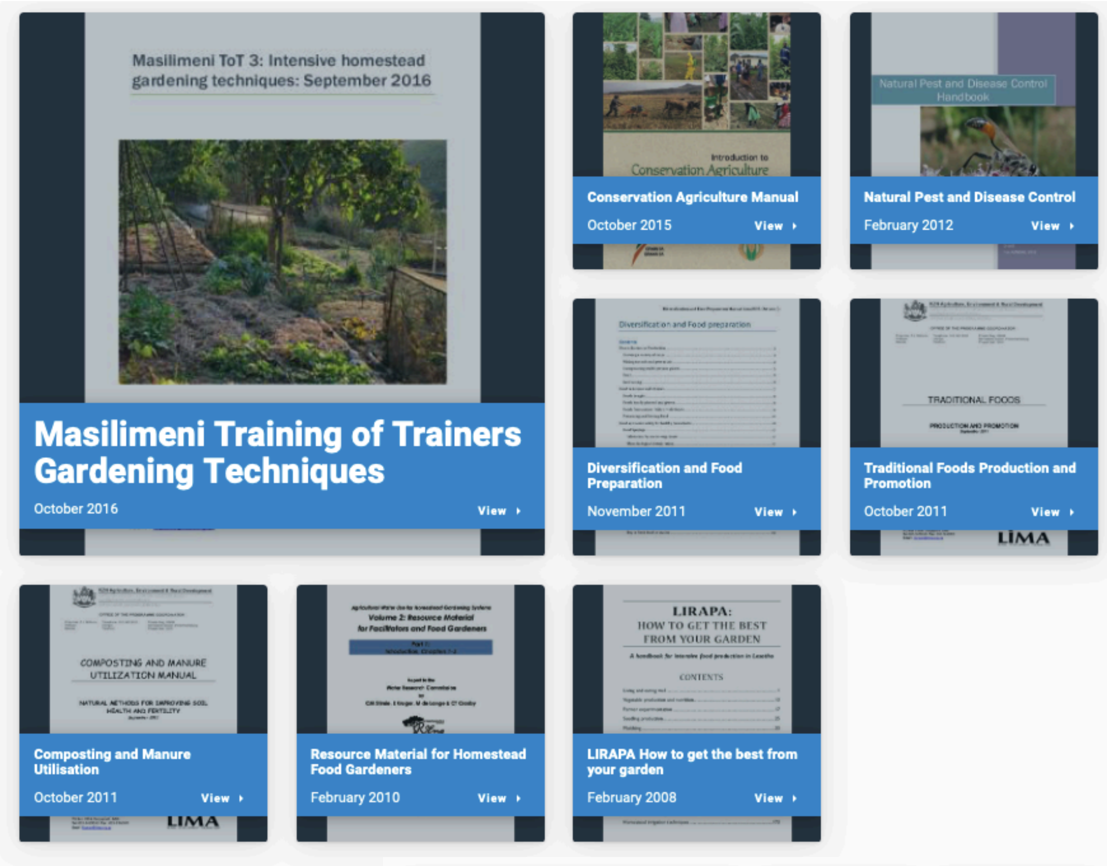
The Olifants' farmers benefit from access to an organic market in Hoedspruit for vegetables and herbs and support for accessing other outlets such as local supermarkets. Emphasis is given to maintaining quality of the produce.

Training of local people to become facilitators or mentors.

Both projects encourage local people to become facilitators or mentors. The DICLAD project of RESILIM-O used locally trained people to assist with translation and facilitation in Dialogues for Climate Change Literacy and Adaptation (DICLAD) workshops. Younger facilitators were able to better explain to older participants about technical aspects such as using cell phones for weather forecasts (AWARD-RESILIM-O annual report 2017-12018). In the Suid Bokkeveld two Mentor Farmers were appointed. Their role was to assist other famers to manage their resources more sustainably and to counteract the negative impacts of climate change.

Production of appropriate training materials

Both NGO groups are active in producing training materials and documents that support good practice. AWARD partners with the Mahlathini Development Foundation (MDF), which specialises in participatory learning and action processes. A large number of manuals and training videos that can be downloaded from the MDF's website (https://www.mahlathini.org) (see Figure 18). The Indigo web site (www.indigo-dc.org) provided access to number of resources for community learning approaches as listed in Box 2. More examples of training materials and relevant media are given in Appendix C.



Topics

Training of trainers

Conservation Agriculture manual

Natural pest and disease control

Diversification and food preparation

Traditional foods production and promotion

Composting and manure utilisation

Resource material for homestead food gardens

LIRAPA How to get the best from your garden

Water issues

Rain water harvesting

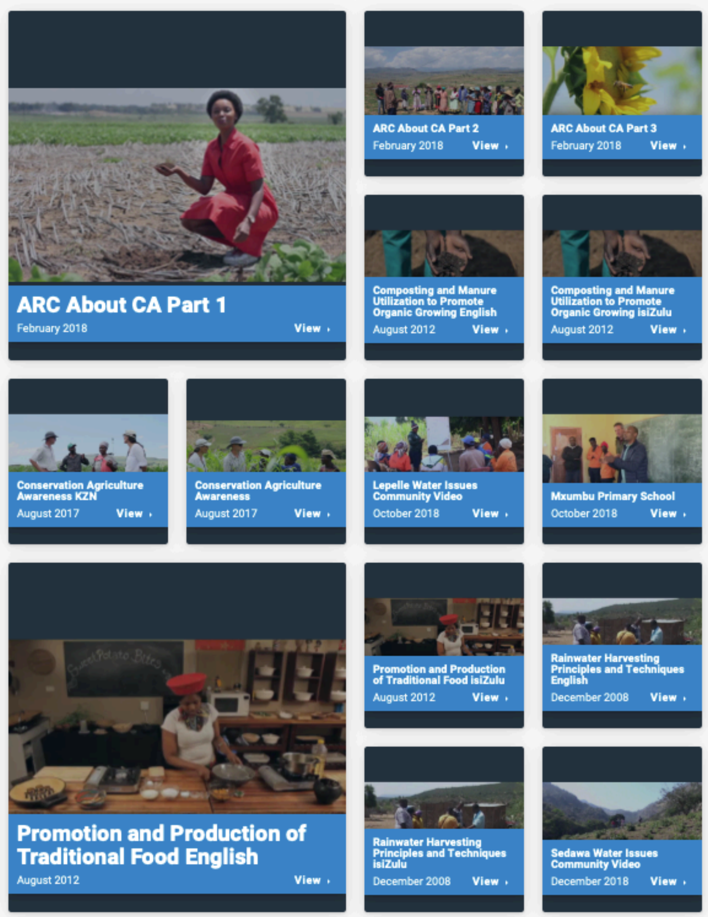


Figure 18. Manuals (top) and videos (bottom) available from the Mahlathini website https://www.mahlathini.org

BOX 2 Indigo development and change resources for climate change adaptation practitioners Available: https://www.indigo-dc.org/research.html	
Oettle, N; Koelle, B; Law, S; Parring, S; Schmiedel, U; Archer van Garderen, E; Bekele, T (2014) Participatory Adaptation Handbook - A practitioner's guide for facilitating people centred adaptation, doi: 10.7809/book.001.	
Koelle B, Oettle N, Parring S, 2014. Experiential learning for adaptation - facilitation cards	
Reader: Adaptation and Beyond	
Adaptation and beyond CASE	Adaptation with a human face
Adaptation and beyond No 1.	Community Based Adaptation
Adaptation and beyond No 2	Basic principles when working with individuals, households and
Adaptation and beyond No 3	Climate science for adaptation
Adaptation and beyond No 4	Gender and climate change adaptation
Adaptation and beyond No 5	Concepts for multi-disciplinary learning with young adults
Adaptation and beyond No 6	Defining adaptation
Adaptation and beyond No 7	Using climate data
Adaptation and beyond No 8	Climate change preparedness workshops
Adaptation and beyond No 9	Modelling rooibos crop suitability and distribution under scenarios of
Adaptation and beyond No 10	The seasonal forecast game
Adaptation and beyond No 11	Livestock monitoring for adaptation
Adaptation and beyond No 12	Multilevel partnerships for mainstreaming climate change in local
Adaptation and beyond No 13	Climate Change Adaptation and Ethics
Additional resources available from the Adaptation network http://www.adaptationnetwork.org.za/	
Adaptation and beyond No 14	Participatory photography
Adaptation and beyond No 15	Sharing lessons of adataption
Adaptation and beyond No 16	Adaptation in the local context

7. Municipal climate change adaptation planning in the Tsitsa river catchment

South African municipalities are mandated by law to develop Integrated Development Plans which, as noted by Lethoko (2016), should be the main instrument for climate change adaptation and mitigation response at both district and local municipality level. The DEA have developed a municipal support tool called the LetsRespond Tool Kit (available from http://www.letsrespondtoolkit.org/home) which has been used to develop climate change response plans at the Provincial and District level. The Tsitsa river catchment falls within the Elundini Local Municipality of the Joe Gqabi District Municipality and the Mhlontlo Local Municipality of the OR Tambo District Municipality. The two districts share many climate related issues in common and the climate change response at the district level, based on the LetsRespond Tool Kit, is summarised below in Table 8. While various risks related to climate change are identified, both districts recognise a lack of capacity and limited finance as constraints on dealing effectively with these. The extent to which climate change mitigation and adaptation is built into the IDPs of the Jo QGqabi District Municipality and the Elundini and Mhlontlo Local Municipalities is examined in more detail below. Climate change response strategies promoted by the Tsitsa Project should take account of and support municipal plans and actions.

Table 8. Climate change response in the Jo Gqabi and OR Tambo District Municipalities

Theme	Indicator	Jo Gqabi	OR Tambo
Agriculture	Maize production at risk;	Commercial farmers conducting research on suitable cultivars; LandCare programme addressing alternative crop production.	Develop Agriparks focussing on maize, vegetables and nuts
	Increased exposure of crops (fall army worm) and animals (swine flu, bird flu) to pests	Municipality implemented initiatives such as sprays for gardens and manure but not enough.	Low capacity to respond
	Livestock - heat stress, impacted immune systems, lower food intake, increased disease, veld fires damaging grazing	Recent droughts have caused veldfires. Farmers battling to adapt to severe climate conditions.	District-wide livestock improvement programme aimed at communal farmers, better access to veterinary services, research to support livestock management practices
Biodiversity and environment	Wetland health, loss of biodiversity due to land use change and soil erosion	Wetlands a priority, no adaptive capacity; need to integrate planning and legislation to protect vulnerable ecosystems. Need for a legislative framework. Further research required to understand extent of biodiversity loss, especially grassland and Nama-Karoo.	District Environmental Management Plan and Environmental Management and Spatial Planning Forum but issues of staff capacity and funding. Lack of implementation due to insufficient resources. Ability to tackle soil erosion and land use management compromised by lack of cooperative governance, for example traditional leaders and municipalities working together through COGTA.
Human health	Increase in water borne and communicable diseases.		Need for provision of clean water. early warning systems, community education and awareness, water sampling.
	Occupational health - heat stress	Financial capacity limited	Unsure of capacity to deal with this.
	Risk from increased storms		Unsure of capacity to deal with this.
Human Settlements, Infrastructure and Disaster Management	Damage to traditional dwellings	Traditional dwellings at risk to severe events, need to fast track provision of fixed structures in urban and rural areas	Disaster Risk Management Plan

	Flood damage roads and bridges	Impacts on service delivery and isolation of communities. Snowfall also a problem in high lying areas. review formula for equitable share (what does this mean?) Task team formed, lack of finance	
	Fire risk	Limited capacity. local municipalities to render fire services.	
	Rural-urban migration	Low capacity to deal with this, needs investment in economic projects	Rural-urban migration to Mthatha puts stress in urban infrastructure
Tourism		Tourism an important potential asset. Investment needed to reduce unemployment	Damage to tourism related infrastructure (roads?)
Water		Storm runoff will increase blocking of stormwater systems and sewers by litter. funding a constraint; improve working relationships with municipalities and relevant departments	Frequent droughts and high evaporation rates cause decreased water quality and reduced availability - response: desilting of existing earth dams, managing anti-erosion structures, constructing new earth dams, rainwater harvesting tanks, off channel storage dams to collect flood water to collect water on floodplains. Fast track Ntabelanga and Lalini dams

7.1. Key learning

The Elundini Municipality does not have the capacity to develop its own Environmental Management Plan and Climate Change plan but has adopted those of the district. It is therefore apposite to examine the IDP of Elundini within the context of that for the Jo Gqabi District Municipality.

The Draft IDP of the Jo Gqabi District Municipality IDP for 2019/20 (Jo Gqabi District Municipality 2019) addresses a number of issues that are relevant to climate change adaptation although not necessarily explicitly linked. Climate risks recognised as possibly increasing include floods, tornados, drought, veld fires, forest fires, severe snow falls and gale force winds. Eastern areas of Elundini (the Tsitsa catchment) are expected to become wetter; there is already evidence of increased storm activity, flooding, high winds and hailstorms, damage to crops, settlements, roads and bridges, and increased agricultural pests.

The District Municipality's climate change policy focusses on GHG mitigation rather than adaptation. It seems that the writers of the climate change strategy took the generic list of GHG emitters and mitigation responses and more could be done to develop a locally relevant plan. For example, identified producers of GHG emissions include rice paddies, not found in this area. Suggested mitigation responses include increased use of public transport, increased electricity efficiency in homes and businesses, promotion of renewable energy (solar and wind) and prevention of deforestation. In reality, there is limited potential for large scale commercial farmers to use public transport while the majority of the population already have little alternative but to use it. Extending access to electricity in rural areas using renewable energy is a sound strategy but needs support from national government and any new municipal housing should be well insulated so as to cut down the use of electricity for heating in winter and also reduce heat stress in the summer. There are plans to develop a renewable energy strategy linked to business opportunities. Burning following deforestation is recognised as a problem though burning of veld and fuel wood is not because the veld and wood are renewable. However, excessive burning puts CO_2 into the atmosphere and prevents carbon being returned to the soil so should be limited as far as possible. The Elundini local municipality is represented on the SAGA working group for Environmental Planning and Climate Resilience.

The district municipal environmental management plan was developed in 2005 and adopted in 2011. Financial resources and capacity to adopt the plan are lacking. Key issues identified in Elundini Local Municipality are biodiversity (extinction of species), waste management, air quality and sand mining. Soil erosion is not included. Mountain grasslands and wetlands are identified as critical biodiversity areas in the local municipality IDP; they are seen as important for ecosystem services. Land invasion and lack of land use management is seen as resulting in wetland degradation. Payment for ecosystem services is suggested as a way to protect wetlands. Processing factories, the transport sector, PG Bison, burning of domestic wood, coal, waste and tyres, veldt or forest burning, burning of municipal waste contribute to air pollution. These are all contributors to GHGs and should be addressed through the climate change strategy. There is at present no baseline data against which to monitor emissions.

Opportunities identified in the Elundini IDP include rain water harvesting, solar panels, alternative energy sources and recycling initiatives. The IDP recommends that land use management planning is extended to rural areas. A Land Use and Environmental Management Plan has been commissioned for the Tsitsa River basin.

The Jo Gqabi District is developing a District Disaster Management Scientific Assessment Plan and a District Disaster Management Unit has been established. In addition to the climate hazards and pollution mentioned above, the Disaster Management Unit is also concerned with outbreaks of disease, specifically cholera, HIV/AIDS and foot and mouth. Veld and forest fires are frequent hazards as well as flood incidents. It is notable that only the District and not the Local Municipalities have a fire fighting budget. BG Bison and farmers provide help at the local level.

Agriculture can play a big role in climate change adaptation (section 5). Some of the District plans can be extended to play a role here. Agriculture has been supported in the past by the Massive Food Programme, which, as noted by the DAFF (section 5.5), is counter to conservation agriculture. A maize-meat hub is planned for Elundini to stimulate the maize and livestock industry, with small holder and communal farmers forming partnerships with commercial farmers. If carefully managed this could provide the necessary markets to support sustainable agriculture, for example by providing a market for livestock from communal lands. An Agri-Park is planned for Lady Grey, with a farmer Production Support Unit in Mt Fletcher (in Elundini). The aim of the Agri-Park is to develop the wool, maize and red meat industry through providing a“network innovation system of agro-production, processing, logistics, marketing, training and extension services” (Jo Gqabi IDP page 88). The IDP notes that agricultural development requires investment in rural roads and electricity infrastructure, skills development and training, while theft and vandalism of farm infrastructure and (small) stock need to be addressed.

The proposed Agri-Park has potential to act as a hub for promoting Climate Smart Agriculture throughout the district. Extension officers could be trained in CSA approaches and the hub can serve as a marketing centre of produce from CSA farms. The Tsitsa Project should engage with the Farmer Production Support Units in Mt Fletcher to promote CSA for both gardens and livestock.

The Jo Gqabi Municipal District Development Plan states that the district has high rainfall favourable for agriculture, especially in the eastern areas (Elundini). This ignores the propensity for drought, which is likely to increase in the future, and the widespread erosion. Moreover erosion is blamed largely on over grazing and other human impacts, underestimating the highly erodible nature of many of the soils. The soils of Elundini are described as having only moderate erodibility. The main programmes for restoration of degraded areas are given as the DEA's wetland rehabilitation (Working for Wetlands) and alien clearance (Working for Water) as well as the dryland rehabilitation in the Tsitsa catchment (Working for Ecosystems - the Tsitsa Project). EPWP related programmes such as these are seen as important job creation opportunities.

Forestry is a significant land use in Elundini LM. It is a significant contributor to employment (> 2000 jobs) and the economy. PG Bison produces chip board for the local and international market. While recognising its economic contribution, forestry practices need to take account of GHG emissions due to burning trash, reduced soil carbon storage relative to the grassland that it takes over and the problem of sediment movement related to roads. The IDP notes the problem of sediment sourced from forestry vehicles travelling on the main roads.

7.2. Climate change mitigation and adaptation in Mhlonto Municipality

According to the Mhlontlo Local Municipality Final IDP review 2018-19, the Local Municipality does not have the resources to develop its own climate change strategy but has adopted the district strategy (Oliver Tambo District Municipality). Relevant actions related to a climate change strategy indicted in the IDP are controlled burning of refuse and the development of a recycling and by-back centre. Other actions include biodiversity planning and protection of wetlands, improved infrastructure for water conservation through reduction of leaks. The IDP points to good potential for stock farming and a favourable climate and soils for high value crops and fruit production. This ignores the high erosion potential of the area and the description of land capability classes which refers to small pockets in the eastern section of the area that are suitable for pasture and crop production. The IDP report stresses the rural character of Mhlontlo Local Municipality and the need to support rural communities and enhance food security. Key spending programmes include support for emerging farmers and soil conservation measures and sustainable land use management. The role of local government includes the promotion of home production for food security, facilitating the development of local markets for agricultural produce and improving transport links to urban centres. Together these actions would support climate change adaptation. Weaknesses identified in the IDP include poor implementation of land use management, limited expertise in livestock chain development and limited equipment and plant to support agricultural development.

In August 2009 Mhlontlo Municipality was declared a "Comprehensive Rural Development Pilot Site" by the Eastern Cape Premier. The project was launched in the two wards of Tsolo and Qumbu. The Tsolo ward lies in the Tsitsa river catchment. There was no municipality funding for this project, rather it was to be funded through government sector departments and coordinated by the ARC. The project falls under the LED directorate and is advise by a Council of Stakeholders that comprises government sector Departments, Mhlontlo Municipality managers, portfolio councillors, the Mayor, Community Development workers, traditional leaders, Council of Churches, government parastatals and other community based organisations. Potentially this is a forum that the Tsitsa project could engage with.

8. Case studies of climate change adaptation - climate change adaptation planning in the Alfred Nzo District Municipality

Conservation South Africa (2015a) prepared a report on behalf of the Alfred Nzo District Municipality (ANDM) detailing a climate change response strategy for the district. This report aimed to support planning at the District and Local Municipality level through, for example, the Integrated Development Plan. The lack of capacity in both the OR Tambo and Jo Gqabi District Municipalities has already been noted; this report provides a model that could be adopted by these institutions. It is also possible that the Tsitsa Project could develop a similar plan for the Tsitsa catchment as opposed to a municipal area.

Projected climate change and impacts are similar to those described for the Tsitsa (section 2.6). The report confirms likely changes to the savanna biome due to spread of savanna. The ANDM has a low emission of GHGs equivalent to to 0.44% of the national total in 2009. This is largely due to the energy poverty in the area and the lack of access to the national grid, which is largely dependent on coal fired power stations. The report recognises the need to increase household access to electricity but recommends that renewable options are sought. At present the main contributors to GHG emissions are uncontrolled burning of uncollected waste (52%), household fuel consumption (34%) and purchased electricity (8.7%). Other sources include field burning of crop residues and wild fires. Improved waste management is a priority and could be linked to biogas production as a renewable energy source. Recommended landscape mitigation activities that are relevant to the Tsitsa Project include restoration of grasslands, soil conservation and avoiding deforestation. These are aligned with ecosystem services and ecosystem-based climate change adaptation ventures and, according to Conservation South Africa (2015a), may be the largest opportunity to sequester carbon in the ANDM. The potential spatial extent of Conservation Agriculture in small holding areas is estimated at 36 000 ha, reducing carbon emissions by 33 000 tCO_2e per year. If commercial farms also applied CA the potential area would increase to 190 000 ha.

Section 5 of the report sets out an integrated climate response action plan for the district. Key to this plan is effective service delivery to increase resilience, with action on water supply, sanitation, waste disposal, transport and well designed settlements and houses. Landscape scale measures include Climate Smart Agriculture and Ecosystem-based Adaptation, with support given especially to both urban and small-scale agriculture. One adaptation response is to investigate alternative crops to those presently grown. Maize is the main cereal crop for subsistence farmers in the area but Conservation South Africa (2015a) refer to studies that show that under future climate conditions rain-fed sorghum will give a significantly better return on investments than maize. It is also recommended that opportunities for diverse livelihood options, that are less at risk to climate change, are developed. There should be integration of mitigation and adaptation strategies as these are often mutually beneficial.

A top priority is seen to be the protection and restoration of critical ecological infrastructure such as wetlands, river buffers and water catchments. EbA priority areas have been mapped for the district according to their present value. This should help integrated land use planning and is, to a considerable extent, being emulated in the Tsitsa Project area.

Essential to climate change adaptation is increased awareness of risks and possible response. The plan prioritises education and awareness raising to influencing behaviour and training and capacity development of officials to enhance institutional capacity for climate change and disaster preparedness. The Eastern Cape Climate Change Response Strategy is referred to for ideas for communication and awareness raising. The report recommends climate change is mainstreamed into all day-to-day activities, projects and plans of local authorities. A set of 30 cartoons related to climate change mitigation and adaptation, together with lesson plans, have been developed to support learning in schools. Media channels such as radio, newspapers and television should be used to spread climate change messages; these could be linked to events such as flooding.

Conservation South Africa (2015a) recommend that all projects planned by the ANDM should be evaluated in terms of their climate change response outcomes. They state that "In general terms, climate change response projects should 'do no harm', aim to boost and support social, economic, and environmental rights, and enhance natural ecosystems so that they are better able to manage and respond to climate change" (Conservation South Africa 2015a p. 78). Projects can be prioritised according to the following criteria:

- Effectiveness
- Contribution to development priorities
- Economic cost
- sustainability
- Implementation capacity
- Other considerations

An multi-criterion matrix for evaluating any climate response action by the ANDM is also given under the headings of:

- vulnerability hotspot (yes/no)
- robustness (high, medium, low)
- no regrets (yes/no)
- benefits (high, medium, low)
- cost (high, medium, low)
- environmental sustainability (yes/no)
- implementation capacity (high, medium, low)
- timeframes (high, medium, low)
- opportunity (yes/no)
- social acceptability (yes/no)

Potential projects relevant to the ANDM were listed under the headings:

- water and sanitation (including catchment management initiatives)
- renewable energy
- solid waste management

This method of evaluation could be considered for evaluation of projects in the Tsitsa river catchment.

9. Mitigation and adaptation in the Tsitsa catchment

The likely climate change impacts in the Tsitsa catchment are summarised in section 2.6. It is anticipated that changes to rainfall will be relatively small but the direction of change is uncertain. Some models predict a later start to the rainy season but increased autumn rainfall. Rain storms are likely to be more intense, leading to local flooding and soil erosion, especially if ground cover is depleted due to low soil moisture. Snow fall, an important contributor to groundwater and river baseflow, will decrease in extent and duration. The most likely impacts will be an increase in average and extreme temperatures, increased heat stress and evaporation loss, and prolonged dry spells with an increased propensity for serious drought. One positive aspect may be that a shift to autumn rainfall together with warmer temperatures and fewer frosts may prolong the growing season but if spring rainfall is decreased (the current trend), planting will be delayed.

The landscape of the Tsitsa river catchment is largely rural, though as pointed out in section 5.1, close to a quarter of the population live in the small urban centres of Maclear, Ugie and Tsolo. With the scope of the Tsitsa Project effectively being defined by its land restoration initiatives funded through the DEA, climate change adaptation and disaster risk reduction through the project will be focussed on the rural areas. This is in line with the South African Climate Change Response White Paper that highlights the agriculture sector as a priority in terms of addressing climate change (DEA 2018).

Restoration activities fit well within the remit of Ecosystem-based Adaptation (EbA) (section 5.3), as promoted by the DEA. Catchment scale restoration that limits sediment movement and recharges soil and groundwater contribute to climate proofing. To merit EbA funding, however, the restoration activities need to demonstrate close alignment with climate change adaptation principles. As mentioned in section 5.3, programmes such as Working for Land, Ecosystems, Water or Wetlands need to be linked more explicitly to the four EbA cornerstones of climate change adaptation responses, services from biodiversity and ecosystems and benefits for people within the context of sustainable development. The Tsitsa Project's focus on sustainable livelihoods that create benefits for people brings the Working for- programmes closer to the EbA objectives. Table 6 in section 5.5 demonstrates the extent to which the Tsitsa Project is and could be aligned to the principles and criteria of EbA.

Sustainable livelihoods that are resilient to climate change will not be achieved through short term (and unreliable) employment as currently promoted through the EPWP or the CWP that is integrated into the Working for programmes. For livelihood options to become better adapted to climate change it is necessary to engage with crop production and livestock management. Where crops are limited to home gardens it should be relatively easy to get uptake of Climate Smart Agriculture (CSA) methods (section 5.4) that incorporate the principles of Conservation Agriculture (minimum tillage, cover crops, mixed cropping and crop rotation) (section 5.5). In Sinxaku, for example, the more successful gardeners already practice these to some extent. Integration of water harvesting will also increase the capture of rainwater and allow some drought proofing. Other responses include changing to more drought resistant crop types, for example replacing maize with sorghum as the staple. To bring about these changes will require a concerted and sustained effort of working with rural people to explain the significance of climate change, and to explore realistic adaptation options. It is also important to understand that CSA will not help in a prolonged drought that causes widespread crop failure. Households need alternative income streams while the Local, District, Provincial and National Disaster Management agencies need to have a proactive policy to support people in need, both during and after a drought.

Much of the land use in the upper Tsitsa catchment is commercial farming or forestry. Commercial farmers should be persuaded to convert to CSA and forestry should use practices that are better suited to climate change mitigation and adaptation. Conservation Agriculture has been promoted by the DAFF and GrainSA but it is important that all three aspects of CA are adopted, not just minimum tillage. The DAFF supports CSA through their Framework (DAFF 2018) (section 5.4). The Tsitsa Project could work with the local DAFF to put this framework into practice. CSA is compatible with a landscape management approach and stresses the importance of considering the broader value chain such as links to urban supply chains and marketing of produce. This may be outside the scope of the Tsitsa Project but is something that DAFF should consider. The proposed AgriParks go someway to assisting with marketing.

Winter burning is a common practice in grazing land, croplands and forest margins, especially in upland areas. Trash is also burnt after forest clearance. While burning may have beneficial outcomes the amount of burning should be restricted, given the negative aspects regarding climate change mitigation. Carbon should rather be stored in the soil.

Forestry in the Tsitsa river catchment makes an important economic contribution but at the expense of water and grassland. Climate change will put more pressure on water resources so forest plantations may need to be restricted in the future. Grasslands are also an important biodiversity asset and are an effective carbon store. Grasslands are also threatened from upward movement of the savanna biome (section 2.6). There are therefore critical tradeoffs to be considered between forestry and grassland. Forestry was formerly under the agriculture ministry but since May 2019 falls under the environment ministry which should lead to better environmental protection.

The Tsitsa Project is well situated to have a strong community engagement in the catchment. Effective facilitation is a key ingredient to successful climate change adaptation and disaster risk reduction. Two models for community engagement are presented in section 6: AWARD's RESILM-O Project and the Suid Bokkeveld project (EMG and Indigo development and change). AWARD addresses climate change adaptation through promoting sustainable crop production as well as climate change awareness of small holder farmers whereas EMG and Indigo development and change are more proactive in terms of climate change awareness of the wild Rooibos tea gatherers in the Suid Bokkeveld. A number of key characteristics identified as being common to the success of these two projects are:

- long term sustained engagement,
- location of NGO in proximity to the project area,
- bottom-up approaches using participatory and action research methodologies for social learning and empowerment,
- frequent interaction,
- support for farming practices that support adaptation,
- farmer experimentation,
- support with marketing produce,
- training of local people to become facilitators or mentors,
- production of appropriate training materials.

Following the models provided by these two projects it is recommended that the Tsitsa project works towards setting up hubs where members of the local village communities and the local community coordinators can come together on a regular basis (quarterly?) to learn about climate resilient practices and share their experience of weather events. Following the Farmer Field school mode (section 5.6), these hubs could also be the location of demonstration plots. In Suid Bokkeveld the quarterly meetings involve presenting the seasonal forecast, sharing weather data collected by participants and discussing weather related farming experiences. Zuma et al. (2013) recommend that researchers work with both people's traditional knowledge and scientific understanding of weather; something that the Tsitsa Project can engage in. LIMA's presence in the catchment as social facilitators could help to establish a sustained presence in the catchment and to engage officials from local government departments.

Disaster Risk Reduction is the responsibility of the Local and District Municipalities. Section 7 gives an overview of municipal climate change response activities in the Tsitsa river catchment. In the Tsitsa river catchment the main risks are increased heat stress, fire and drought due to higher temperatures coincident with longer dry spells and floods due to higher storm intensities. There is a lower risks of land slides. Drought and fire are already experience as hazards that are responded to at the District level. There are not many settlements at risk to flooding but collapse of bridges is already common. Woody debris carried by the flood water increased the risk of damage to bridges. Collapse can cause settlements to become isolated for prolonged periods before the bridge is fixed. The Governance CoP and the Lima Rural Development Foundation can work with the municipalities to raise awareness about the likelihood of climate change at its impact on disasters so that they are better able to respond.

The municipalities are also mandated to develop an effective climate change response through their IDP. A review of the IDPs of Jo Gqabi/Elundini and Oliver Tambo/Mhlonto fall short of what is required. Conservation South Africa (2015a) have put together a climate change response strategy for the Alfred Nzo District, which is located directly to the east of the Tsitsa river catchment (section 8). A similar strategy could be developed for the Tsitsa river catchment with input from the Tsitsa Project. The present document could form the basis of such a strategy.

There are many research opportunities related to climate change response. DEA-SANBI (2017) highlight a number of EbA related core research areas that would be eligible for support from the NBRES (section 5.3). Many of these fall directly under the objectives and activities of the Tsitsa Project:

- Slowing the rate of habitat loss and habitat degradation
- Reducing the threat status of South Africa's indigenous species
- Reducing land degradation and desertification
- Reducing and reversing declines in ecosystem health
- Rehabilitation and restoration of ecosystems
- Improving the status of freshwater and marine ecosystems, including transformed wetlands and estuaries
- Decreasing the spread of invasive alien species
- Minimising over-harvesting of indigenous species (DEA-SANBI 2017 p. 23-24)

Gaps and areas to strengthen are given by DEA-SANBI (2017) as:

- Lack of an effective monitoring system
- Find ways that can EbA contribute to sustainable development
- Strengthen connections between professional 'experts' and non-professional participants

- Encourage citizen science and indigenous knowledge
- Improve communication, encourage peer learning, capacity building and policy relevance
- Use a transdisciplinary approach to bring together the three key EbA research areas: biodiversity benefits for people, climate change adaptation strategies for people, and biodiversity resilience to climate change.

The Tsitsa Project is already addressing these gaps but could be more explicit in its consideration of climate change adaptation.

Further funding opportunities that support climate change response and research are given in Appendix B.

10. Embedding climate change and disaster risk reduction in the Tsitsa Project: a preliminary analysis of the Research Investment Strategy

This section critiques the Research Investment Strategy of the Tsitsa Project as presented in Volume 2, looking specifically at how climate change and disaster risk reduction has been and can be embedded within the project.

The vision of the Tsitsa Project is given as "To support sustainable livelihoods for local people in the Tsitsa catchment, through integrated landscape management that strives for a resilient social-ecological system and which foster equity in access to ecosystem services." (Strategy Report page 9). With climate change increasingly becoming a present and future reality it is paramount that adaptation to climate change is taken up in support of sustainable livelihoods. Moreover, a resilient social-ecological system is one which can contribute to mitigating climate change and its impacts. The project therefore needs to recognise that we are dealing with a changing system and an unknown future, not a variable system in some sort of dynamic equilibrium. Climate change should not be seen as a separate aspect to be considered but must be embedded into all objectives.

The strategy document recognises six 'headline objectives': founding principles of our approach; ecological infrastructure and services - the biophysical; livelihoods and wellbeing; institutional actors and governance; realising agency and collective action; knowledge flow, communication and advocacy. Embedding climate change and disaster risk reduction will be considered under each of these objectives.

10.1. Founding principles of the Tsitsa Project approach

Given the immediacy of climate change it is important that the Founding Principles embrace and act on this risk to the social-ecological system of the Tsitsa catchment. While climate change is implicit in objective 1.1, Social-ecological Principles and Resilience Thinking, the threat of climate change should be foregrounded. We need to think in terms of resilience in the face of climate change and what this means in terms of risk and vulnerability. The remaining six objectives all have relevance to building resilience to climate change and managing disaster risk reduction. Acknowledging climate change should be central to the project, not an add on. CC&DDR should be embedded in all COPS. Systems thinking should be a founding principle.

Recommendation: Addressing climate change and disaster risk reduction becomes a new founding principle (or sub-principle). For example 'Recognise the immediate risk imposed by climate change and align project actions so as to build resilience of the social-ecological system through mitigation and adaptation'.

10.2. Ecological infrastructure and services - the biophysical

Restoration of ecological infrastructure is an important mitigating action. It builds resilience against climate change, reduces water stress, creates or protects carbon stores and so forth. It also contributes to climate change adaptation in that it supports livelihoods. It is important to restore and sustain the functional ability of the landscape to provide essential ecosystem services, but to what extent is this endangered by climate change? How resilient is the system to climate change? How can the negative impacts of projected change be addressed timeously? Taking climate change into account might change the prioritisation of actions.

Restoring ecological infrastructure and services falls under the Sediment and Restoration Community of Practice (COP). Also relevant is the Grazing and Fire Management COP. Wild fires are likely to increase in frequency and intensity under increasing temperatures. The condition of grassland and livestock become increasingly at risk to drought and the implications of GHG emissions from livestock should be considered.

The DEA promotes Ecosystem-based Adaptation as a climate change adaptation response. The Tsitsa Project meets many of the goals of EbA and should be in a good position to seek further funding that is linked to EbA practice (see section 5.5) but needs to position itself more explicitly within climate change adaptation context.

10.3. Livelihoods and wellbeing

In a rural area such as the Tsitsa catchment, livelihoods and wellbeing are highly vulnerable to climate change. Food security is threatened and heat-related health issues are a likely concern. People in the catchment need to become fully aware of the likely future consequences of climate change and associated risks and practices such as Climate Smart Agriculture or Conservation Agriculture should be strongly advocated. Restoring ecological infrastructure (section 5.3) provides support for climate change adaptation. There is also opportunity to encompass household, farm or village scale renewable energy projects and to encourage improved housing designs that reduce risk.

The Livelihoods and Ecosystems Services COP is the one which drives this project component. The Grazing and Fire Management COP also contributes to livelihoods and well being because livestock are an important source of income as well as having traditional value.

10.4. Institutional actors and governance

A coordinated effort to mitigate and adapt to climate change and disaster risk reduction requires effective governance at all levels. It is not possible for the DEA, through the Tsitsa Project, to tackle climate change and disaster risk reduction on its own. The potential for the Tsitsa project to work with a range of government entities is illustrated in Figure 19. Baudoin & Ziervogel (2017) stress the need to strengthen the capacity of local organisations that can support vulnerable communities. Interaction with national agencies becomes especially important for DDR. It is therefore important that the Governance COP promotes climate change mitigation and adaptation through the different layers of catchment governance and seeks to open up effective channels for Disaster Risk Reduction. The extent to which the IDPs of the District and Local Municipalities address climate change adaptation and disaster risk reduction is reviewed in section 7. There is good opportunity to work with the local municipalities to promote climate adaptation responses related to land restoration and livelihoods within the mandate of their respective IDPs. The proposed Land and

Water Forum is potentially a good platform for communicating climate change to a broad range of stakeholders.

10.5. Realising agency and collective action

Realising agency and collective action for addressing climate change directly interfaces with achieving the same for the Tsitsa Project as a whole.

10.6. Knowledge flow, communication and advocacy

Poor communication has been noted as a problem in raising awareness about climate change and hence providing the impetus for agency and collective action. The Tsitsa Project Knowledge Management COP can play a critical role both in making links to available resources such as those published by SAWS (e.g. WaterSmart News) and the ARC (e.g. Umlindi) and repackaging material so that it becomes accessible to village communities. AWARD (2017) provides a good example of how this can be achieved. This would fall in line with the proto-vision of the Knowledge Management COP:

> *"To make information, data and knowledge within the Tsitsa Project and T35 catchment accessible, available, understandable, transparent and usable to all stakeholders at different governance levels to best aid further research, management and implementation and enable interaction with similar projects."*

A comprehensive list of resources is available in Appendix C.

10.7. PMERL

PMERL - Participatory Monitoring, Evaluation, Reflection and Learning - is the approach advocated to monitor and evaluate the Tsitsa Project. It moves away from quantitative monitoring of actions to a more qualitative evaluation of meaningful outcomes. This is in line with the approach put forward by the DEA (2017) to monitor climate change adaptation (see section 4.4), as well as the DAFF (section 5.5). PMERL is designed to inform Strategic Adaptive Management (SAM) which can also be applied to CC&DRR. Climate change adaptation should therefore be integrated into the evolving PMERL.

10.8. Land, Biodiversity and Ecosystems Climate Change Flagship

DEA (2017) mentions a number of flagship programmes that have been launched to address climate change. The DEA is mandated by the NCCRP to oversee and coordinate the implementation of climate change policy, including the Climate Change Flagship Programmes. Of particular relevance to the Tsitsa Project is the Land, Biodiversity and Ecosystems Climate Change Flagship which advocates investment in the restoration and rehabilitation of South Africa's natural resource base . The Land, Biodiversity and Ecosystems Climate Change Flagship is implemented through The Climate Change Response Public Works Flagship Programme, which incorporates the 'working for ….' programmes. There is therefore very close alignment with the rehabilitation activities of the Tsitsa Project. It is, however, essentially biophysical in its approach, with social benefits measured in labour days. With its emphasis on social-ecological systems the Tsitsa Project has potential to become a model for this Climate Change Flagship that challenges the narrow approach proposed by the DEA (2017).

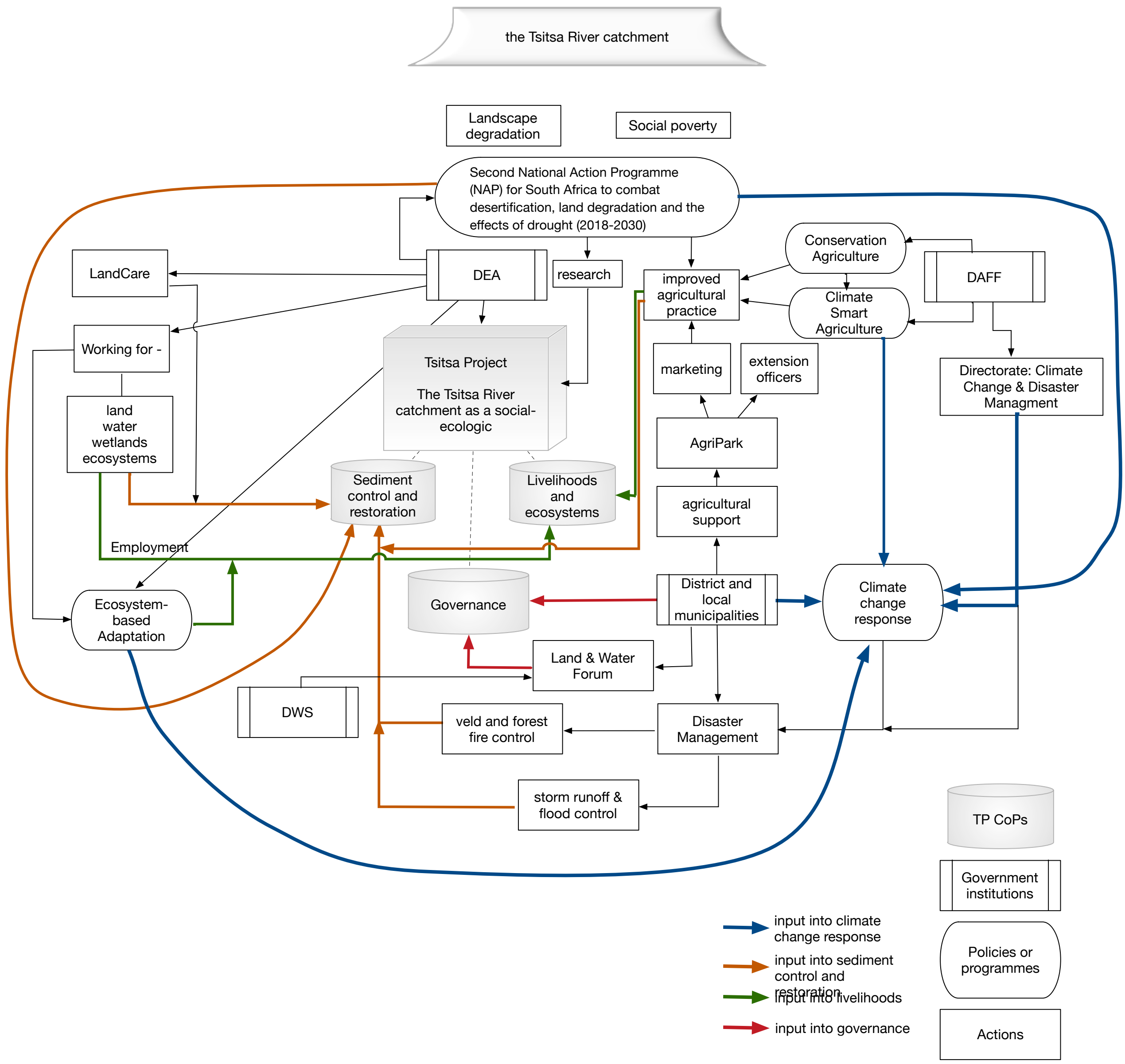


Figure 19. The potential role of government institutions in supporting climate change adaptation and risk reduction through the Tsitsa Project

11. Conclusions

This report provides background to global climate variability and change as observed over the last century and projected into the future as background context to the situation in the Tsitsa catchment. An updated precipitation data set has been analysed to demonstrate recent trends in the project area. It is clear that temperatures are rising steadily and could exceed 1.5°C above the pre-industrial baseline the near future. Associated impacts threaten weather patterns, biodiversity and society; poor people reliant on ecosystem goods and services are especially vulnerable. South Africa's policy response to climate change is outlined in the DEA's report of 2017 (DEA 2017) and the draft National Climate Change Adaptation Strategy of 2019 (DEA 2019). There is a comprehensive statement of intent but there needs to be meaningful and urgent action on the ground if climate change mitigation and adaptation are to be achieved. The Tsitsa Project is one of a number of ongoing projects in a good position to embrace climate change at a local level and to turn national policy into action. It will need strong will and commitment to break down barriers due to the local political ecology that constrains change in the Tsitsa social-ecological system.

Ecosystem-based adaptation, Climate Smart Agriculture and Conservation Agriculture have been promoted recently as viable approaches to support climate change adaptation that have all been given government support through policy drafts. These are all approaches that can be taken up through the Tsitsa Project using participatory engagement to promote climate change awareness and adaptation agency. Three case studies are presented, two based on landscape scale community engagement and one on developing a climate change response at the District scale. These case studies provide possible models for embedding climate change into the Tsitsa Project.

This review has highlighted the existence of a number of government policies, current and draft, that urge action on climate change. It has shown how these can be taken up at the household, community and catchment scale but that it will be necessary to bring together the different role players if there is to be an effective response before it is too late. The Tsitsa Project is well placed to be a climate change action catalyst, working towards a sustainable socio-ecological system both now and in the future.

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APPENDICES

A. Desired Adaptation Outcomes for KwaZulu-Natal Province (Source: DEA 2017 Table 4.)

	desired adaptation outcomes	data and information needed to monitor progress
1	Climate change adaptation fully integrated into provincial and municipal planning processes, including governmental, sectoral and multi-sectoral planning [G1].	Data on number of provincial and municipal development plans (e.g. Spatial Development Frameworks, Growth and Development Strategies, Disaster Management Plans, Conservation Plans, Food Security Strategies, Energy Security Strategies, Coastal Management Programmes) and sectoral plans incorporating climate change adaptation initiatives.
2	appropriate processes and mechanisms for coordinating climate change adaptation in province and municipalities [G2].	Details of: • dedicated climate change champions / nodes / units for provincial sectors and municipalities (metropolitan, district and local) • climate change training programmes facilitated by DEA local government officials • climate change agendas of provincial and municipal forums / committees (e.g. KwaZulu-Natal Provincial Committee for Environmental Coordination, Provincial Climate Change Sustainability Council, Municipal Climate Change Task Team, Disaster Management Forums) • implementation of climate change action plans in province and municipalities.
3	accurate weather forecasting, seasonal predictions, climate projections and effective early warning systems for extreme weather and other climate-related events provided for province and municipalities [G3].	Details of: • fine-scale projections, forecasts (seasonal to inter-annual and intra-seasonal variability) and early warning systems for provincial and municipal use • dissemination and communication platforms for weather and climate-related events (e.g. SMS and media) • utilisation and uptake of data/information products by end-users.
4	Capacity development programmes in province and municipalities informed by locally-specific adaptation research [G4].	Data on: • number of capacity development programmes (including students, staff, researchers and institutions) addressing climate change adaptation in province and municipalities • scope of adaptation research and training being undertaken and financed by province and municipalities • uptake of research outcomes and human capacity trained in adaptation by province and municipalities • partnerships/collaborations between province, municipalities and researchers • incorporation of climate change issues in curriculum.

	desired adaptation outcomes	data and information needed to monitor progress
5	Development and implementation of new technologies or knowledge on climate change adaptation for province and municipalities [G5].	Data on: • new technologies/knowledge adopted in province and municipalities • indigenous knowledge systems • technology needs assessments • technology transfer and access (national and global • technology transfer and access (national and global • other adaptation challenges and opportunities.
6	Systems, infrastructure, communities and sectors in province and municipalities less vulnerable to climate change impacts [G6].	Details of provincial and municipal risk profiles and vulnerability assessments in easily accessible formats; and data on number of vulnerable systems, resources or communities with provincial or municipal adaptation plans to reduce risk and vulnerability.
7	Reduction in non-climate pressures and threats in province and municipalities [G7].	Data on land use and land use change, population demographics, pollution, water quality and siltation of dams, protection and enhancement of natural resources and other environmental assets, service delivery protests, non-maintenance of infrastructure, and socio-economic status/ factors.
8	Secure food, water and energy production and supplies in province and municipalities take climate change considerations into account [G8].	Details of food, water and energy security strategies, plans, programmes and projects in province and municipalities to support development and implementation of climate resilient production and distribution/supply systems and infrastructure.

B. Funding opportunities

Conservation South Africa (2017) note that although District Municipalities have a responsibility to respond to climate change related risks there is a lack of specific budget for climate change adaptation and mitigation at the local level. They recommend, however, that available funding streams can be used to support climate response projects; there is also a wide range of funding opportunities available but there is a need to develop capacity in proposal writing at the District level to access 'green' funding. The following list of funders is taken from the Conservation South Africa report (section 5.6)

(a) Available international funding

The World Bank Climate Investment Funds (CIFs)
The Global Environmental Facility (GEF)
Critical Ecosystem Partnership Fund (CEPF)
Gesellschaft für Internationale Zusammenarbeit (GIZ) support programme
United States Agency for International Development (USAID)
KfW Development Bank
Green Climate Fund (GCF)
Global Adaptation Fund (AF)

(b) SADC funding

TerrAfrica

(c) National resources

The South African Green Fund
Industrial Development Corporation (IDC)
Natural Resources Management (NRM) and Expanded Public Works Programmes (EPWP)
Environmental Protection and Infrastructure Programme (EPIP)
WWF Nedbank Green Trust
Local government support
South African Local Government Association (SALGA)

(d) New financial instruments

Payments for Ecosystem Services (PES)
Environmental subsidies
Tradable permits and quotas
Eco-labelling and certification

(e) Legal and voluntary instruments

Enforcement of legal liability
Non-compliance charges
Voluntary environmental agreements.

C. Resources

There is a large amount of material available, both globally and in South Africa, that supports climate change adaptation. These are summarised below.

(a) Climate change predictions

South African Environmental Observation Network (no date) *Risk and Vulnerability Atlas*. Available http://sarva2.dirisa.org/atlas Accessed February 2019

South African Weather Service (2017) *A Climate Change Reference Atlas*. Pretoria Water Research Commission and South African Weather Service

(b) Climate change adaptation and mitigation - general

SA Government documents

Department of the Environment 2019. Draft National Climate Change Adaptation Strategy. Government Gazette no. 42446, Notice 644 of 2019. Available: https://www.gov.za/sites/default/files/gcis_document/201905/42446gon644.pdf accessed June 05 2019

Department of Agriculture, Forestry and Fisheries (DAFF) (2013) *Draft Climate Change Sector Plan for Agriculture, Forestry and Fisheries. Government Gazette, 9 January 2013, No. 36063. General Notice 7 of 2013*. Accessed 25 May 2017 at: http://www.gov.za/sites/www. gov.za/files/36063_gen7.pdf.

Department of the Environment (DEA) (2017) *South Africa's 2nd Annual Climate Change Report 2016*. Pretoria, Department of Environmental Affairs.

(c) Climate Smart Agriculture

Global institution guidelines

Food and Agricultural Organisation (FAO), 2010, *'Climate-smart' agriculture: Policies, processes and financing for food security, adaptation on and mitigation,* United Nations, Rome. Available: http://www.fao.org/3/i1881e/i1881e00.htm accessed June 2019

Web site of the CGIAR/CCAFS guide to Climate Smart Agriculture - https://csa.guide/csa/ accessed June 2019

Climate Smart Landscapes

Minang, P. A., van Noordwijk, M., Freeman, O. E., Mbow, C., de Leeuw, J., & Catacutan,D.(Eds.) (2015). *Climate-Smart Landscapes: Multifunctionality in Practice.* Nairobi, Kenya:WorldAgroforestryCentre(ICRAF). 405 pp. Available: http://www.worldagroforestry.org/sea/Publications/files/book/BK0179-14.pdf accessed June 2019

Scherr SJ, Shames S and Friedman R 2012. From climate-smart agriculture to climate-smart landscapes. *Agriculture & Food Security* **1**:12 https://doi.org/10.1186/2048-7010-1-12

SA Government documents

Department of Agriculture, Forestry and Fisheries 2018. *Draft Climate Smart Agriculture strategic framework for agriculture, forestry and fisheries*. Department of Agriculture, Forestry and Fisheries Government Gazette no. 41811, Notice 428 of 2018. Available: https://www.nda.agric.za/docs/media/gazzette-climatesmartagriculturestratframework-draft.pdf accessed June 2019

Other SA documents

FANRPAN 2017. *Climate-Smart agriculture in South Africa*. Policy Brief 15/2017. 8 pages Available: https://www.fanrpan.org/sites/default/files/publications/Policy%20Brief%20Issue%2015.2017%20CSA%20South%20Africa%20-%20Final%20Draft02.pdf accessed June 2019

Research articles (South Africa)

Mathews, J.A., Kruger, L. & Wentink, G.J., 2018, 'Climate-smart agriculture for sustainable agricultural sectors: The case of Mooifontein', *Jàmbá: Journal of Disaster Risk Studies* 10(1), a492. https://doi.org/10.4102/jamba.v10i1.492

(d) Conservation agriculture

SA Government documents

Republic of South Africa: Department of Agriculture, Forestry and Fisheries 2017. Draft Conservation Agriculture Policy, May 2017. Available: https://www.nda.agric.za/docs/media/Draft%20Conservation%20Agriculture%20Policy.pdf accessed June 2019

Republic of South Africa: Department of Planning, Monitoring and Evaluation 2017. Socio-economic impact assessment system (SEIAS) Final impact assessment template (phase 2), May 2017. Available: https://www.daff.gov.za/daffweb3/Home/aid/975 accessed June 2019

Research articles (South Africa)

Blignaut J, Knot J, Smith H, Nkambuke N, Crookes D, Saki A, Drimie S, Midgley S, de Wit M, von Loeper W, Strauss J. 2015. *Promoting and advancing the uptake of sustainable, regenerative, conservation agricultural practices in South Africa with a specific focus on dryland maize and extensive beef production.* Asset research, booklet no. 2. Pretoria: ASSET Research.

Kruger E, Ngcobo P, Dlamini M.C and Smith H.J 2018. *Learning Conservation Agriculture the Innovation Systems way.* Mahlathini Development Foundation. Available: https://www.mahlathini.org/our-work/conservation-agriculture-smallholder-farmer-innovation-programme//learning-conservation-agriculture-the-innovation-systems-way-article//

Swanepoel C M, Swanepoel L H and Smith H J. 2017. A review of conservation agriculture research in South Africa. [DOI: 10.1080/02571862.2017.1390615] *South African Journal of Plant and Soil, 2017*.

von Loeper W, Drimie S, Blignaut J 2018. The Struggles of Smallholder Farmers: A Cause of Modern Agricultural Value Chains in South Africa. In *Agricultural Value Chain* Chapter: 9 Publisher: IntechOpen http://dx.doi.org/10.5772/intechopen.75710

von Loeper W, Musang J, Brent A, Drimie S, 2016. Analysing challenges facing smallholder farmers and conservation agriculture in South Africa: A system dynamics approach. *South African Journal of Economic and Management Sciences (SAJEMS)* 19(5):747 DOI: 10.4102/sajems.v19i5.1588

(e) Ecosystem-based Adaptation

Global institution guidelines

Jiménez Hernández, A. (2016). *Ecosystem-based Adaptation Handbook*. IUCN NL, Amsterdam.

SA Government documents

DEA and SANBI, 2016. Strategic Framework and Overarching Implementation Plan for Ecosystem-Based Adaptation (EbA) in South Africa: 2016 – 2021. Department of Environmental Affairs, Pretoria, South Africa. Available: https://www.sanbi.org/wp-content/uploads/2018/09/Strategic-Framework-and-Overarching-Implementation-Plan-for-EbA-in-SA.pdf Accessed June 2019.

DEA and SANBI, 2017. Guidelines for ecosystem-based adaptation (EBA) in South Africa. Department of Environmental Affairs, Pretoria, South Africa. Available: https://www.sanbi.org/wp-content/uploads/2018/09/SA-Ecosystem-based-Adaptation-EbA-Guidelines.pdf Accessed June 2019.

Midgley G, Marais S, Barnett M, Wågsæther K. 2012. Biodiversity, Climate Change and Sustainable Development—Harnessing Synergies and Celebrating Successes: Final Technical Report. South African National Biodiversity Institute; Conservation South Africa; Indigo Development and Change

Research articles

Vignola R, Harvey CA, Bautista-Solis P, Avelino J, Rapidel B, Donatti C, Martinez R. 2015. Ecosystem-based adaptation for smallholder farmers: Definitions, opportunities and constraints. *Agriculture, Ecosystems & Environment*, 211: 126-132 http://dx.doi.org/10.1016/j.agee.2015.05.013 Accessed June 2019

(f) Farmer Field Schools

Research articles

Anandajayasekeram P, Davis KE, Workneh S 2007. Farmer Field Schools: An Alternative to Existing Extension Systems? Experience from Eastern and Southern Africa *Journal of International Agricultural and Extension Education* 14(1) Available: https://www.researchgate.net/publication/228860619_Farmer_Field_Schools_An_Alternative_to_Existing_Extension_Systems_Experience_from_Eastern_and_Southern_Africa/stats Accessed June 2019

Simpson, B. M., & Owens, M. (2002). Farmer field schools and the future of agricultural extension in Africa. *Journal of International Agricultural and Extension Education*, *9*(2), 29–36. doi: 10.5191/jiaee.2002.09204 Available: https://www.researchgate.net/publication/269677436_Farmer_Field_Schools_and_the_Future_of_Agricultural_Extension_in_Africa

(g) South African climate change adaptation at the Municipal District level

SA Government documents

Department of Economic Development and Environmental Affairs 2011. Eastern Cape Climate Change Response Strategy. Available: http://www.cityenergy.org.za/uploads/resource_182.pdf [accessed Jun 05 2019]

Department of Environmental Affairs Local Government Climate Change Support Program - Lets Respond Toolkit. Available: http://www.letsrespondtoolkit.org [accessed Jun 05 2019]

Research articles

Bourne A, Donatti C, Holness S, Midgley GF. 2012. Climate Change Vulnerability Assessment for the Namakwa District Municipality: Full Technical Report. Conservation South Africa: Cape Town, South Africa

Bourne, A., Pasquini, AL, Donatti CI, Holden P, Scorgie S. 2017. 'Strengthening the role of local authorities to support community-based adaptation: The case of South Africa.' In:J. Atela, S. Huq, C. Ochieng, V. Orindi and T. Owiyo (eds) Enhancing Adaptation to Climate Change in Developing Countries. ACTS Press, Nairobi,63-76. Available from: https://www.researchgate.net/publication/319208951_Strengthening_the_role_of_local_authorities_to_support_community-based_adaptation_The_case_of_South_Africa [accessed Jun 05 2019].

Lethoko, M.X., 2016, 'Inclusion of climate change strategies in municipal Integrated Development Plans: A case from seven municipalities in Limpopo Province, South Africa', *Jàmbá: Journal of Disaster Risk Studies* 8(3), a245. h p://dx.doi.org/10.4102/ jamba.v8i3.245

(h) South African case studies of good practice

AWARD 2018: Annual Report 2017/2018 Financial Year. Resilience in the Limpopo - Olifants. 10/31/2018

AWARD 2018: Resilience in the Limpopo - Olifants, Milestone 4: Progress Report No 3 30/11/2018

EMG 2015. *The Heiveld Cooperative: A vehicle for sustainable local development*. http://dry-net.org/initiatives/the-heiveld-cooperative-a-vehicle-for-sustainable-local-development/

Oettle 2012. Adaptation with a human face: lessons learnt from an ongoing adaptation and learning process. EMG, Suid Bokkeveld, South Africa. Summary Available: http://www.emg.org.za/images/downloads/rural_dev/Rural-Adaptation_with_a_Human_face_small.pdf accessed Jun 05 2019

OR Full version available: http://dry-net.org/wp-content/uploads/2015/09/Adaptation_with_a_human_face_Case_study_full_rev_Feb_20.pdf accessed Jun 05 2019

Oettle N, Koelle B, Law S, Parring S, Schmiedel U, Archer van Garderen, E; Bekele, T. 2014. Participatory Adaptation Handbook: A Practitioner's Guide for Facilitating People Centred Adaptation to Climate Change. Indigo Development and Change, Nieuwoudtville, South Africa doi: 10.7809/book.001 accessed Jun 05 2019

(i) Outreach and communication

(1) NGOs

Indigo development and change (https://www.indigo-dc.org)

The web site of Indigo development and change hosts a number of different resources as listed in Box Z. Some of these are also available through the Adaptation network web site. These resources are designed for practitioners working with communities on climate change adaptation projects.

BOX 2 Indigo development and change resources for climate change adaptation practitioners Available: https://www.indigo-dc.org/research.html	
Oettle, N; Koelle, B; Law, S; Parring, S; Schmiedel, U; Archer van Garderen, E; Bekele, T (2014) Participatory Adaptation Handbook - A practitioner's guide for facilitating people centred adaptation, doi:10.7809/book.001.	
Koelle B, Oettle N, Parring S, 2014. Experiential learning for adaptation - facilitation cards	
Reader: Adaptation and Beyond	
Adaptation and beyond CASE STUDY	Adaptation with a human face
Adaptation and beyond No 1.	Community Based Adaptation
Adaptation and beyond No 2	Basic principles when working with individuals, households and communities
Adaptation and beyond No 3	Climate science for adaptation
Adaptation and beyond No 4	Gender and climate change adaptation
Adaptation and beyond No 5	Concepts for multi-disciplinary learning with young adults
Adaptation and beyond No 6	Defining adaptation
Adaptation and beyond No 7	Using climate data
Adaptation and beyond No 8	Climate change preparedness workshops
Adaptation and beyond No 9	Modelling rooibos crop suitability and distribution under scenarios of climate change (not available online)
Adaptation and beyond No 10	The seasonal forecast game
Adaptation and beyond No 11	Livestock monitoring for adaptation
Adaptation and beyond No 12	Multilevel partnerships for mainstreaming climate change in local government
Adaptation and beyond No 13	Climate Change Adaptation and Ethics
Additional resources available from the Adaptation network http://www.adaptationnetwork.org.za/	

Adaptation and beyond No 14	Participatory photography
Adaptation and beyond No 15	Sharing lessons of adataption
Adaptation and beyond No 16	Adaptation in the local context

AWARD

The following resources are available from http://award.org.za/index.php/resources/

Pollard S, de Villers A. No date. *Climate Change: understanding scenarios, RCPs and ppm*. AWARD and USAID Southern Africa.

de Villers A, Pollard S. No date. *Core concepts for climate change thinking in the Olifants river catchment*. AWARD and USAID Southern Africa.

USAID Southern Africa No date. *The Olifants river catchment: a users guide.* AWARD and USAID Southern Africa.

Critical Biodiversity Area (CBA) Series

no. 1. Caring for our biodiversity - made easy
no. 2. Brief land management guidelines
no. 3. A step by step guide to integrating biodiversity into land use planning
no. 4. Developing environmental policies
no. 5. Biodiversity integration into Municipal spatial planning
no. 6. Glossary of biodiversity and spatial planning terms
no. 7. Biodiversity and climate change

Mahlathini development foundation (https://www.mahlathini.org)

Available resources from the Mahlathini development foundation include the following topics in the form of manuals and/or videos (Figure X):

Training of trainers
Conservation Agriculture manual
Natural pest and disease control
Diversification and food preparation
Traditional foods production and promotion
Composting and manure utilisation
Resource material for homestead food gardens
LIRAPA How to get the best from your garden
Water issues
Rain water harvesting

(2) Government institutions

SAWS

SAWS HOME - WeatherSA Portal http://www.weathersa.co.za

The following products are available from this site:

Current weather

Daily weather forecast for selected stations - nearest to the Tsitsa river catchment is Mthatha

Weather alerts

Fire danger indicator - maps the fire danger index for the day

Drought monitoring

Rainfall anomalies are presented for the past month and the last three months.

Standard precipitation indices (SPI) are presented for the last month, the last three months, the last six months, the last year and the last two years. This gives an indication of the severity of current and long term drought.

NB. The 'last' month may be two months previous. e.g. April 2019 on 6th June 2019.

Long term forecasting

Long range forecast - gives global and regional maps of predicted temperature and precipitation. Global maps for three future seasons, two models. Regional maps for three sets of three months but may be outdated. (e.g. in June 2019 there were maps for JFM, FMA, MAM).

Seasonal climate watch (5-month forecast) This is a technical report that requires a moderately high level of climate knowledge to interpret fully.

Skill masking - areas where the model uncertainty is high are blocked so that areas shown are those where the forecast is likely to be most accurate.

Climate Change Atlas (SAWS 2017) - gives long term (decadal) predictions of future climate 2036-2065; 2066-95

Media

WeatherSmart newsletter published twice a year (February and August); contains articles of general interest to the public, often based on recent weather events. Would be a useful reference resource for climate change adaptation practitioners.

Applications

Hydromet - a web-based decision support system that provides reliable weather forecasts (including the 6 month seasonal forecast in Grid format), real-time and historical weather data. can be used on a computer, tablet or phone.

AgriCloud is a smart phone app available through directions on the Hydromet portal. It is designed especially for extension officers and small holder farmers, giving location specific information on forecasts on planting dates, spraying advice and weather information. Information is available in the language of the user.

Weathersmart Application - available for IOS and Android devises. Gives weather information and warnings for a specified location.

Weather API (developed in collaboration with AFRIGIS)- measurements, forecasts, thunderstorms, lightening, weather alerts for a given location; recommended for municipal officials for hazard warning activities. The setup for this API requires a moderate level of technical expertise.

CSIR

Green Book

https://greenbook.co.za (focus on municipal planning of urban systems)

"The CSIR in partnership with the National Disaster Management Centre launched the long-awaited Green Book early in March, which is currently available as an online interactive tool that provides information to municipalities to help them mainstream climate change adaptation into their planning instruments and processes. Some of the features of the Green Book include:

- Various story maps giving the necessary background information in an easy-to-follow and visually interactive manner, with focusses on Coastal Flooding; Floods; Wildfires; Drought; Settlement Vulnerability; Urban Growth; Climate Change; Economy; Agriculture, Forestry & Fisheries; Surface Water; and Ground Water;
- An interactive Risk Tool, where individual municipalities can view their local vulnerability; settlement vulnerability & growth projections; climate information; hydro-meteorological hazards; critical resources & impact assessments; and adaptation actions. Information for all of these are given for the current time period as well as 2050;
- Once municipalities are informed regarding their specific climate risks and vulnerabilities, they can then identify appropriate adaptation actions using the Adaptation Actions Tool. Each adaptation action includes a description of that action, the goals and benefits of implementing the action, a discussion of the costs of implementing the action, as well as examples. Supporting actions that link to the selected action are also identified.

The home page also has an introductory video that takes the user through the various tools and explains the functionalities of each tool. For more information, please visit the various links provided above. If you experience problems with using the Green Book please contact the CSIR directly." (email from Ms Frances van der Merwe, Directorate: Climate Change, Department of Environmental Affairs and Development Planning, Western Cape Government)

3. Media

The Farmers' Weekly has published a number of relevant articles accessible to the general faming public. Examples are given here of published articles.

- Richard Findlay: April 12, 2015. Why conservation agriculture must be promoted in SA.
- Prof E Wale Zegeye, Dr Unity Chipfupa and Dr Gerhard Backeberg: April 3, 2019. Why smallholders need to think like entrepreneurs.
- Lloyd Phillips: April 5, 2019. Switching to no-till? Restore degraded soil first!

- Annelie Coleman: April 9, 2019. Grass-fed beef: the trend that favours communal farmers.
- Denene Erasmus April 15, 2019 The difference half a degree of global warming can make.

Harvest SA

Anon. Challenges and constraints facing small-scale agricultural productivity in South Africa

Conservation Agriculture

Anon. The big C. The role of organic carbon and conservation agriculture in soil health.

Afgriland May/June 2018

Dr Gugu Zuma-Netshiukhwi. The importance of agrometeorological services and extension.

UMLINDI (ARC)

Gives national maps for the previous month(s) with an overview

Weather Smart

SAWS publishes the WeatherSmart magazine online twice a year in February and August. Examples of articles relevant to climate change mitigation and adaptation include the following:

February 2016

Dr Asmerom Beraki: STEPPING TOWARDS IMPROVED SEASONAL FORECASTS WITH THE USE OF AFRICA'S FIRST COUPLED MODEL.

Dr Eugene Poolman. TOWARDS AND IMPACT-BASED SEVER WEATHER FORECASTING SYSTEM FOR SOUTH AFRICA.

Mr. Morne Gijben. LIGHTENING THREAT INDEX.

August 2016

Dr Joël Botai, Prof Hannes Rautenbach, Dr Andries Kruger, Dr Asmerom Beraki & Ms Elsa de Jager: LESSONS LEARNT FROM THE 2015-16 DROUGHT IN SOUTH AFRICA.

Mr Lotta Mayana: IDENTIFYING REGIONS OF STRONG WIND HAZARDS IN SOUTH AFRICA

February 2017

Dr Jyotsna Singh: INITIATIVES OF THE SOUTH AFRICAN WEATHER SERVICE TOWARDS SUSTAINABLE DEVELOPMENT.

Hannes Rautenbach, Andries Kruger, Mthobisi Nxumalo, Thabo Makgoale & Nosipho Zwane: FROM GLOBAL WARMING TO CLIMATE CHANGE.

August 2017

Joël Botai, Hannes Rautenbach, Michael Mengistu, Absolom Mfumadi, Lucky Ntsangwane, Katlego Ncongwane, Nosipho Zwane, Thabo Makgoale, Thato Masilela, Jaco de Wit & Sphamandla Daniels. COMMUNICATING WEATHER, CLIMATE AND AGRO-METEOROLOGICAL APPLICATIONS TO AGRICULTURAL EXTENSION OFFICERS IN THE LIMPOPO.

Abiodun Adeola & Hannes Rautenbach. **S**AWS CLIMATE CHANGE AND VARIABILITY RESEARCHERS ON THE HEELS OF MALARIA.

Andries Kruger, Stephanie Landman & Louis van Hemert. THE KNYSNA FIRES – METEOROLOGICAL CONDITIONS CONDUCIVE TO RUNAWAY FIRES AND RELATED WARNINGS.

February 2018

Katlego Ncongwane & Joël Botai. THERMAL WATCH INDEX FOR GAUTENG.

Christina Botai, Joël Botai & Jaco de Wit. CHARACTERISTICS OF DROUGHT PROPAGATION IN THE HYDROLOGICAL CYCLE IN SOUTH AFRICA.

August 2018

Kevin Rae, Wayne Venter, Mbavhi Maliage & Victoria Nurse. SIGNIFICANT WEATHER OVER THE PAST SIX MONTHS.

Lebogang Makgati. UNEXPECTED SEVERE THUNDERSTORM CAUSES HAVOC OVER THE NORTH-EASTERN PARTS OF SOUTH AFRICA ON 27 MAY 2018

Hannes Rautenbach & Elizabeth Webster. CLIMATE CHANGE: IS IT ONLY A PROBLEM OF THE FUTURE OR CAN SAWS RESOURCES ALREADY BEGIN TO FACILITATE CLIMATE RESILIENCE?

Tsitsa Project

Climate change: the Tsitsa River Catchment future

Kate Rowntree
August 2019

Key messages

- Climate change in globally and in South Africa is a reality
- Temperatures are rising and there is strong consensus that they will continue to rise; this affects both means and extremes
- The precipitation response is regionally variable and future response is uncertain but there is a strong likelihood of more variability, more intense storms and longer dry periods i.e flooding and droughts more common
- Mitigation to keep global temperature rise below 2ºC essential for long term sustainability of ecosystems and human wellbeing; heading for 2ºC increase by 2050
- The DEA is responsible for developing & enacting South Africa's climate change policy
- The DEA has clear proposals and there has been some success in achieving Desired Outcomes but much more is needed
- Tsitsa Project can contribute to climate change mitigation and more especially to local scale-adaptation

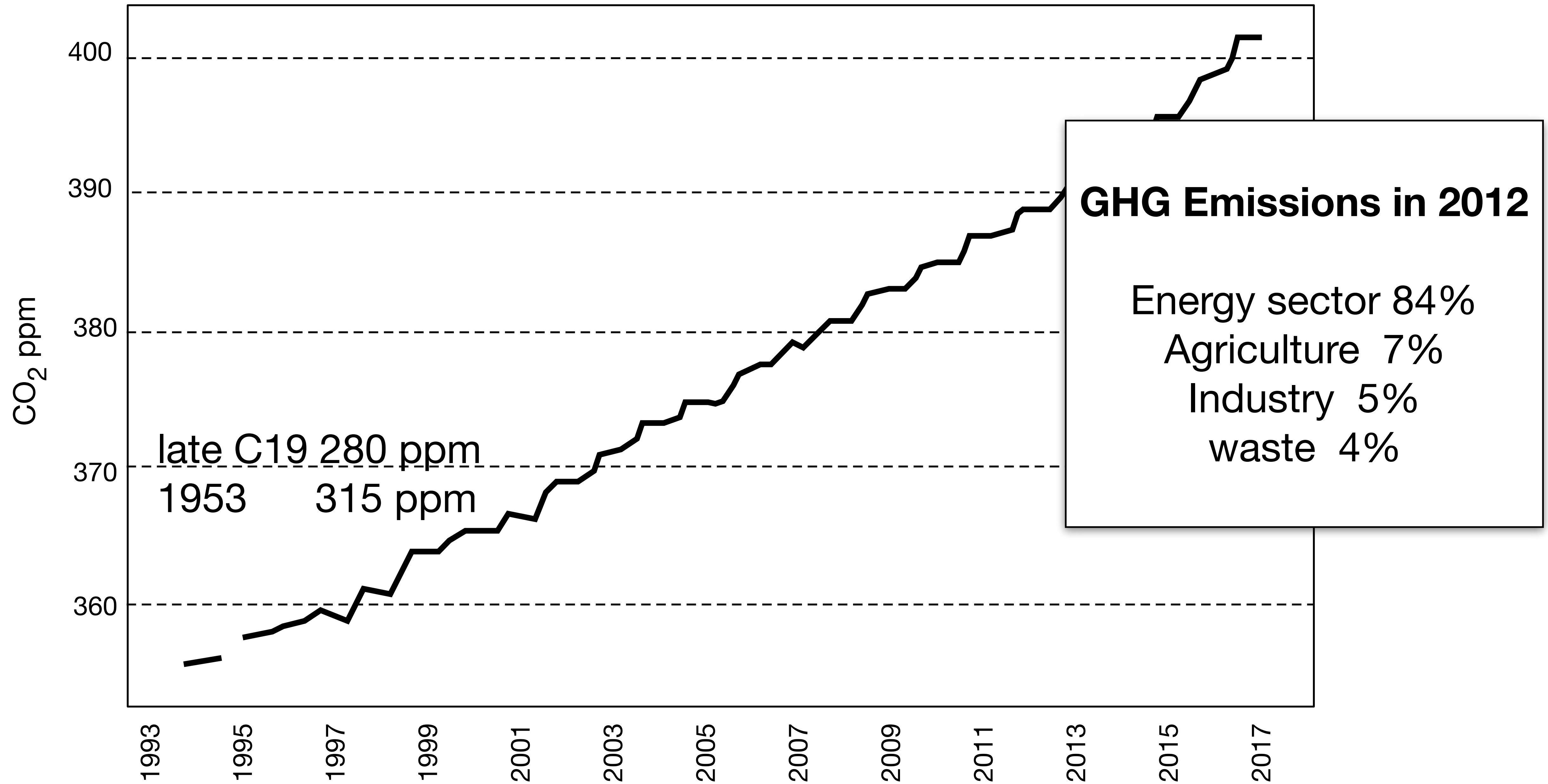
Outline

- Historic climate change trends
- Projected change
- SES impacts
- Mitigation and adaptation options for livelihoods and ecosystems
- Working with catchment communities
- Working with local and provincial government

Greenhouse gases (GHGs)

- global carbon emissions increased tenfold over the twentieth century
- globally, CO_2 is the most important GHG; effective GHG and long lived
- concentrations increased from 280 ppm in late 19 century to 315 ppm in 1958 to 410 ppm in 2019.
- trend similar in South Africa

South African greenhouse gas (GHG) emissions



Measured CO_2 concentrations at Cape Point. Source: redrawn from WeatherSmart August 2018

Global trends

Temperature

- Global mean temperature increased by 1ºC by 2017 relative to pre-industrial conditions; increase is greatest over land and for extremes (up to 2-3ºC)

- A temperature increase of 1.5ºC will have significant impacts on ecosystems, health and economy

- A temperature increase of 2ºC will have severe and probably irreversible impacts on ecosystems, health and economy

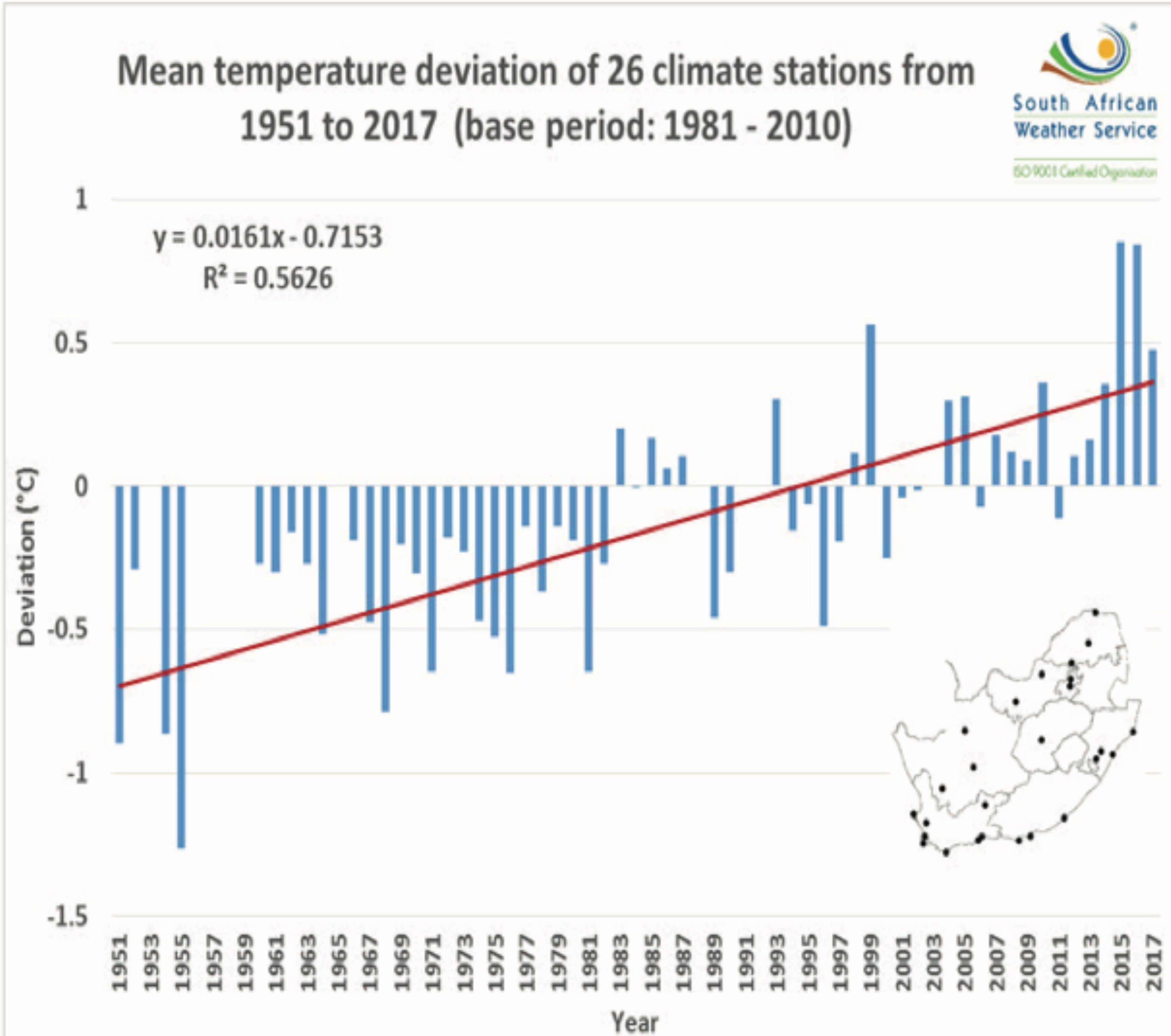
- A less than 2ºC increase is the global target (Paris Agreement 2015)

Precipitation

- Predicted global precipitation changes are regionally variable and uncertain
- Indication that storms will be more severe and drought more frequent (also linked to increased evaporation)

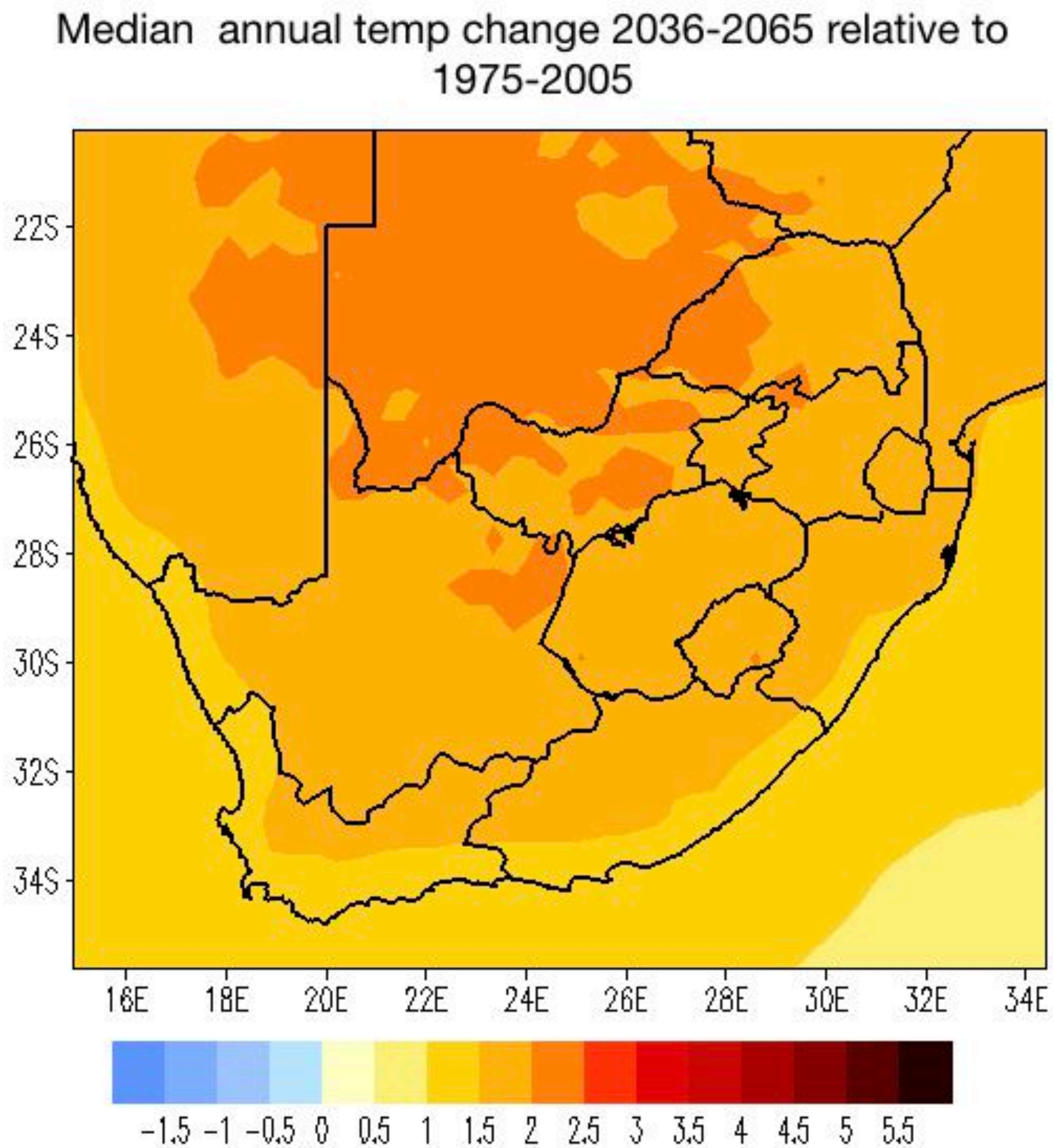
Local trends

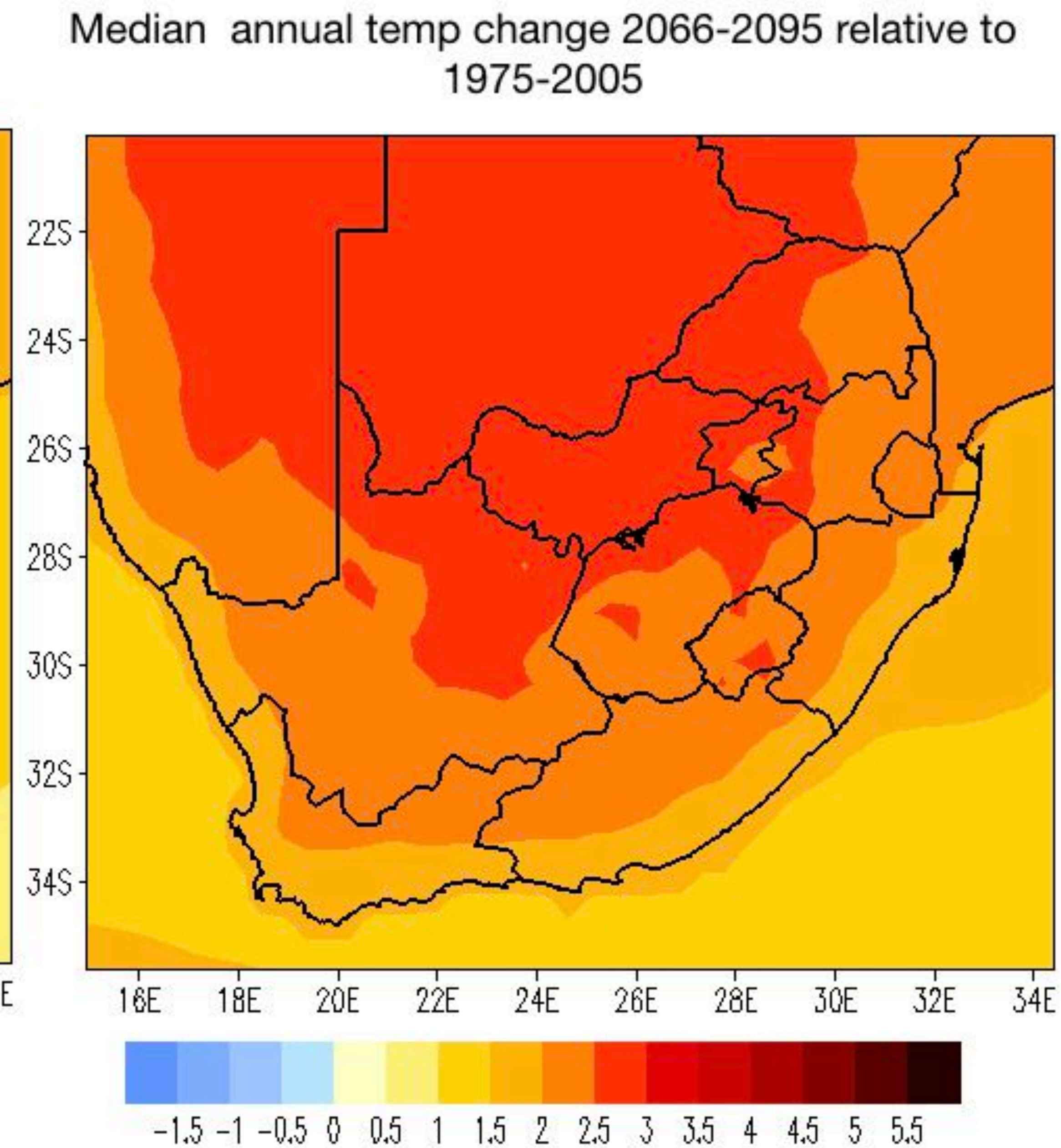
Temperature



Temperature trend in South Africa, 1951-2017 (Source: Kruger et al. (2018) p. 2

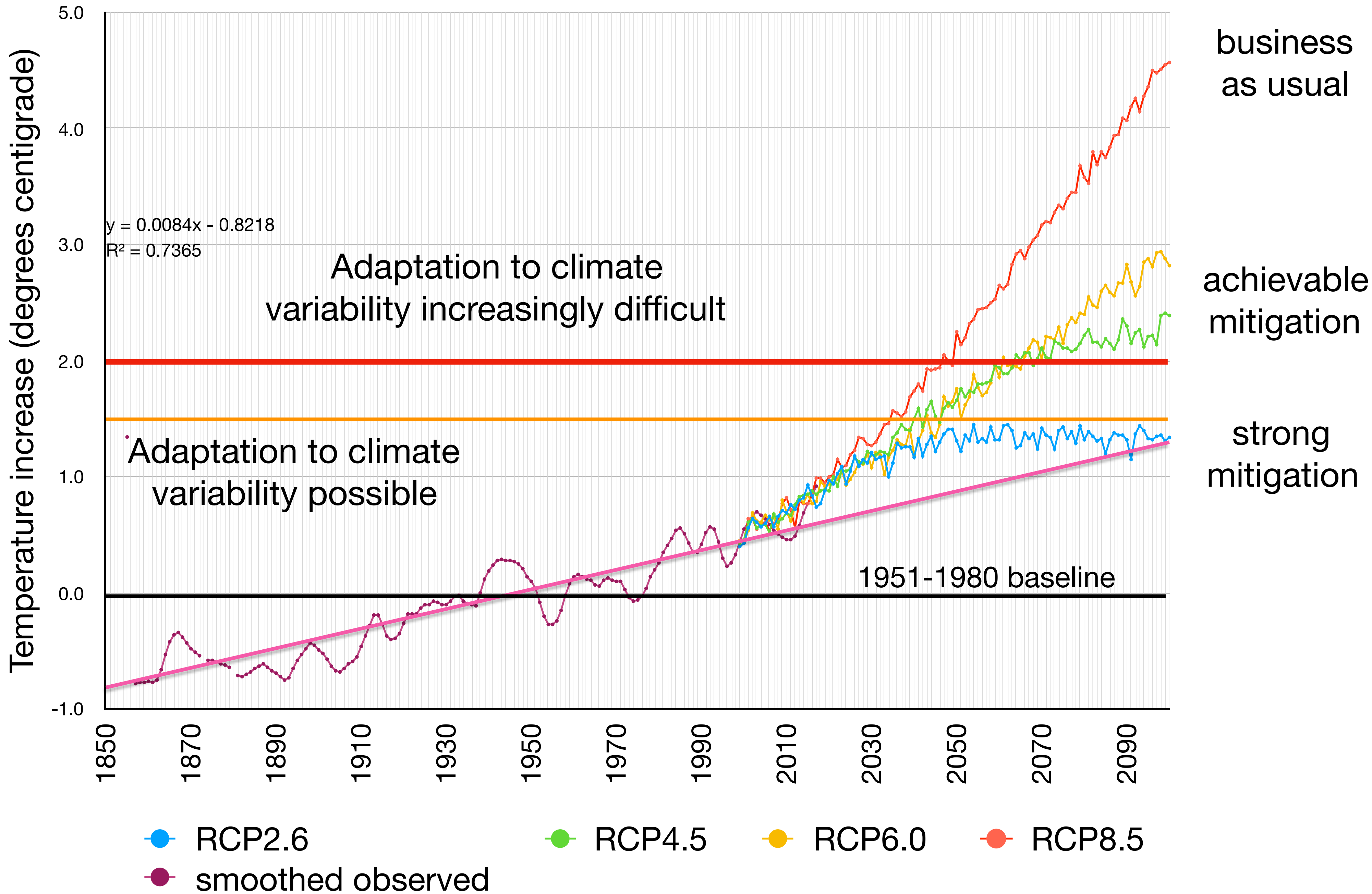
Projected temperatures





source : SAWS CC reference atlas

Integrated output from 9 different models - RCP 4.5

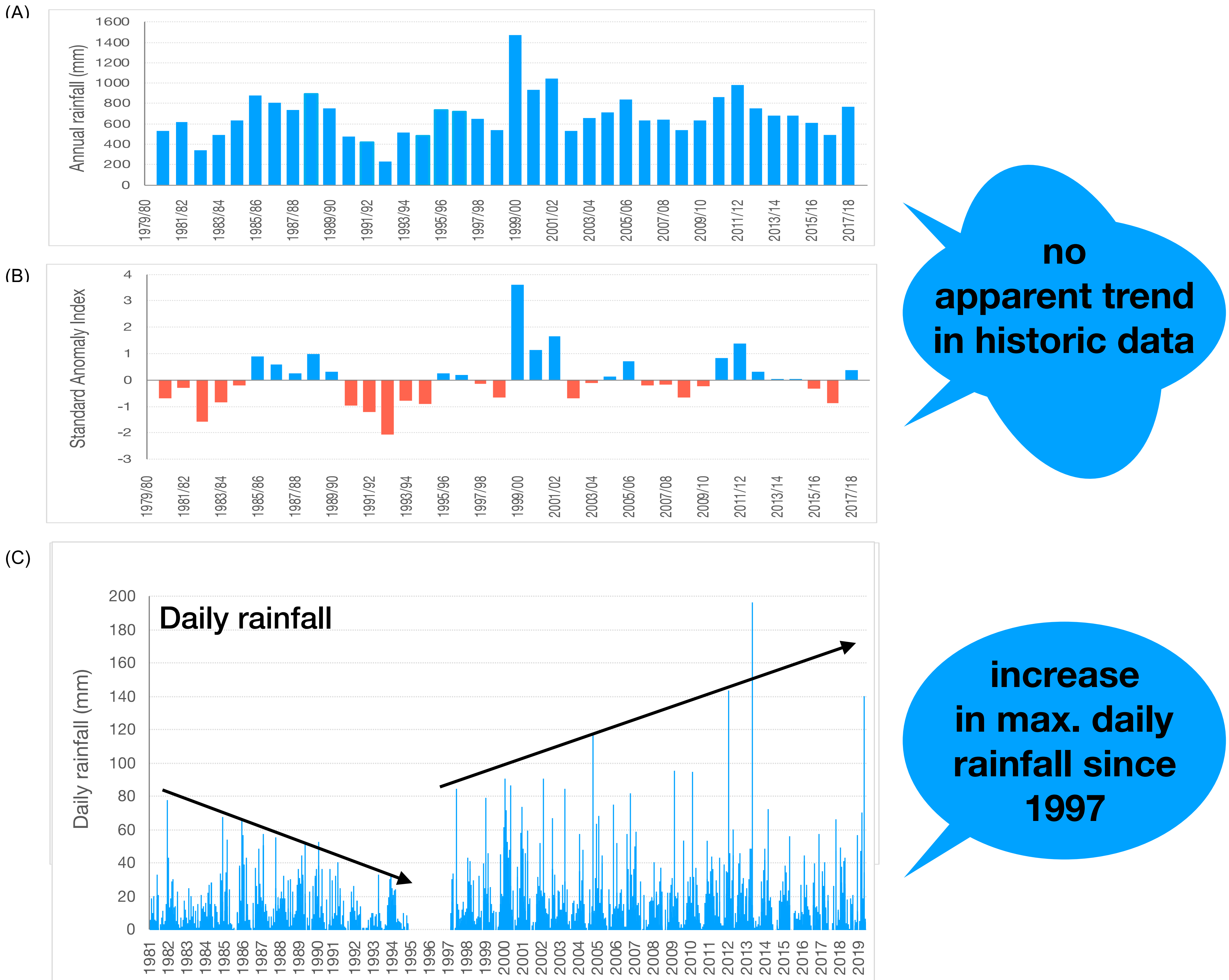


Regional 'observed' and modelled temperature trends in the Tsitsa river catchment

(Data source: Pearce & Hausefather 2018. Carbon Brief online February 2019)

RCP - Representative Carbon Pathway

Precipitation



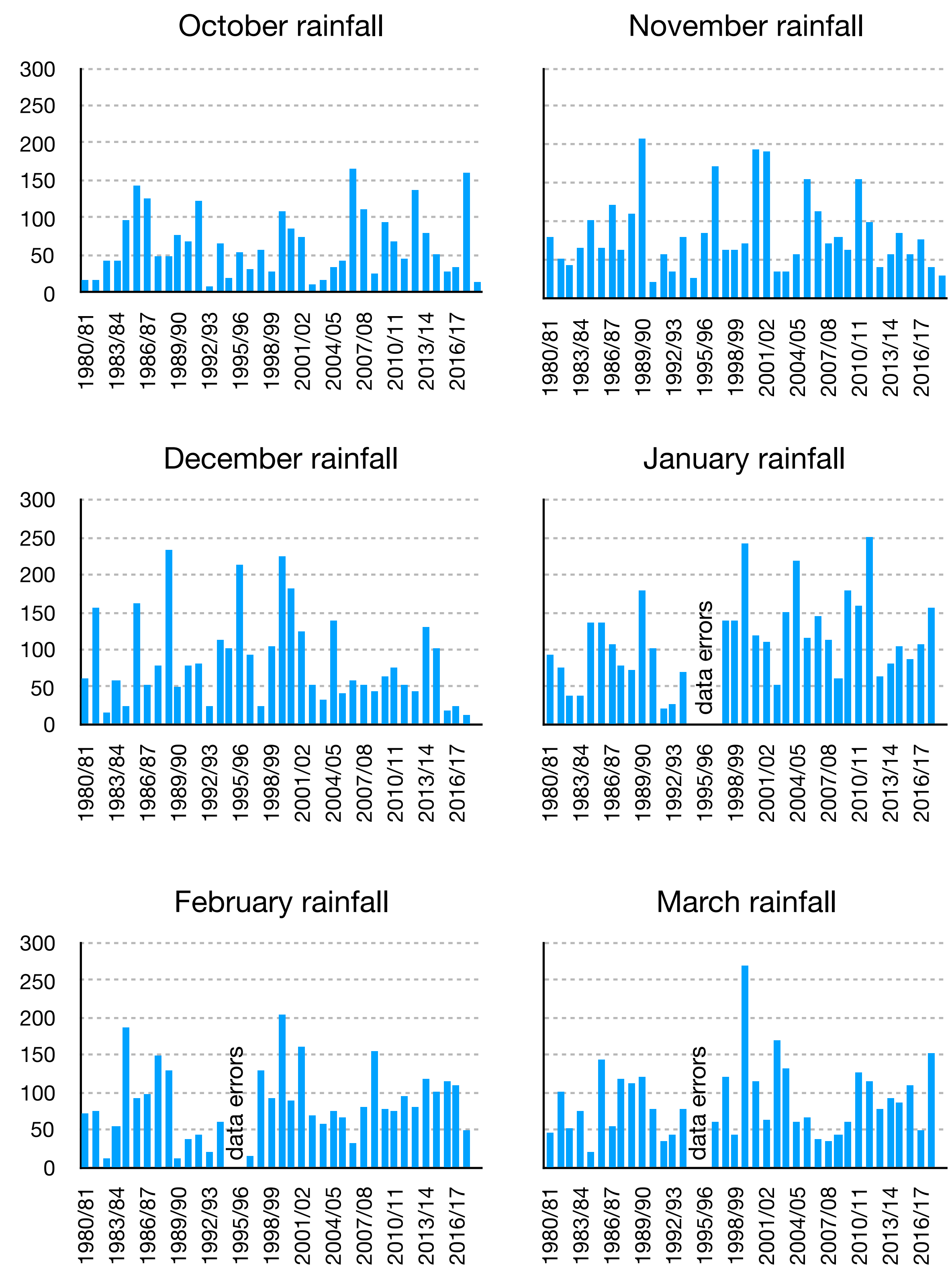
Rainfall time series for Mtata Dam 1980-2018:
Data source DWS online July 2019

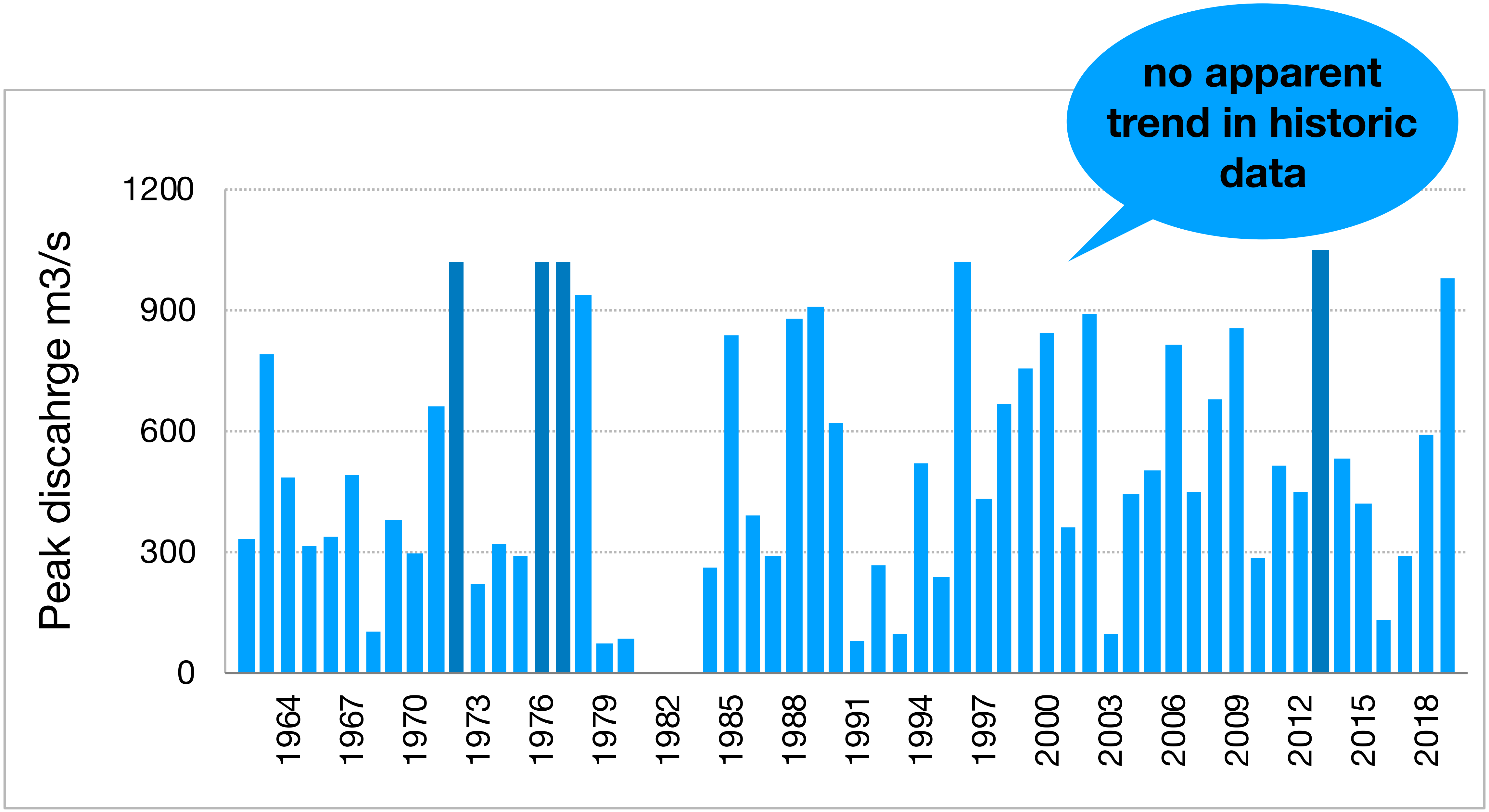
Time series of monthly rainfall at Mtata Dam. Date indicate water years, starting in October.

Data source DWS online February 2019

Trends:
general decrease in spring rainfall since 2000

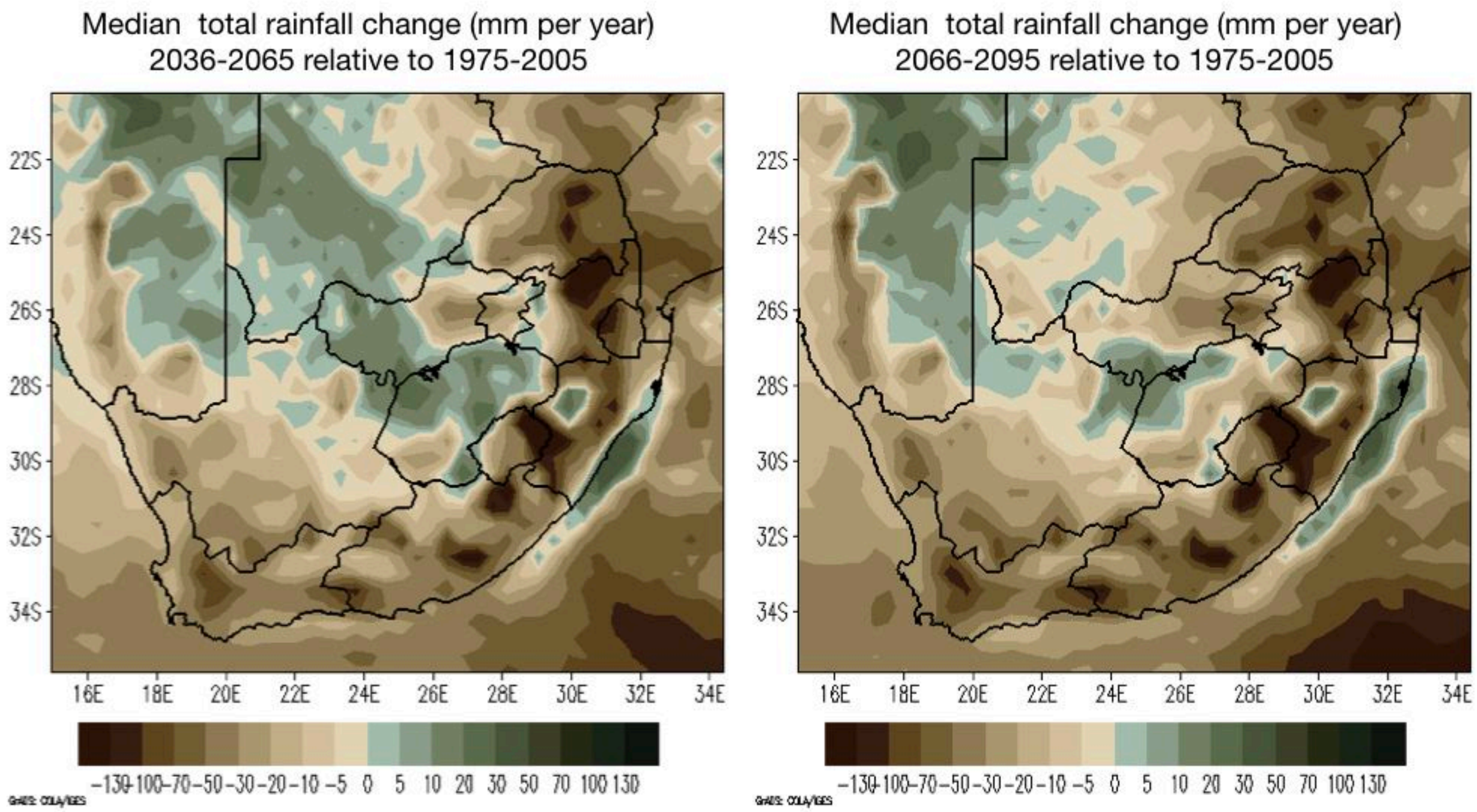
general increase in autumn rainfall since 2006





Annual flood series for the Tsitsa at Xonkonxa (N2 road bridge) 1962-2018. Darker columns indicate years when the gauge was overtopped.
Data source DWS online July 2019

Projected precipitation

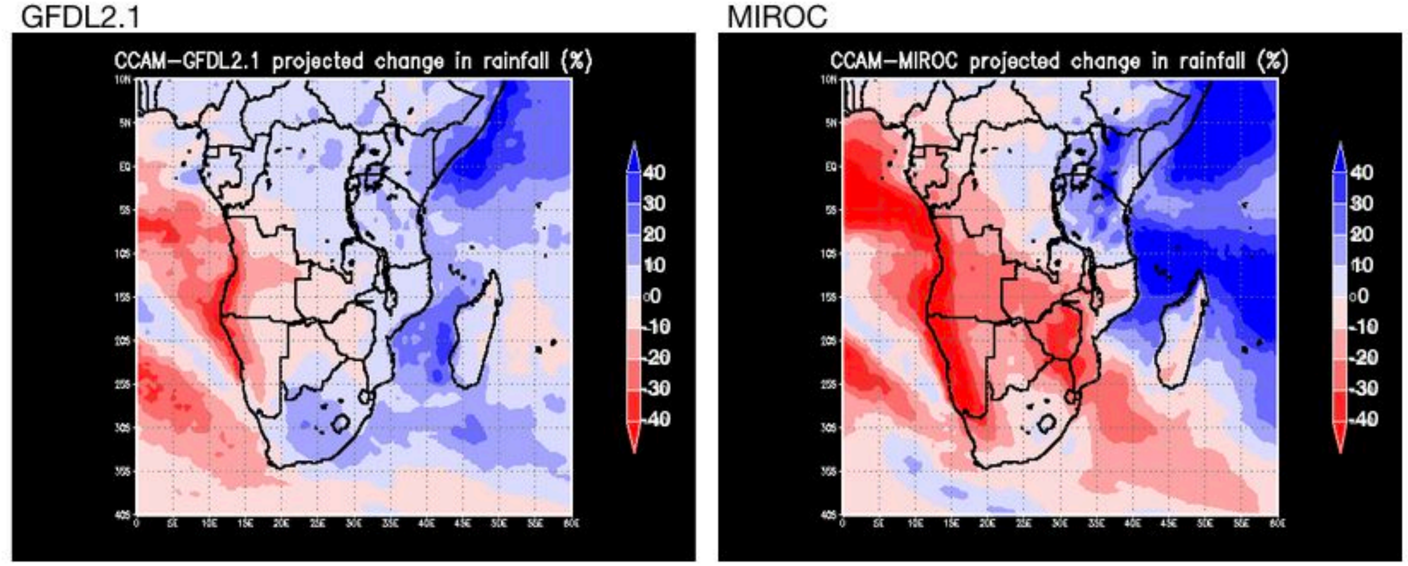


source : SAWS CC reference atlas

Integrated output from 9 different models RCP 4.5

Change in annual rainfall 2041 - 2070 v. 1961-1990

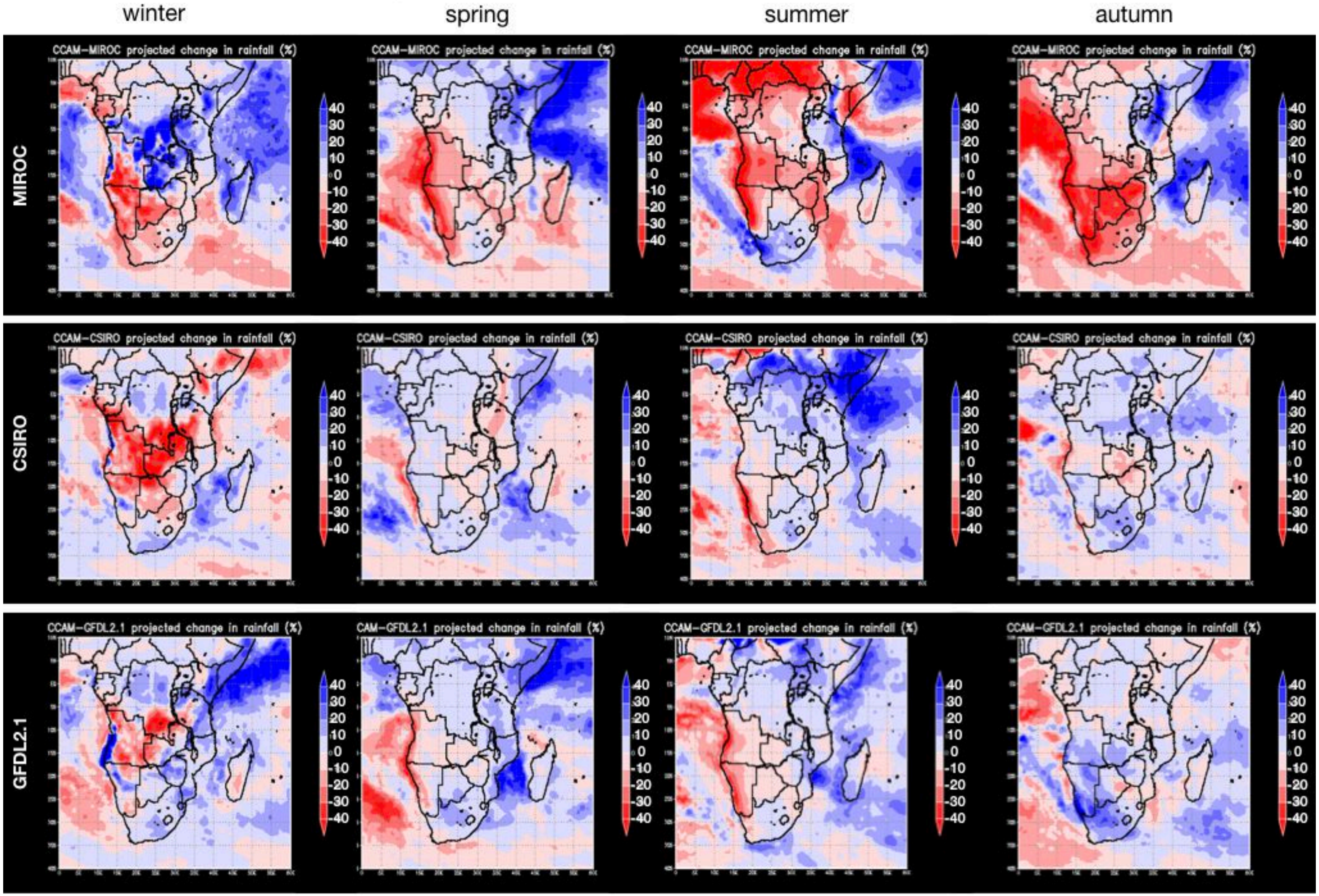
GFDL2.1 MIROC



Source: SA Risk and vulnerability atlas. SAEON

Output from different models give different patterns

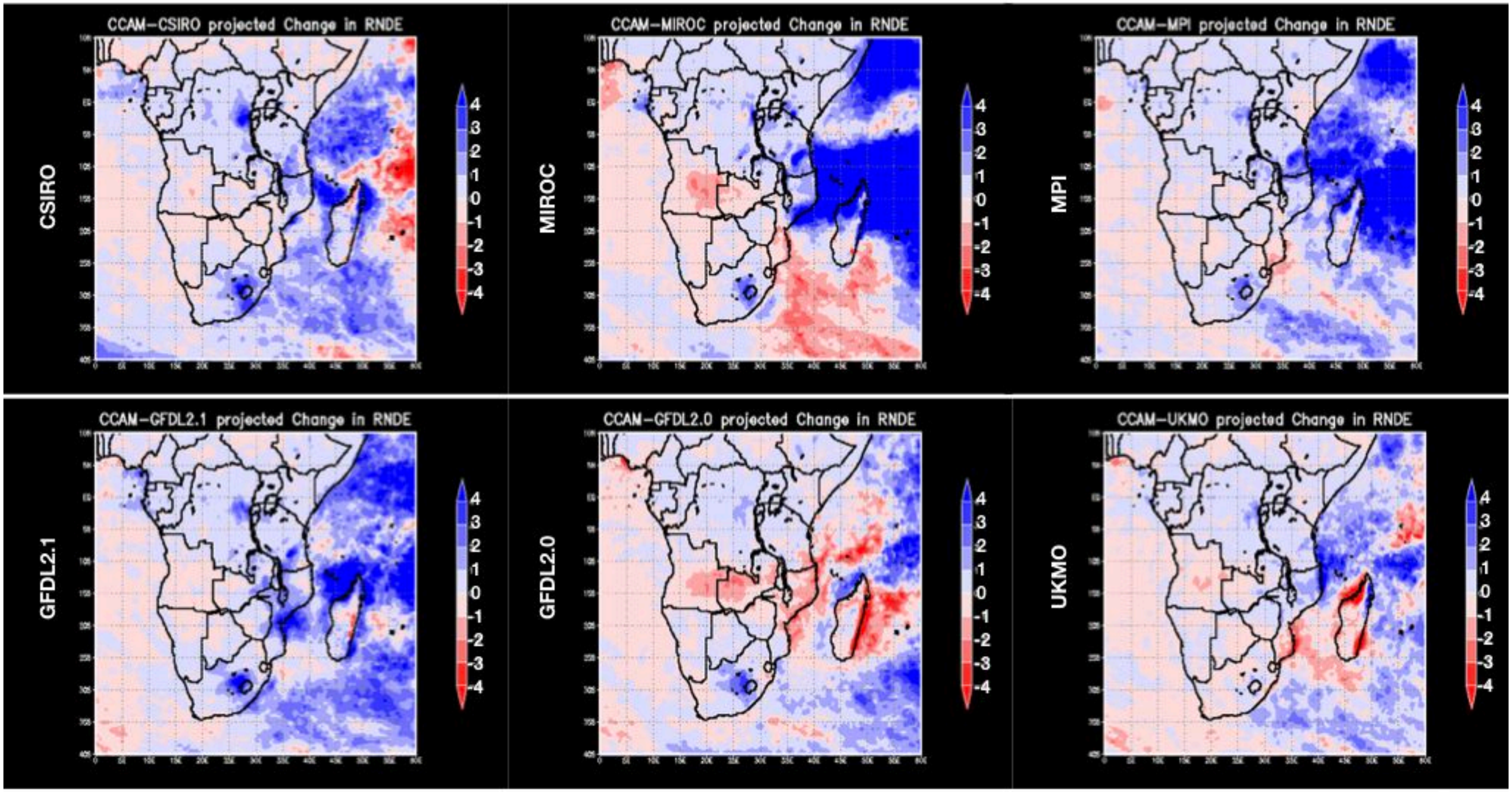
Change in seasonal rainfall 2011-2040 v. 1961-1990



Source: SA Risk and vulnerability atlas. SAEON

Output from different models show different patterns

Increase in annual rain days > 20 mm   2011-2040 v. 1961-1990

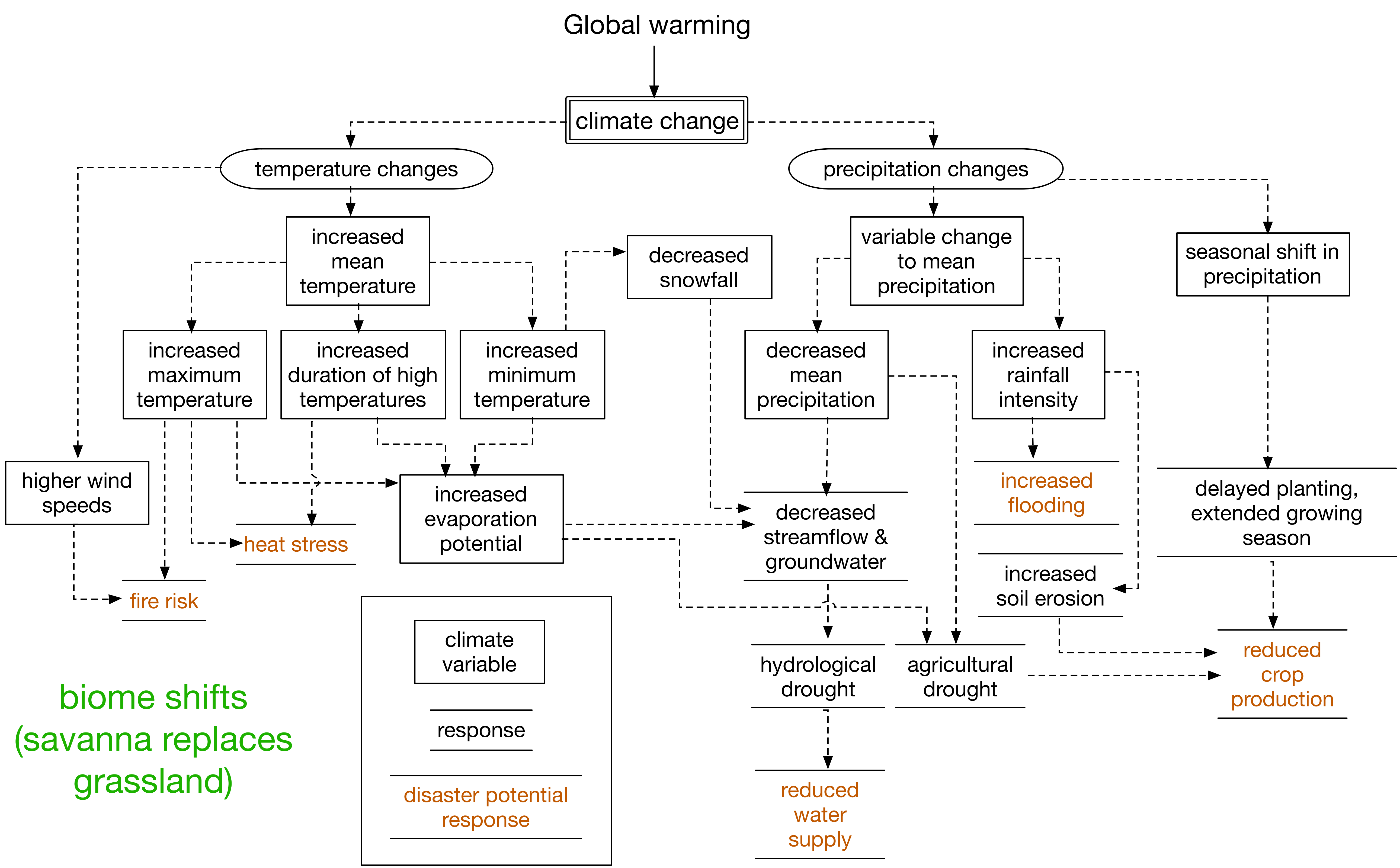


Source: SA Risk and vulnerability atlas. SAEON

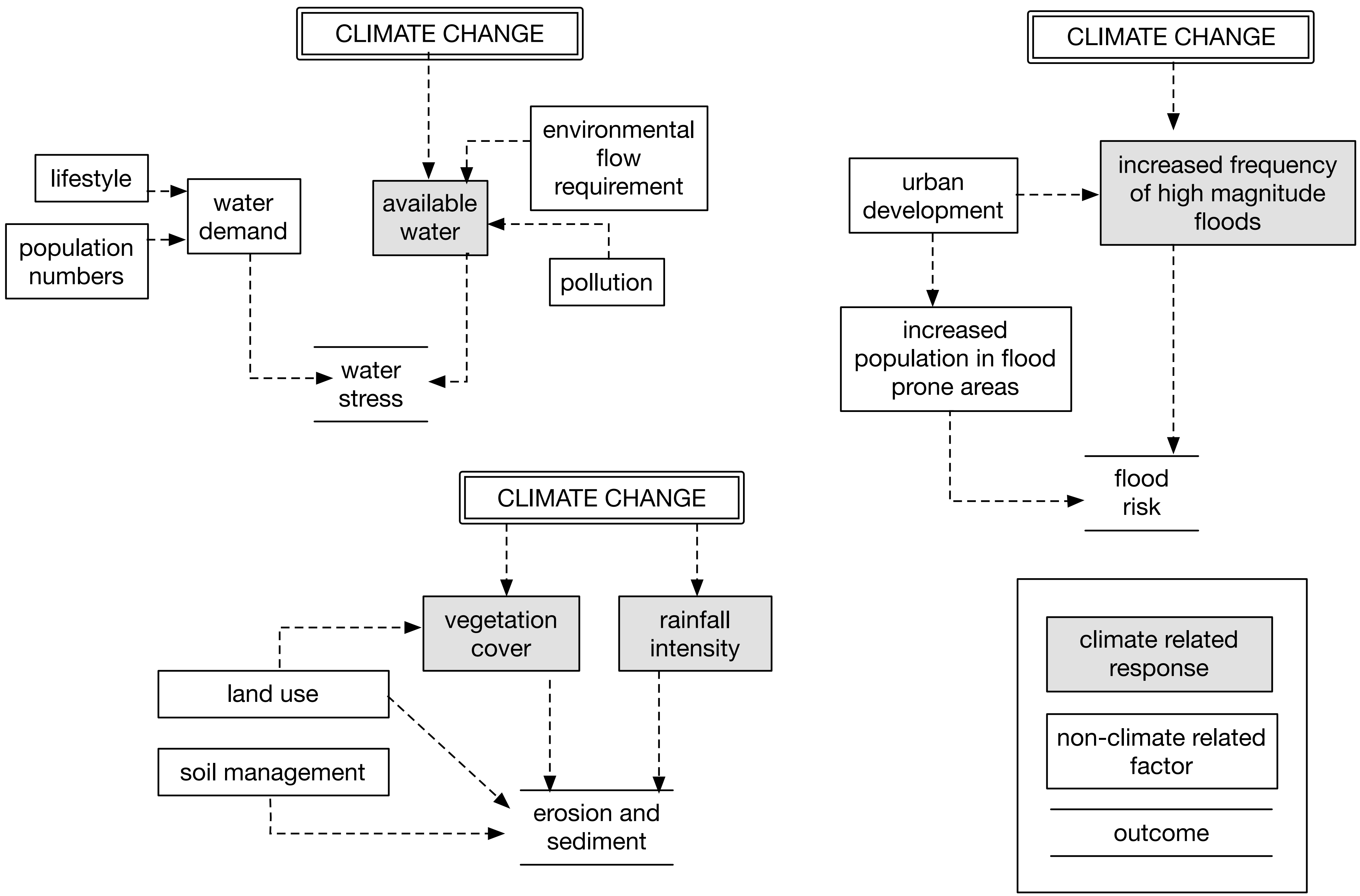
Projected changes to the climate of the Tsitsa river catchment (IPCC 2018)

Tsitsa catchment (Eastern Escaprment)	1.5°C global increase	2°C global increase	direction of change
mean temperature (°C change)	1.5 - 2.0	2.0 - 3.0	increase
Annual Max. temp (°C change)	2.0 - 3.0	3.0 - 4.0	increase
Annual Min temp (°C change)	2.0	2.0 - 3.0	increase
Mean precipitation (% change)	0% - -5%	0% - -5%	decrease
Precipitation extremes (annual max. 5-day rainfall)	0 - 5%	5 (-10)%	increase

SES impacts



SES response to projected changes of climate change on temperature and precipitation

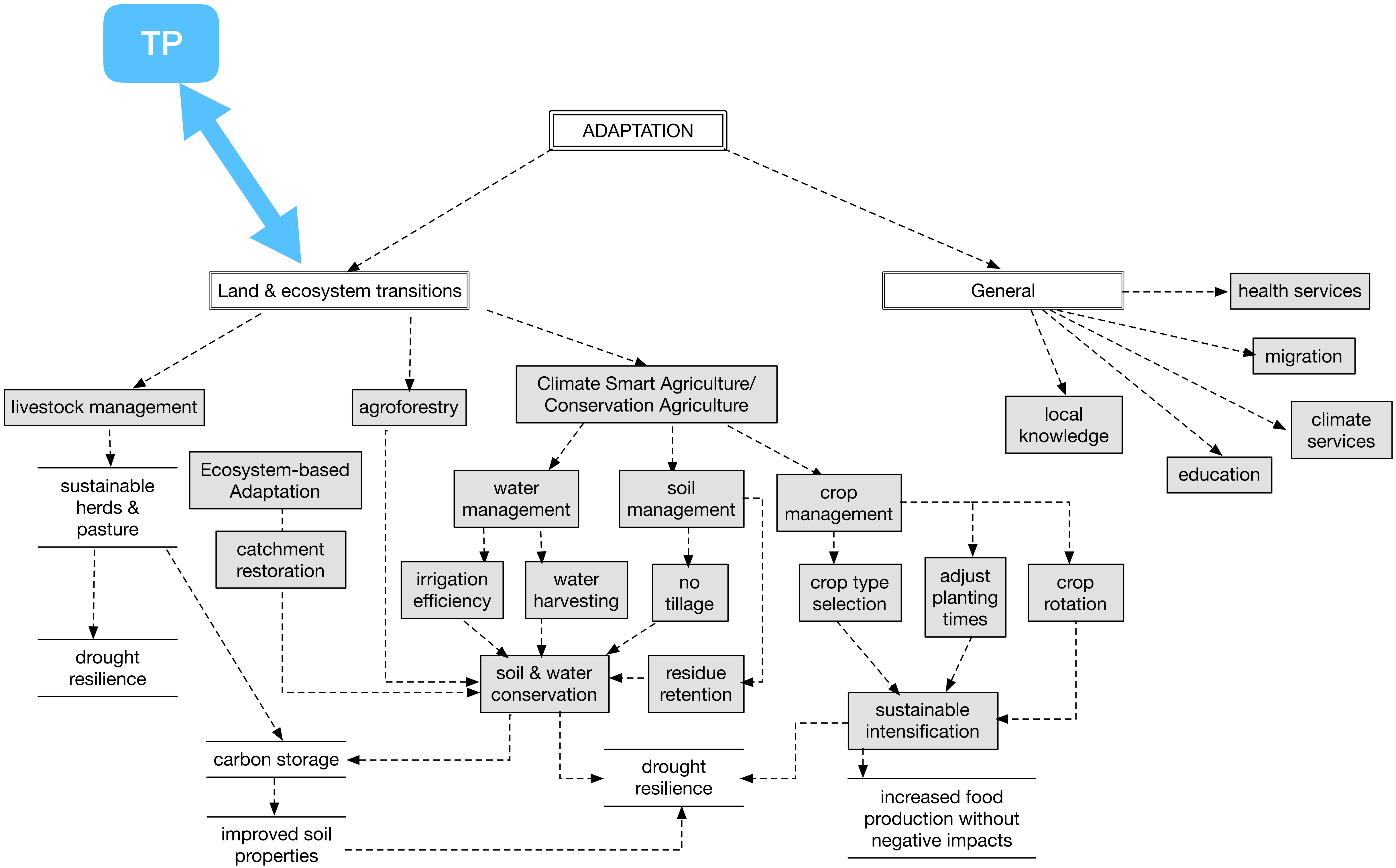


Interaction of climate change impacts with social factors affecting risk to water stress, flooding and soil erosion.

Mitigation and adaptation

Mitigation

- Main source of GHGs in South Africa is energy production (84%)
- Agriculture contributes 7%
- In the Tsitsa catchment <u>fire</u> , poor <u>waste management</u> and <u>agriculture</u> contribute GHGs
- Storage of carbon in soils and wetlands
- **Adaptation more relevant than mitigation to the TP context although there are synergies**


TP
ADAPTATION
Land & ecosystem transitions
General
health services
migration
climate services
local knowledge
education
livestock management
agroforestry
Climate Smart Agriculture/ Conservation Agriculture
sustainable herds & pasture
Ecosystem-based Adaptation
catchment restoration
water management
soil management
crop management
irrigation efficiency
water harvesting
no tillage
crop type selection
adjust planting times
crop rotation
drought resilience
soil & water conservation
residue retention
sustainable intensification
carbon storage
drought resilience
improved soil properties
increased food production without negative impacts

SA Policy Response

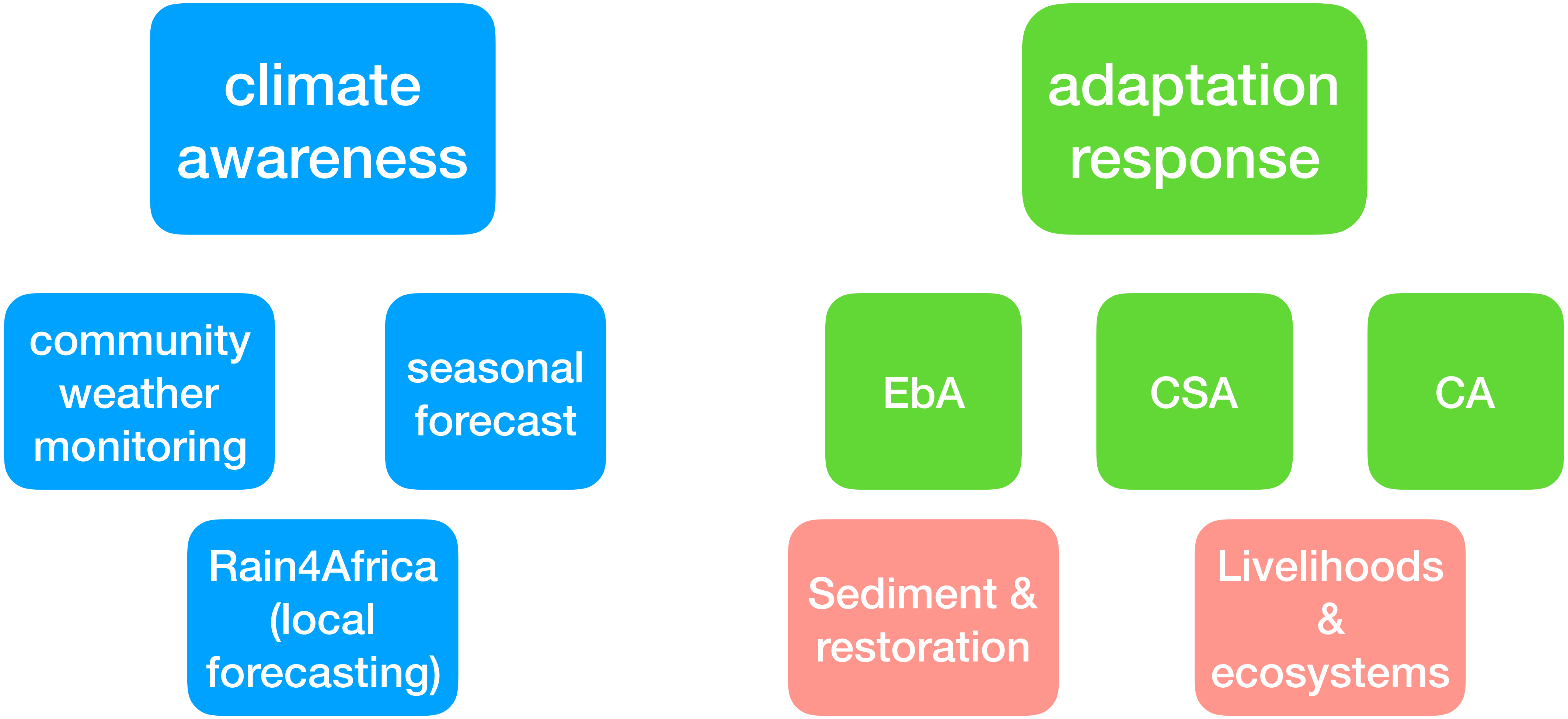
- DEFF (DEA) Ecosystem-based adaptation
- DALR&RD (DAFF) Conservation Agriculture
- DALR&RD (DAFF) Climate Smart Agriculture

Tsitsa Project Response

- Catchment communities (adaptation at the household level)

- Local and provincial government (supporting adaptation and disaster risk response)

Catchment community engagement for climate change adaptation



Proposed Plan of Action

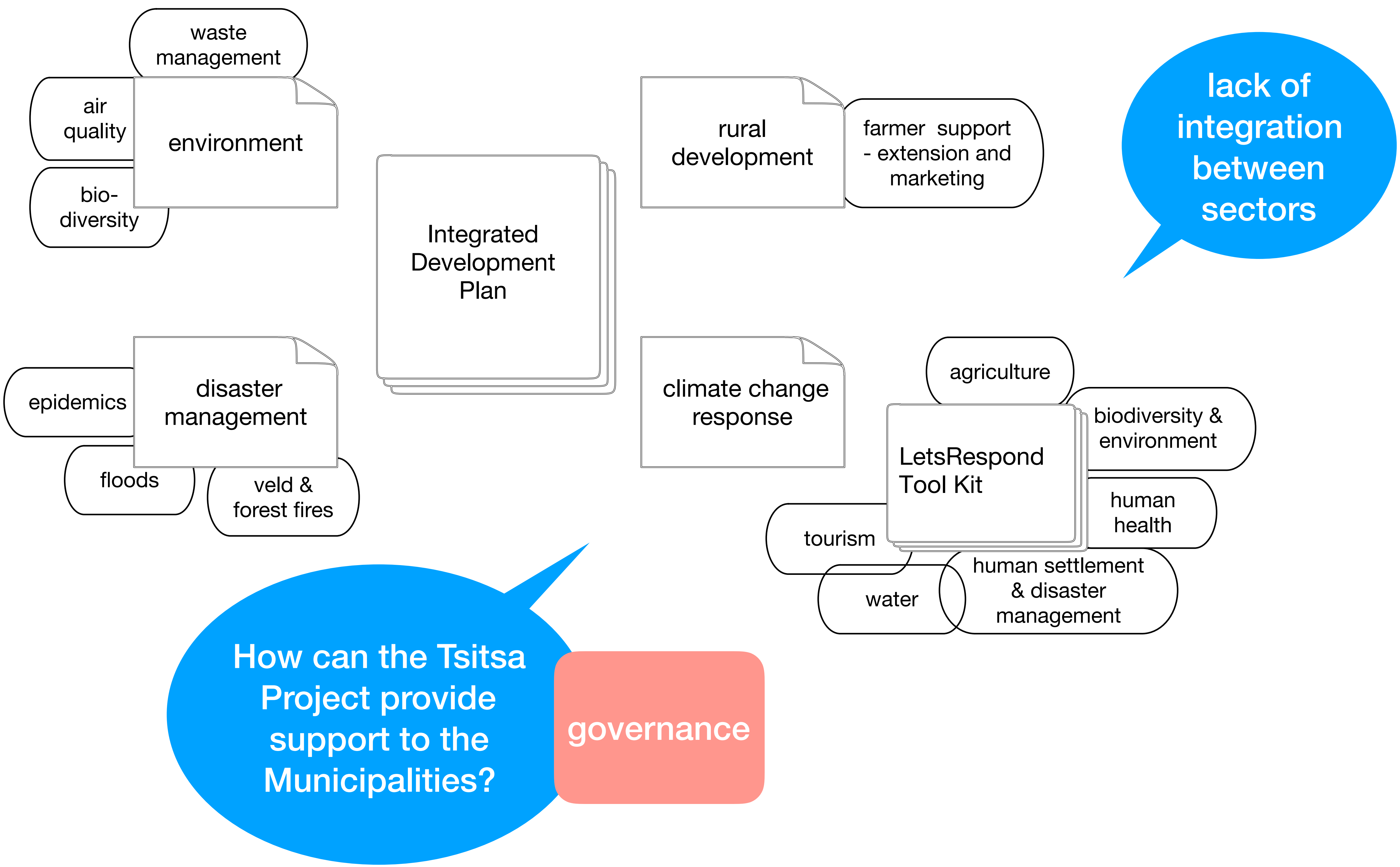
- first workshop in the Elangeni area (Qulungashe)
  - develop farming calendars (seasonal activities)
  - relationship to weather patterns
  - presentation of weather data from community monitors
  - local weather forecasting
  - presentation of SAWS seasonal forecast
  - workshopping ‘what if?’ scenarios linked to future climates
  - proposals for future meetings
- establish 3 hubs for climate change meetings (Tsitsana, Elangeni, Gqukunqa
-

Criteria for Success

(AWARD - RESILIM-O & Suid Bokkeveld wild rooibos harvesters)

- presence in the catchment
- frequent interaction
- participatory methods
- raising weather awareness
- support for climate change adaptation
- farmer experimentation
- support for marketing
- training local people to be facilitators/mentors
- production of training materials

Working with Local Government



Climate Change Flagship Programmes

The DEFF has proposed a number of Climate Change Flagship Programmes as focal points for attracting and leveraging investment from both the private and public sectors at the scale required to enable meaningful climate action.

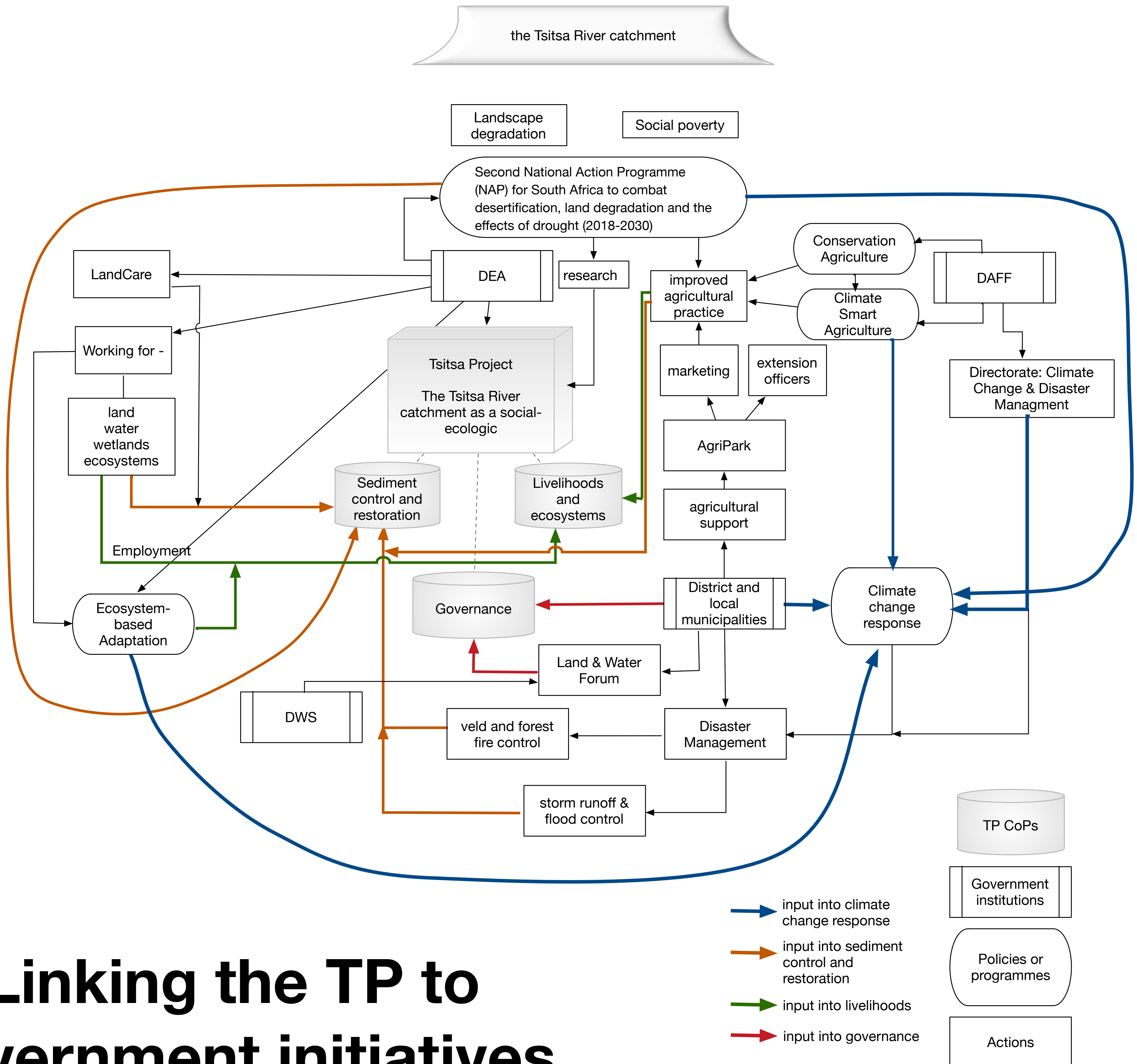
Agriculture, food systems and food security

Land, Biodiversity and Ecosystems Climate Change Flagship

“The aim is to demonstrate the mitigation–adaptation nexus characteristic of land-based climate change response measures. This work package will develop mechanisms to support a sustainable land management regime that enhances ecological infrastructure and resilience, and reduces GHG emissions from the land sector” (DEA 2017)

The core focus is a “demonstration scale implementation of integrated approaches to rehabilitation and management of grasslands, sub-tropical thicket, forests and woodlands” (DEA 2017)

Tsitsa Project as a Climate Change Flagship Programme?



Linking the TP to government initiatives

Recommendations for Climate Change Response support through the Tsitsa Project

DEFF is the government ministry mandated to take responsibility for developing climate change mitigation and adaptation policies so, given that the Tsitsa Project is led by DEFF, it should be in a good position to integrate climate change response into project activities. The project can adopt an addition founding principle: 'Recognise the immediate risk imposed by climate change and align project actions so as to build resilience of the social-ecological system through mitigation and adaptation'. Climate change adaptation is not the sole responsibility of any one CoP but should be adopted in the work of all CoPs where appropriate. That said, it will be necessary to give someone in the Tsitsa Project the responsibility of coordinating climate change response activities and networking with external climate change groups.

The main focus of the Tsitsa Project is the restoration of degraded land linked to sustainable livelihoods in the former homeland areas of the catchment. The principle climate change adaptation activity should therefore target village households and communal land use practices. While climate change adaptation can be integrated into most Tsitsa project activities, it is recommended that as a priority a programme of climate change adaptation workshops are run with village members. It is also important to work with the Municipal offices within the catchment as these are the local government bodies responsible for disaster relief planning and developing a climate change response plan. The Project should also network with other government departments where they can provide support for the catchment's climate change adaptation response. Commercial farming and forestry are the two main land uses in the upper catchment and the project should engage with relevant stakeholders to support climate change adaptation and risk reduction.

Working with DEFF

The Tsitsa Project lies within DEFF, which is also the department directly responsible for climate change policy and action. Tsitsa Project researchers can:

- help position landscape restoration in the Tsitsa river catchment as EbA
- help position the Tsitsa Project as a Climate Change flagship project.

Village level Climate Change Adaptation workshops

These workshops should begin by focusing on raising weather awareness and developing an understanding of weather variability and the best coping strategies. This can lead into discussions on future climate change and adaptation response. This can be linked to catchment rehabilitation and appropriate land management practices.

Workshops should be piloted in the Sinxaku area because this is where most work is happening at the moment and we are known to the community. Participation should be extended to all villages in the Elangeni Traditional Area, in discussion with the new leadership. The model can at a later date be extended to one or two new nodes where the Tsitsa project has a presence such as the Tsitsana and Gqukunqa catchments.

Previous experience shows that working for climate change adaptation requires a sustained engagement through repeat meetings, not a one-off road show approach.

Supporting municipal climate change response

The Tsitsa Project is in a good position to provide support and guidance regarding the climate change response at the District and Local Municipality level. The municipal responsibilities include actions that can support the vision of the Tsitsa Project; these should be promoted. A first workshop with municipal officials would stress the imminence of climate change, anticipated problems in the area and point to ways in which a municipality can respond. The workshop would then explore ways in which the municipality and the Tsitsa Project can work together to develop an effective climate change response that covers both adaptation and risk reduction.

Ways in which the Tsitsa Project can support the climate change response of municipalities include:

- direct officials to relevant published resources that give information about climate change (Appendix C of report)
- direct officials to available climate change funding sources (Appendix B of report)
- advocate adoption of Climate Smart Agriculture & Conservation Agriculture among smallholders, including the creation of marketing opportunities, explore potential for proposed AgriParks to support climate change adaptation
- advocate improved waste management, including reduced open burning of waste
- stress importance of fire control in a warmer, drier environment
- provide guidance for improved storm water control in urban and peri-urban areas
- stress the need to ensure that housing developments are designed to mitigate impacts of climate change – better insulation against heat stress, water harvesting (tanks), increase water use efficiency
- provide guidance for land use planning in line with Tsitsa Project objectives
- devise a climate change support programme for the Tsitsa River catchment that integrates the resposne of the different municipalities.

Networking with other government departments

DALRRD

Support the Department's advocacy of Climate Smart Agriculture. Help village communities to engage with DALRRD officials.

DWHS

Encourage climate change resilience – promote household water tanks, waterless toilets, off-channel storage dams in upper catchment.

Networking with other land users

Commercial farmers

Engage with CFs to find out more about their understanding of climate change and how they are adapting.

Propose a meeting to explore ideas.

Forestry

Engage with PJ Bison to find better ways to manage forests and fires; conserve wetlands, avoid further encroachment of forests onto grassland. Propose a meeting to explore ideas.