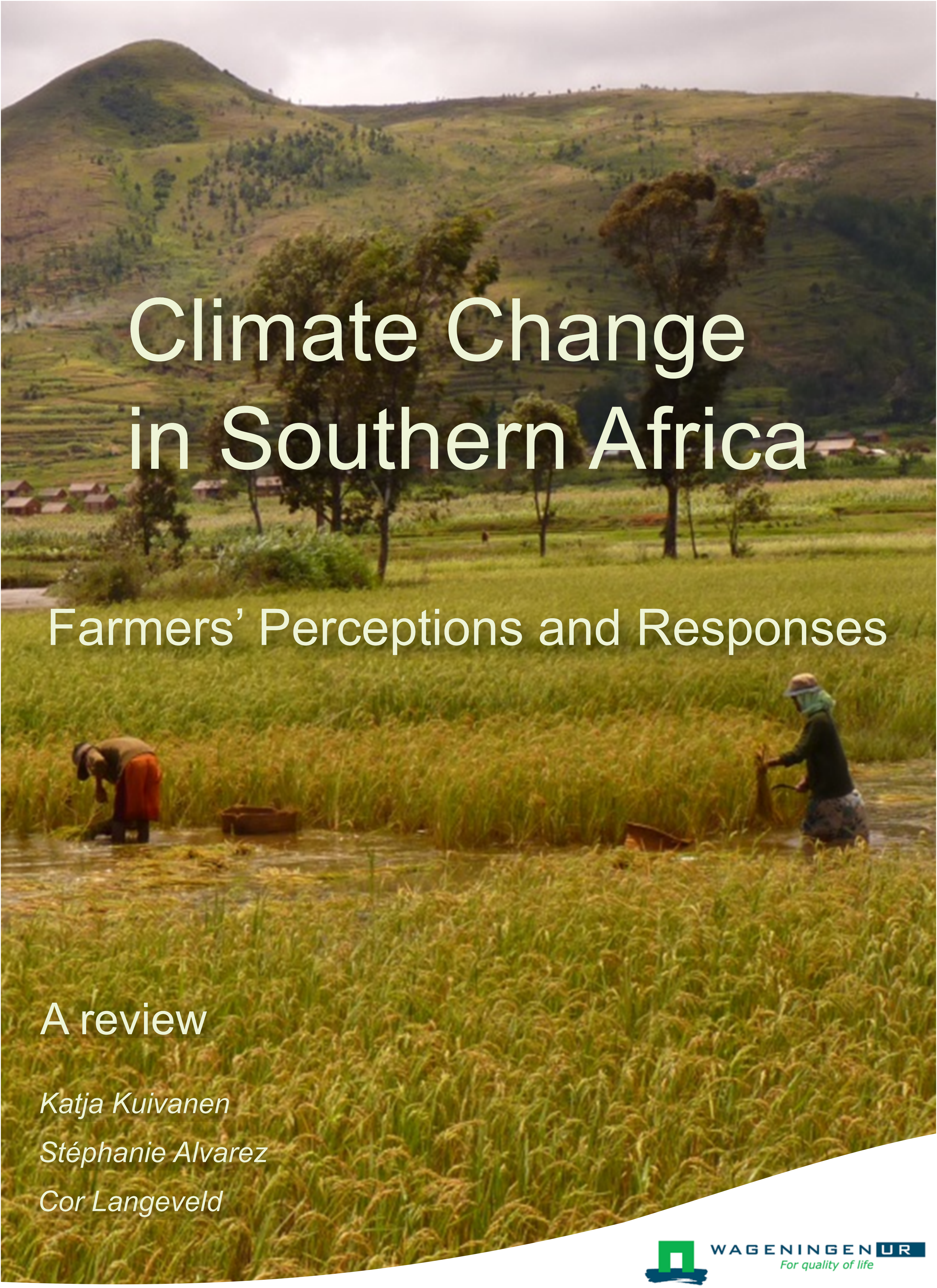

Climate Change in Southern Africa

Farmers' Perceptions and Responses

A review

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For quality of life

Climate Change in Southern Africa: Farmers' Perceptions and Responses

Produced by

Farming Systems Ecology - Wageningen University

Acknowledgements

This review was conducted as part of the project 'Supporting smallholder farmers in Southern Africa to better manage climate-related risks to crop production and post-harvest handling' led by the Food and Agriculture Organization (FAO) of the United Nations (UN). The project is funded by the European Union and focuses on Southern Africa, in particular Madagascar, Malawi, South Africa and Zimbabwe. The contents are the responsibility of the producing organization and do not necessarily reflect the opinion of the UN.

Reference

Kuivanen K., Alvarez S., Langeveld, C., *Climate Change in Southern Africa: Farmers' Perceptions and Responses*, 2015, Review report, Farming Systems Ecology, Wageningen University, Netherlands

Pictures

Harvesting rice in Madagascar (cover page, credits: Stéphanie Alvarez, 2009)
Farmers in Nalitoya, Zambia (credits: Trinidad del Rio, 2014)

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Summary

Southern Africa is characterized by natural climate variability onto which human-induced climate change is being superimposed. Rural communities that depend heavily on rain-fed agriculture for their livelihood are particularly vulnerable to the effects of climate-related change. This report takes stock of existing perceptions of- and responses to climate change among smallholder farmers in the region, in the hope of contributing to a better understanding of the complexities of local knowledge- and adaptation systems.

Farmers' perceptions can provide valuable insights into climate-related changes, and may contradict views held by other stakeholders, such as scientists and policy-makers. Sometimes, perceptions of climate change appear to be in line with actual climate data but more commonly, they tend to differ from meteorological evidence. Experience, as moderated by other contextual factors such as socio-cultural values, is an important determinant of farmers' perceptions of climate change. Often farmers perceive supernatural factors to be associated with the causes of climatic variability.

Farmers' responses to climate variability and change can be classified as coping (short-term, reactive) or adaptation (longer-term, reactive or anticipatory) strategies. Responses to cope with shocks such as drought and floods include income diversification, drawing on social safety nets and the sale of assets. Common agricultural adaptations include diversifying crops, changing varieties and planting dates, soil conservation and supplementing livestock feed. Coping- and adaptation responses can be further divided into six broad categories: (1) crisis response; (2) modifying farming practices; (3) modifying crop and animal types, varieties and breeds; (4) natural resource management; (5) livelihood diversification and (6) knowledge management.

While perceptions of climate change are a necessary prerequisite for adaptation to climate change, a number of studies show that there is often a disconnection between land users' perceptions of climate change and on-the-ground responses. It seems that farmers with more resources and better education tend to be more willing to adopt new strategies. Using a baseline of existing responses; new or improved adaptation practices can be developed that will potentially have the advantage of being both technically effective and socially accepted. Ultimately, it is envisioned that integrating existing farmer knowledge with scientific best practices will improve the effectiveness of agricultural adaptation research and planning in the long term.

1. Introduction

It is now widely accepted that the Earth's climate is changing, to the detriment of agricultural production everywhere (Christensen *et al*., 2007; IPCC, 2014). According to the Fifth Assessment Report of the International Panel on Climate Change (IPCC); traditional knowledge systems and practices are a major resource for adapting to climate change among natural resource-dependent communities (Field *et al*., 2014). This has reiterated the need to better understand how these communities have responded to climate variability and change in order to integrate their knowledge with existing best practices. Such an endeavour could increase the effectiveness of agricultural adaptation policies, and therefore, the resilience of agriculture for future generations (Below *et al*., 2012; Bryan *et al*., 2009; Mertz *et al*., 2009).

1.1 Scope and objectives of the report

In recent years, vulnerability, adaptation, and adaptive capacity have been become key concepts in explaining the societal implications of climate change (Fussel & Klein, 2006). Despite this, evidence on how adaptation is occurring in the agricultural sector, particularly in developing countries and among producers at the farm-level, is relatively scarce (Arnell, 2010; Berrang-Ford *et al*., 2011; Smit & Skinner, 2002). Projections of climate change tend to agree on the particular vulnerability of Southern Africa's rural communities (Stern, 2006; IPCC, 2007). These communities are generally under-resourced to adequately adapt to extreme changes in climate and highly reliant on one of the most climate dependent of human activities: rain-fed agriculture (Hansen, 2002; Nkem *et al*., 2010).

Therefore, the main objective of this study is to take stock of (1) smallholder farmers' existing understanding and perceptions of climate change, and (2) micro-level responses to climate change-related challenges in the agricultural sector of Southern Africa. To do this, the relevant literature was reviewed and subsequently coded into thematic nodes for further qualitative analysis using the software tool *Nvivo10*. It is envisioned that the resulting report could be useful in the formulation of better-targeted adaptation strategies geared at improving the resilience of rural communities in the region that depend heavily on agriculture for their livelihood.

1.2 Study area

1.2.1 Spatial context

Southern Africa is defined here as the total geographical area occupied by the 15 member states of the Southern African Development Community (SADC): Angola, Botswana, Democratic Republic of Congo, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, Swaziland, Tanzania, Zambia and Zimbabwe (Fig. 1). Established in 1992, SADC is a political ensemble committed to regional integration and poverty eradication through economic development and ensuring peace and security (SADC, 2012).

Agriculture remains the primary source of employment and income for most of the rural population of Southern Africa (Hachigonta *et al*., 2013; Wamukonya & Rukato, 2001). The region has a GDP of US$ 575.5 billion, to which the agricultural sector contributes in the different member states between 4% and 27% of GDP (SADC, 2012). Hence the performance of this sector has a strong influence on food security, economic growth and social stability in the region (SADC, 2012). Nevertheless, poverty is a major common development challenge, with statistics from the African Development Bank (2007) indicating that 70% of the region's 277 million people lives below the international poverty line of US$ 2 per day (Chishakwe, 2010).

Fig. 1 The 15 member states of the Southern African Development Community (SADC) in green. *Source: Authors, ArcMap 10.2*

1.2.2 Present climate

The climatic conditions of Southern Africa follow a broad gradient, with more arid conditions in the west and increasingly humid conditions towards the east. However, closer to the equator, the climate is largely humid (Fig. 2A). Precipitation patterns reveal lower annual rainfall in the south versus higher annual rainfall in the north (Kandji *et al*., 2006; Fig. 2B). Thus, the climate ranges from the winter rainfall Mediterranean conditions around the tip of South Africa and semi-arid summer rainfall savannah regions of the Kalahari in Namibia and Botswana to the sub-humid rainfall regimes typical of Malawi, for example (Stringer *et al*., 2009).

The climate of the region is controlled to a large extent by global patterns of atmospheric circulation. Natural rainfall variability is linked to shifts in the tropical temperate trough over the region (Usman & Reason, 2004; McGregor & Nieuwolt, 1998) and also regional sea surface temperature effects explained by a phenomenon known as the El Niño Southern Oscillation (Todd & Washington, 1998; Stringer *et al*., 2009).

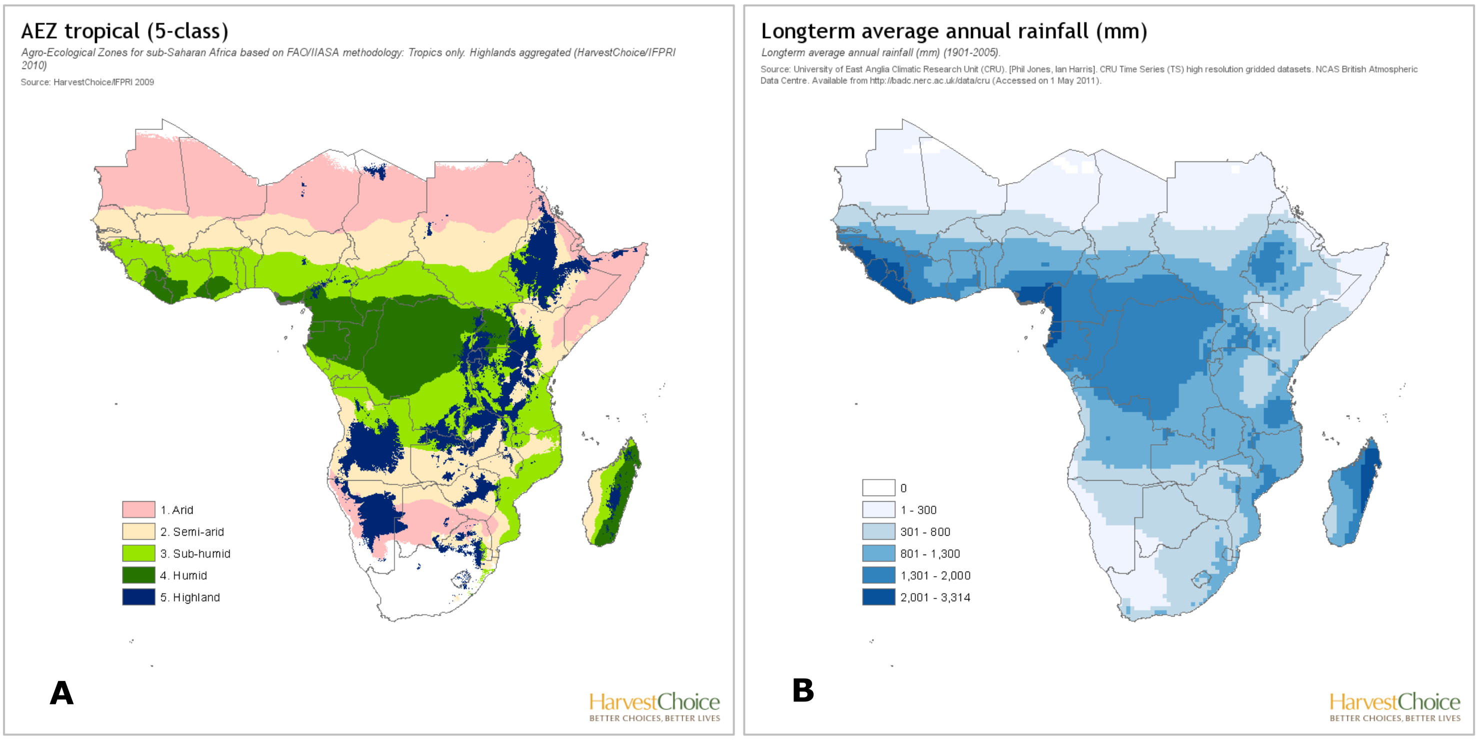


Fig. 2 Climate based agro-ecological zones (A) and long-term (1901-2005) average annual rainfall of Sub-Saharan Africa (B). *Source: Harvest Choice, 2015.*

1.2.3 Agriculture

The Southern African agricultural sector can be roughly divided into two broad subsectors: commercial and subsistence (Wiggins, 2009). Commercial farmers occupy relatively large land areas and tend to be more integrated with the market (Fig 3). Furthermore, they make more intensive use of technologies such as improved seeds, fertilisers and mechanisation (Wiggins, 2009). South Africa, in particular, has a well-developed commercial farming sector (Hachigonta *et al*., 2013). Subsistence-oriented farmers, on the other hand, are commonly smallholders with two hectares or less. This report focuses exclusively on smallholders, who account for the majority (*c*. 80%) of all farms in the region and contribute up to 90% of the production in some countries. In Botswana, for example, 76% of the population depends on small-scale subsistence agriculture; in Kenya, 85%; in Malawi, 90%; and in Zimbabwe, 70-80% (Rockström, 2000; Ngigi, 2011; Kandji *et al*., 2006).

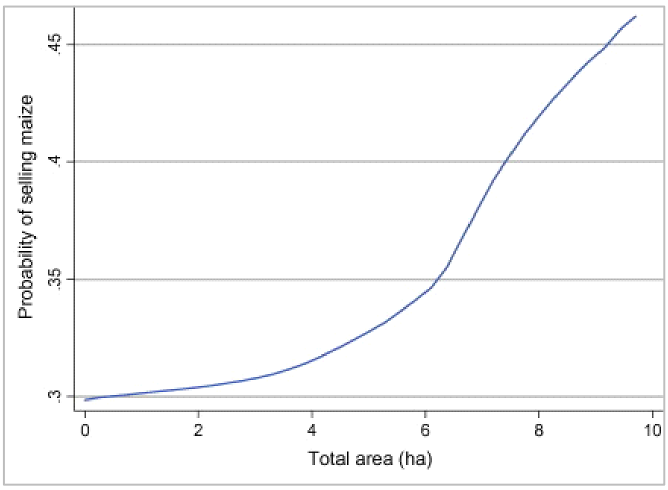


Fig. 3 Maize market participation patterns by land holdings in Mozambique 2001-2002 (Barrett, 2008).

Besides small farm sizes, smallholders share other characteristics (Box 1) such as limited access to financial capital and inputs; all of which places them at higher risk than profit-driven producers (Chamberlin, 2007, 2008). While few small-scale farmers are sellers of produce into the market (Fig. 3), this does not imply widespread food self-sufficiency among smallholders. In fact, many rely on off-farm employment to generate the earnings needed to supplement their own food crop production with market purchases (Barrett, 2008). Of course, smallholders are not homogenous- their circumstances and strategies vary across spatial scales (Zinyengere *et al*., 2014).

Box 1. Typical characteristics of Southern African smallholders

- Pastoral, agro-pastoral and mixed crop-livestock systems
- Limited access to financial capital and inputs
- Small land holdings of ≤2 ha
- Low crop yields
- Subsistence orientation
- Vulnerable to shocks (*e.g.* crop failure) and stresses (*e.g.* erratic rainfall)

Sources: Chamberlin, 2007, 2008; Herrero et al., 2009; Wiggins, 2009

Most smallholders in Southern Africa combine crop farming with animal husbandry (AGRA, 2014). Nevertheless, the arid western parts of Southern Africa (*e.g.* Botswana and Namibia) have little crop farming due to unfavourable climatic conditions, though the livestock sector is very important. The largest croplands are observed in southern Tanzania, Zambia, Zimbabwe and South Africa (Table 1). However, crop yield levels remain low compared to other regions of the world (Chauvin *et al*., 2012).

Maize is the most produced and most consumed cereal in the region (Table 1) although millet and sorghum are important crops in the drier areas (Kandji *et al.*, 2006). Most production is rain-fed, except in South Africa, which is the largest maize producer in the region due to the contribution of irrigated farmlands (Hachigonta *et al.*, 2013). Madagascar is a major producer of paddy rice; wheat is cultivated mainly under irrigation in South Africa and sorghum is mostly grown in Mozambique (Table 1).

Table 1. Average harvest area of leading crop types in Southern Africa, 2010 (ha).

Country	Maize	Millet	Rice	Sorghum	Wheat	Groundnut
Angola	1.489.815	194.381	23.905	166.254	3.800	285.287
Botswana	65.388	9.476	-	57.475	0	3.075
DRC	1.484.775	58.052	420.174	9.288	6.878	477.199
Lesotho	141.340	-	-	33.146	13.693	-
Madagascar	293.313	-	1.613.000	2.565	5.006	52.000
Malawi	1.696.270	47.892	59.098	88.498	1.548	295.236
Mauritius	48	-	0	-	-	208
Mozambique	1.738.042	108.980	226.593	638.165	13.369	365.856
Namibia	32.000	260.000	-	20.000	1.900	720
Seychelles	-	-	-	-	-	-
South Africa	2.742.000	14.100	1.123	86.675	558.100	57.450
Swaziland	55.000	-	35	900	300	7.500
Tanzania	3.050.710	345.855	1.136.290	618.370	54.570	482.310
Zambia	1.080.556	50.806	30.788	28.908	27.291	254.566
Zimbabwe	1.362.563	237.818	288	272.679	5.000	256.207
Total	15.231.820	1.327.360	3.511.294	2.022.923	691.455	2.537.614

Source: FAOSTAT (FAO, 2015)

2. Climate change and impacts in Southern Africa

Emissions of greenhouse gases (GHGs) resulting from many areas of human activity alter atmospheric chemistry, ultimately altering precipitation patterns and causing unprecedented global warming (IPCC, 2014). This in turn will have long-term effects on all the components of our climate system (AGRA, 2014; IPCC, 2014).

The problem of climate change has been called a 'tragedy of the commons' (Hardin, 1968): when a country emits GHGs, its emissions can have planetary-wide negative impacts, while the country itself suffers only a part of the harm it causes (Valentini *et al.*, 2014). Carbon dioxide (CO_2) is a major GHG, accounting for 76% of total anthropogenic GHG emissions in 2010 (IPCC, 2014). Industrialised regions contribute disproportionately to global CO_2 emissions (Fig. 4) yet are also expected to suffer relatively modest physical damage from future climate change. On the other hand, developing regions such as most parts of Africa bear less causal responsibility (Fig. 4), but could suffer significant physical damage from climate change; as shall be outlined in the following sections (IPCC, 2007).

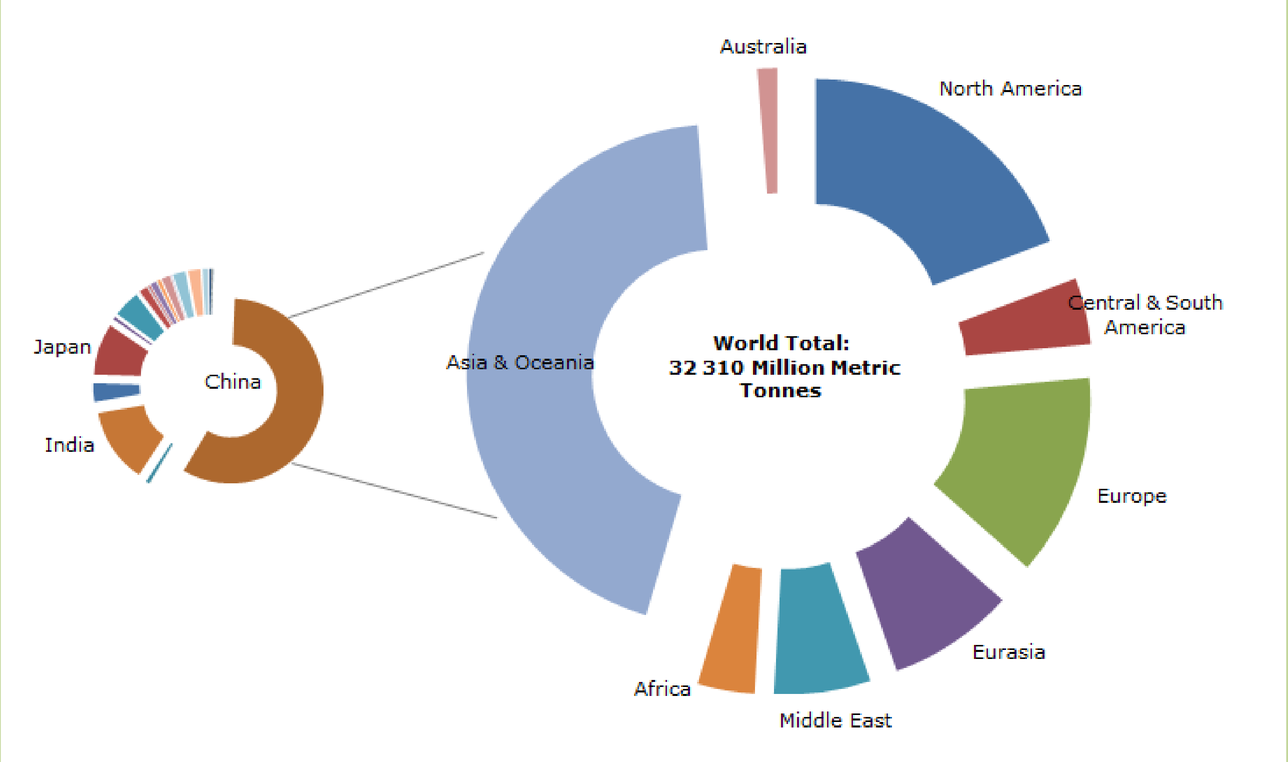


Fig. 4 Total carbon dioxide (CO2) emissions from the consumption of energy (Million Metric Tonnes) show that the top three global emitters are Asia (largely represented by China), North America and Europe. *Source: US Energy Information Administration, 2015.*

2.1 Observed changes in climate

Southern Africa is characterized by inter- and intra-annual natural climate variability onto which human-induced climate change is being superimposed. Changes in the climate system that are already taking place have been reported at the global level in the recently released Fifth Assessment Report of the IPCC (IPCC, 2014).

2.1.1 Temperature

There is strong evidence to suggest that Southern Africa is getting warmer. Since the mid-20th century, most of the region has experienced an increase in annual average, maximum and minimum temperatures. A rise between 0 and 2°C of the average annual temperature has been observed for the largest part of Africa since the start of the 20^{th} century (Box 2), with the most significant warming taking place during the last two decades (CDKN, 2014).

2.1.2 Precipitation patterns

Seasonal rainfall patterns, such as the onset or duration of rains, frequency of dry spells and intensity of rainfall, as well as delays in the onset of rainfall, have changed (Box 2). Western parts of Southern Africa, from Namibia to Angola and the Congo, had less late summer rain in the second half of the 20th century, and Botswana, Zimbabwe and western South Africa have also had modest decreases in rainfall (CDKN, 2014).

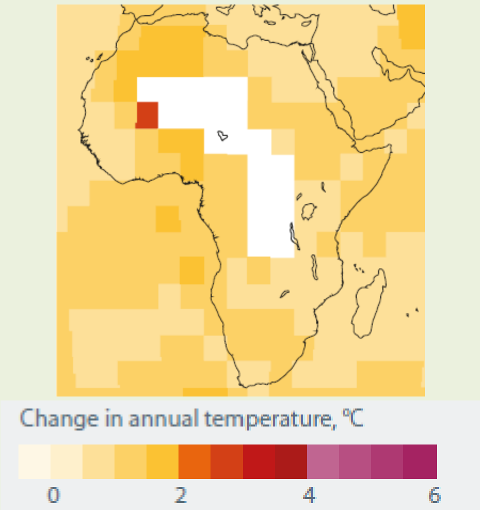
2.1.3 Extreme weather events

More frequent dry spells, coupled with more intense daily rainfall, have implications for surface water management and flood risk (CDKN, 2014). For small islands like Mauritius, extreme climatic events have resulted in mean sea level rise of 1.2mm during the past decade (Chishakwe, 2010).

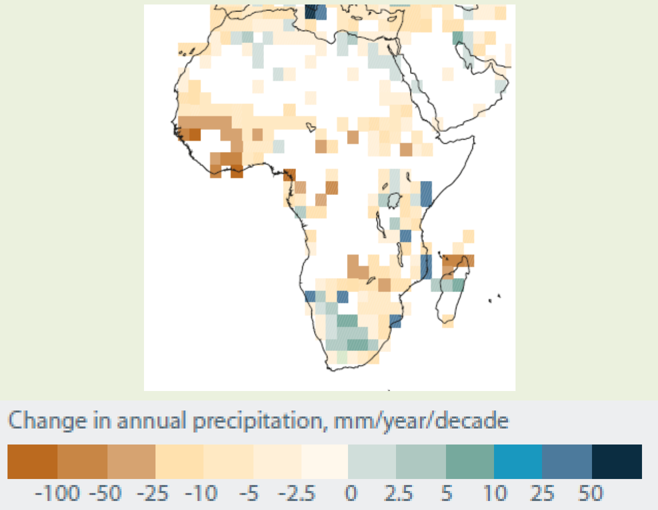
Box 2. **Climate change - Africa**

In this report, we refer to climate change as an alteration in the state of the climate that can be identified by changes in the mean and/or the variability of its properties and that persist for an extended period, typically from decades to millennia. It refers to any change in climate over time, whether due to natural variability or, as increasingly demonstrated, as a result of human activity.

Change in average annual temperature in Africa: 1901-2012



Change in average annual rainfall in Africa: 1951-2012



Sources: CDKN, 2014; IPCC, 2007

2.2 Projections for the future

While there is lack of agreement concerning projected trends for the region as a whole (IPCC, 2014), it is recognized that the impact of extreme events is to be felt more strongly than the impacts of changing weather means in the medium-term (Corbera *et al*., 2006). There may also be large geographical variations in the climate variables both between- and within countries (Table 2).

2.2.1 Temperature

A warmer climate is generally predicted in all Southern African countries by the middle or the end of the 21st century, with particularly rapid warming expected in semi-arid south-western parts of Southern Africa (CDKN, 2014; Davis, 2011). By 2050, average annual temperature is projected to have risen by 1.5-2.5 °C in the southern parts of the region and by 2.5-3.0 °C in the north compared to the 1961-1990 average (Ragab & Prudhomme, 2002).

2.2.2 Precipitation patterns

Estimates suggest some consensus for a small increase in summer rainfall over south-eastern parts of the subcontinent and slightly drier conditions in south-western South Africa, the central and northern regions of Zimbabwe, Zambia and western Mozambique by the latter half of the 21st century (Davis, 2011; Vincent *et al*., 2013). In Botswana, Lesotho, Malawi and Namibia, both wet and dry scenarios are possible depending on the climate model used. Swaziland's climate is expected to become wetter (Kandji *et al*., 2006).

2.2.3 Extreme weather events

Although most parts of Southern Africa have observed increases in extreme rainfall, projections indicate that during the 21st century and beyond, the risk of severe droughts in the drier south-western parts will be high and there will be an increase in the area affected by drought (IPCC, 2014). There is uncertainty concerning projected changes in incidence of cyclones originating in the southwest Indian Ocean, which led to serious floods in the 20th century (CDKN, 2014).

Table 2. Differential vulnerability to climate change: Angola (AN), Botswana (BT), Democratic Republic of Congo (DRC), Lesotho (LE), Madagascar (MD), Malawi (MW), Mauritius (MA), Mozambique (MZ), Namibia (NM), Seychelles (SY), South Africa (SA), Swaziland (SW), Tanzania (TA), Zambia (ZM) and Zimbabwe (ZI). Green = affected countries.

Climate-related challenges	AN	BT	DRC	LE	MD	MW	MA	MZ	NM	SY	SA	SW	TA	ZM	ZI
Changing (weather) patterns															
Decrease in rainfall		*x*		*x*		*x*		*x*	*x*		*x*			*x*	*x*
Increase in rainfall		*x*		*x*		*x*			*x*			*x*			
Seasonal shifts in rainfall	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*
Warming trend	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*
Sea level rise	*x*				*x*		*x*	*x*	*x*	*x*	*x*		*x*		
Increased incidence of extreme events															
Drought	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*
Cyclones					*x*		*x*	*x*							
Floods	*x*												*x*		
Wildfires	*x*	*x*	*x*		*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*

Sources: AGRA, 2014; Chishakwe, 2010; Eriksen et al., 2008; SADC Regional Agricultural Policy, 2011

2.3 Implications for smallholder agriculture

Most Southern African small-scale farmers plan agricultural production based on rainfall (AGRA, 2014), making them vulnerable to increasingly variable weather patterns and other climate-related changes (Parry & Carter 1989; Reilly 1995; Smit & Skinner, 2002). Added to this are many other non-climatic stressors (*e.g*. poor and depleted soils; failed economic policies; social- and political conflict and the HIV/AIDS epidemic) that occur simultaneously and interact in complex ways; thus intensifying existing agricultural problems (De Waal & Whiteside, 2003; Eriksen *et al*., 2008; Van Rooyen & Sigwele, 1998). Nonetheless, changes in mean temperature and precipitation and increased frequency of extreme weather events are projected to have significant direct impacts on the productivity of cropping- and livestock production systems; thus impinging on food security in the region (Corbera *et al*., 2006). Climate change is also projected to have indirect impacts on the availability and prices of food and on income generated from agricultural production at farm and national levels (Hachigonta *et al*., 2013).

2.3.1 Impact on cropping systems

Most of the work done on agricultural impacts of climate change has focussed on cropping systems (Thornton *et al*., 2009). The general consensus among crop effects research appears to be that negative effects on crop yields and productivity in Southern Africa are driven mainly by increased temperature and subsequent water stress (see, e.g. Challinor *et al*., 2007; Schlenker & Lobell, 2010; Vincent *et al*., 2013). There is also evidence of higher risk of pests and diseases of crops under climate change which will increase the likelihood of crop failure- for example due to Maize Streak Virus and Cassava Mosaic Virus in areas where rainfall increases (Harvey *et al*., 2014; Morton, 2007). In addition, more frequent extreme events (*e.g.* heat waves) can damage crops at particular developmental stages, making the timing of agricultural operations more difficult, and reducing incentives to cultivate (Porter & Semenov, 2005).

Nevertheless, the impacts of climate change may vary across locations and crops; some places will be impacted negatively while other places will benefit (Zinyengere *et al*., 2014). For example, the growing seasons in certain areas may lengthen under climate change (*e.g.* parts of Mozambique), due to a combination of increased temperature and rainfall changes (Thornton *et al*., 2006). Furthermore, positive and negative impacts on different crops may occur in the same farming system: Agrawala *et al*. (2003) suggest that in Tanzania; impacts on maize, the main food crop, will be strongly negative for smallholders while impacts on coffee and cotton cash crops may be positive.

Research on the biophysical effects of climate change on the yields of specific crops show that results may vary depending on the Global Climate Model (GCM) and emission scenario used (Box 3). A study by Hachigonta *et al.* (2013), for example, focuses on scenario A1B, using results from four GCMs to illustrate the range of potential effects on key crops across Southern Africa. The A1B scenario describes a future world of rapid economic growth, global population that peaks in mid-century, and the introduction of new and more efficient technologies, along with a balanced use of energy sources (SRES, 2000). Selected outputs of this modelling study are mapped in the following sets of figures, which compare yields for 2050 under climate change with the yields assuming an unchanged (2000) climate.

Box 3. **Climate models and scenarios**

Global Climate Models (GCMs) are the tools that model the physics and chemistry of the atmosphere and its interactions with oceans and the land surface and can simulate climate under a range of emission scenarios.

A scenario is a description of a possible future state of the world, which can be based on changes in the climate system, socio-economic circumstances or other potential changes. Each scenario has an associated emission pathway, which describes the amount of GHGs emitted through human activity in the future. The 4th Assessment Report of the IPCC has three scenarios of greenhouse gas emissions pathways: B1 is a low-emission scenario, while A2 and A1B are higher-emission scenarios. GCMs can use these future emissions to project future climate change. Often, a set of scenarios is adopted to reflect the possible range of future conditions.

Sources: Davis, 2011; Hachigonta et al., 2013; SRES, 2000

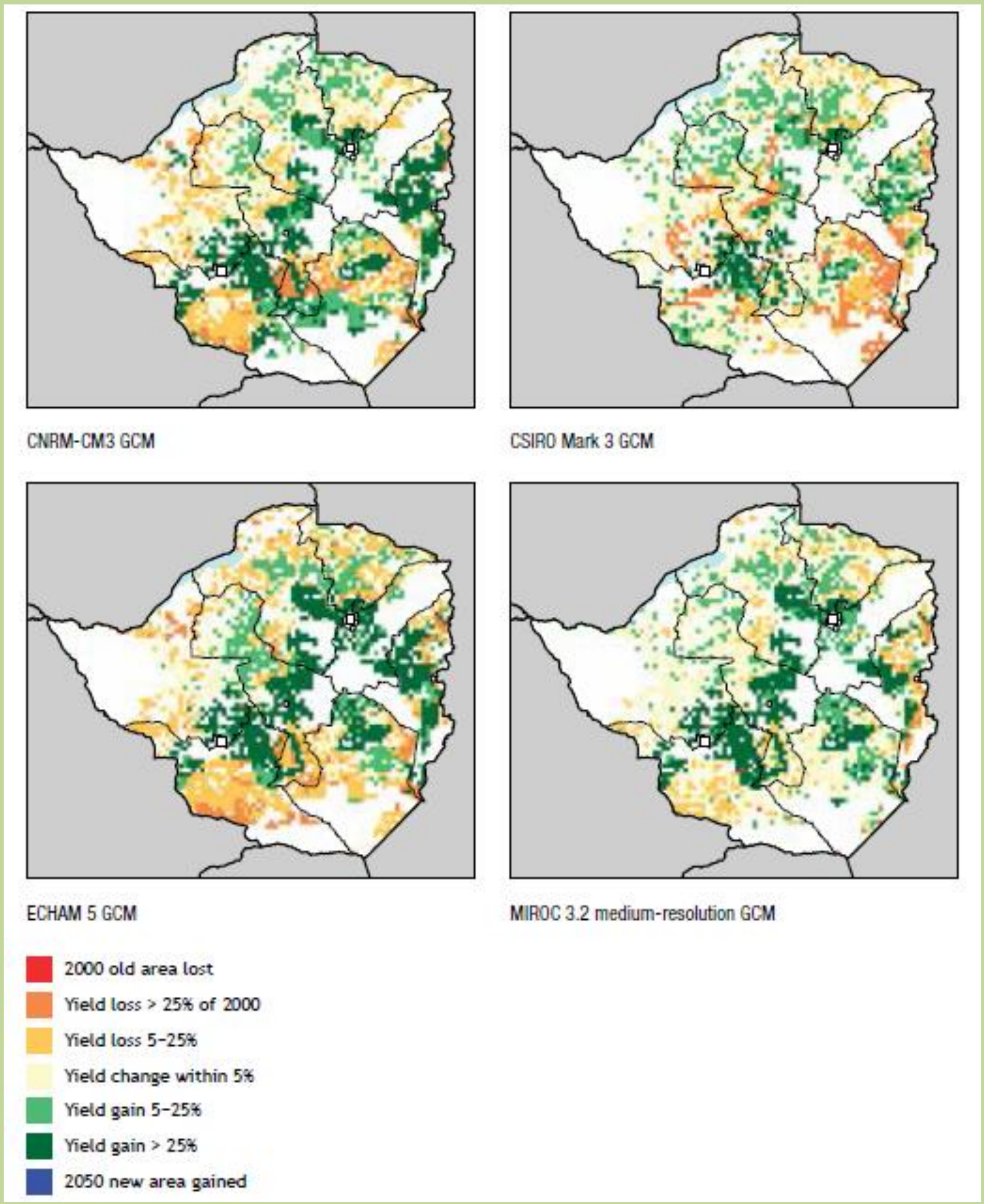


Fig. 5 Yield change under climate change: Rain-fed maize in Zimbabwe, 2000–2050, A1B scenario using results from four GCMs (CNRM-CM3, CSIRO Mark 3, ECHAM 5, and MIROC 3.2 medium resolution).[1]

Zimbabwe is a leading producer of maize in Southern Africa (*c.f.* Table 1). For maize yields in the country, the results of Hachigonta *et al*. (2013) show that all four GCM models predict some yield gains (up to 25% from the baseline) in most of the traditional maize-producing regions, as well as areas of declining yield (mostly between 5 and 25%) and a few cases of lost land (Fig. 5). The CNRM, ECHAM, and CSIRO GCMs show areas with yield losses of greater than 25% in southern Zimbabwe.

[1] CNRM-CM3 is a National Meteorological Research Center–Climate Model 3. CSIRO Mark 3 is a climate model developed at the Australia Commonwealth Scientific and Industrial Research Organisation. ECHAM 5 is a fifth-generation climate model developed at the Max Planck Institute for Meteorology in Hamburg. MIROC 3.2 is the Model for Interdisciplinary Research on Climate, developed at the University of Tokyo Center for Climate System Research.

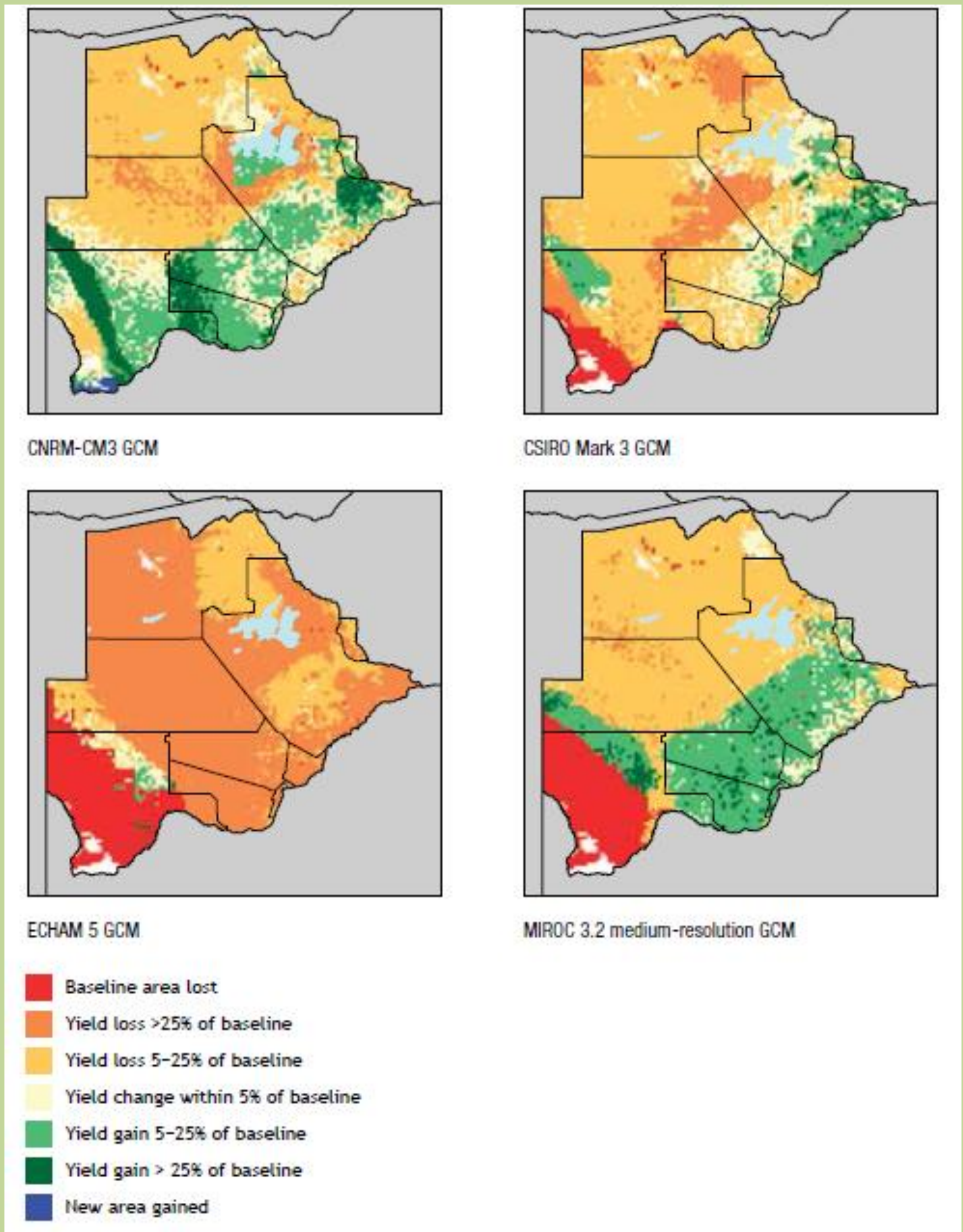


Fig. 6 Yield change under climate change: Rain-fed sorghum in Botswana, 2000–2050, A1B scenario using results from four GCMs (CNRM-CM3, CSIRO Mark 3, ECHAM 5, and MIROC 3.2 medium resolution).

Botswana's climate greatly limits the country's food production capacity, and therefore, livestock production is the mainstay of country's rural population. Nevertheless, sorghum is an important agricultural commodity, accounting for a relatively large portion of Botswana's harvested land area (*c.f.* Table 1). The modelled results of the study by Hachigonta *et al.* (2013) show that projected impacts of climate change on the production of rain-fed sorghum are variable (Fig. 6). While all the GCMs show yield losses ranging from 5 to 25% in the north-central districts, CNRM-CM3 and MIROC 3.2 both show some yield gains in parts of the central district and in almost all of the southern districts. ECHAM 5, MIROC 3.2, and CSIRO-Mark 3 show losses of land compared to the baseline, whereas the CNRM-CM3 GCM projects mostly yield increases and even some addition of arable land.

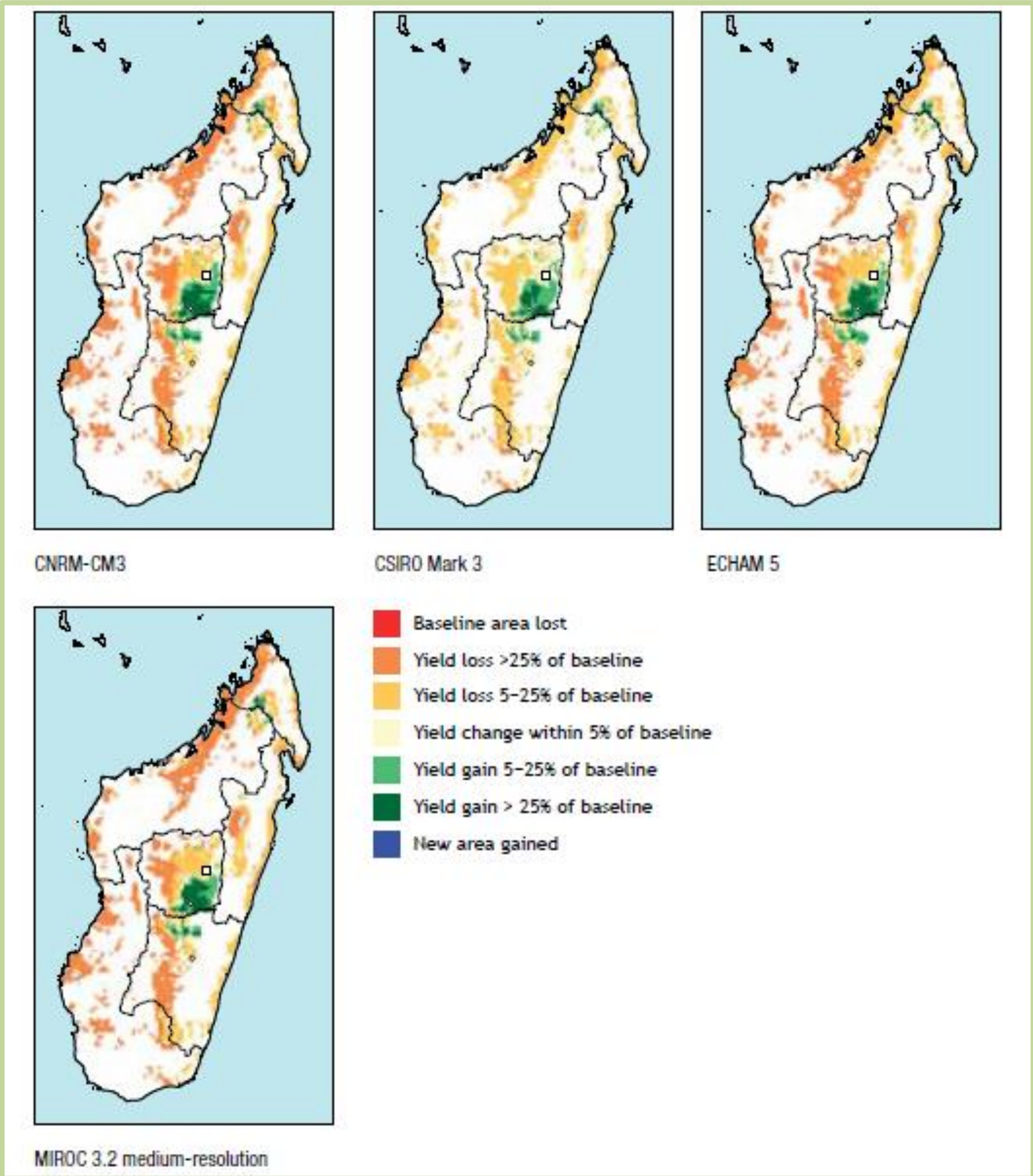


Fig. 7 Yield change under climate change: Irrigated rice in Madagascar, 2000–2050, A1B scenario using results from four GCMs (CNRM-CM3, CSIRO Mark 3, ECHAM 5, and MIROC 3.2 medium resolution).

Much of Madagascar's agricultural production is centred on rice (*c.f.* Table 1). Hachigonta *et al*. (2013) show that, under various GCMs, yield losses are predicted for rice throughout the island (Fig. 7). In the CSIRO Mark 3 model, most of the losses appear to be less than 25%, whereas in the other models the losses appear to be mostly greater than 25%. But there are two areas that appear to show some yield gain; near the capital of Antananarivo and in the north. Both of these areas of yield gain are in high elevations with colder temperatures- conditions which impede rice yields. With warmer temperatures as a result of climate change, rice is predicted to grow much better in these environments.

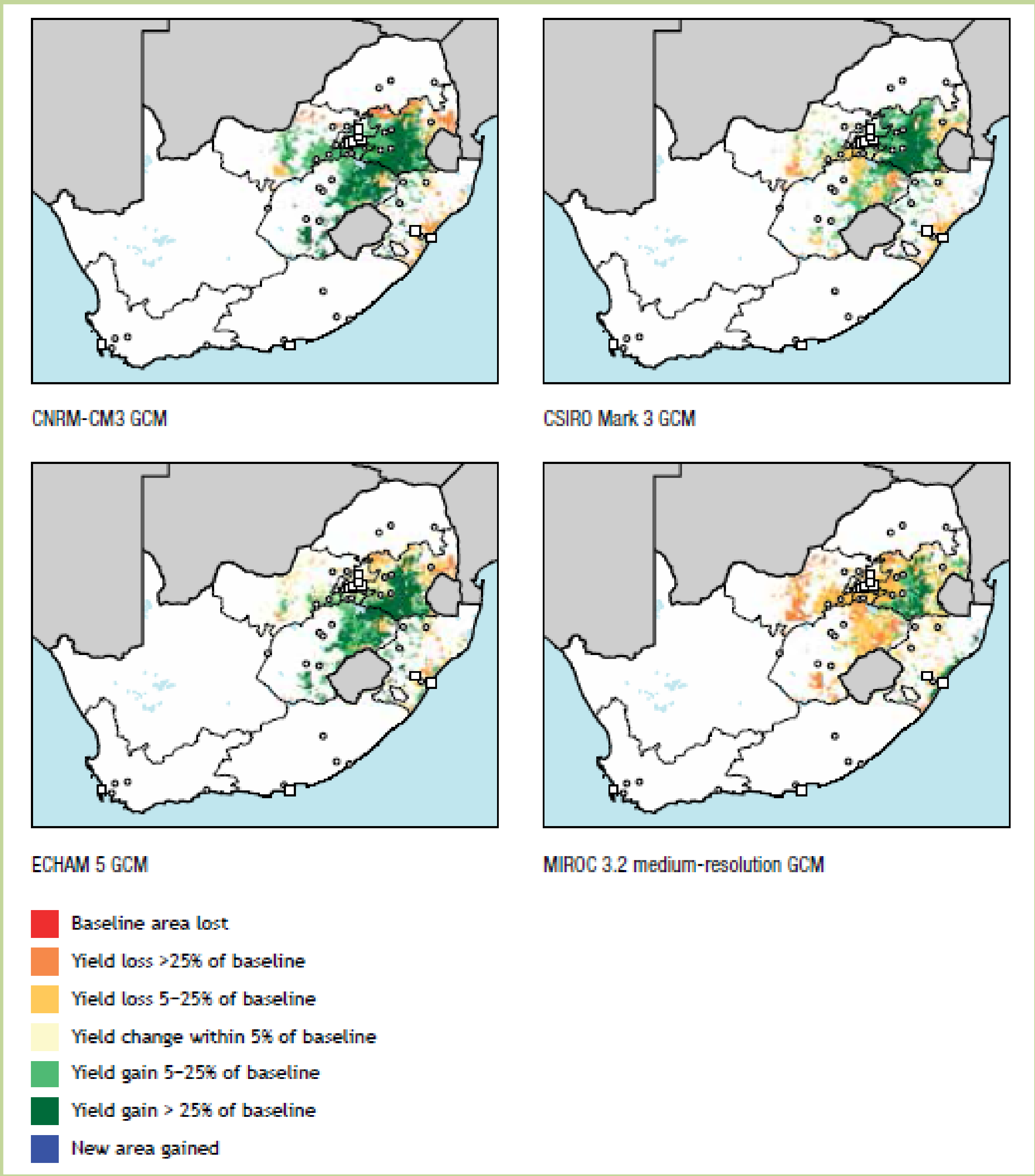


Fig. 8 Yield change under climate change: Rainfed wheat in South Africa (excluding Western Cape), 2000–2050, A1B scenario using results from four GCMs (CNRM-CM3, CSIRO Mark 3, ECHAM 5, and MIROC 3.2 medium resolution).

South Africa is a leading producer of wheat in Southern Africa (*c.f.* Table 1). Figure 8 shows that three out of the four GCMs used in the study by Hachigonta *et al*. (2013) predict large areas of increased wheat yield in the northeast of the country (Free State and Mpumalanga provinces). The models did not assess yield changes for wheat in the Western Cape, but it appears likely that yields will be threatened by increased temperatures and lower levels of rainfall projected for this region.

2.3.2 Impact on livestock systems

While livestock systems in southern Africa are extremely dynamic, climate change can be expected to have several negative impacts on pastoral, agro-pastoral and mixed crop-livestock systems (Thornton *et al*., 2009) (Table 3). The quantity and quality of animal feeds and grazing areas will be affected by changes in herbage growth brought about by changes in atmospheric CO_2 concentrations and temperature (Hopkins & Del Prado, 2007; Silvestri *et al*., 2012). The animals themselves may suffer from heat stress as a result of higher temperatures, causing a decline in productivity, conception rates and health (Morton, 2007; Thornton *et al*., 2009). In addition, pest and disease outbreaks due to flooding, for example, may increase the likelihood of livestock mortality (Harvey *et al*., 2014).

Despite the negative impacts of climate change on livestock outlined in Table 3, in marginal areas of Southern Africa, climate change may drive the transitions from mixed crop-livestock farming to pastoral systems (Jones & Thornton, 2009). This is already occurring in some places (*e.g.* parts of South Africa) where shorter growing periods and increasingly erratic rainfall deter farmers from investing in crops considered too risky in those marginal environments (Thomas *et al*., 2007).

Table 3. Impacts of projected climate change on livestock production in Southern Africa

Direct impacts	Changes in forage quality and quantity Changes in water quality and quantity Reduction in livestock productivity due to heat stress Increased prevalence of 'new animal diseases' Increases in temperature during the winter months could reduce the cold stress experienced by livestock, and warmer weather could reduce the energy requirements of feeding
Indirect impacts	Increased frequency of disturbances, such as wild fires Changes in biodiversity and vegetation structure

Source: Davis, 2011

2.3.3 Impact on biophysical resources

Climate change will amplify existing stress on water availability in agricultural systems of semi-arid environments (Field *et al*., 2014). Rising temperatures may increase irrigation water requirements of major crops (Morton, 2007) and drive up water demand by livestock (Silvestri *et al*., 2012; Thornton *et al*., 2009). For example, the increased reliance on groundwater in the future in Botswana for the cattle sector could lead to problems associated with the sustainability of water resources in the country (Masike, 2007). Moreover, it is expected that in coastal countries; rising sea levels will lead to saline intrusion, contaminating freshwater coastal aquifers along the coasts (Chishakwe, 2010).

Although there are still very few impact studies for tropical grasslands or rangelands, it is expected that the quality of semiarid rangelands will be negatively affected (Morton, 2007). Global warming and accompanying hydrological changes are also likely to affect soils in complex ways, including soil fertility and propensity for erosion (Morton, 2007). Additionally, much prime agricultural land located in the coastal plains of Southern Africa might be lost to rising sea-levels (Chishakwe, 2010).

3. Farmers' perceptions of climate change

As much as science provides evidence of climate change, local understandings- including the cultural and religious dimensions that have traditionally been central to climate prediction and analysis- should not be ignored (Gandure *et al*., 2013). To this end, several authors have drawn attention to the importance of researching farmers' indigenous knowledge and perceptions of climate change (Mapfumo *et al*., 2015; Seely, 1998; Verlinden & Dayot, 2005), in order to better understand local response measures (Davis, 2011). In addition, awareness of possible discordance between farmers' and policy-makers' perceptions of climatic changes and the associated risks may result in more effective agricultural adaptation research and practical agricultural adaptation planning (Patt & Schröter, 2008).

3.1 Factors that influence farmers' perceptions

Psychological research shows that the diversity in our understandings about climate change can be attributed to how, and from whom, we learn about the phenomenon (Clayton *et al*., 2015). In this vein, 'perception' can be described as referring to a range of beliefs, judgments and attitudes that depend on one's context and its characteristics (Heathcote, 1969; Slegers, 2008) (Fig. 9). It has been suggested that farmers are more likely to perceive climate change when they have more farming experience (Maddison 2006; Silvestri *et al*., 2012). Slegers (2008) indicates that previous experiences of poor seasons, for example, may bring back memories and be responsible for how farmers tend to describe different season types. Weber (2010) argues that knowledge concerning climate change is often indirectly influenced by the media from events occurring in distant areas rather than local events. Farmers are also likely to be influenced by the perceptions of their peers and other people in terms of climate change and variability (Silvestri *et al*., 2012). For example, extension advice is a factor that is believed to create awareness about climate change. Farmers with access to extension services are likely to perceive changes in the climate because extension workers provide information about climate and weather (Gbetibouo 2009; Maddison 2006; Silvestri *et al*., 2012).

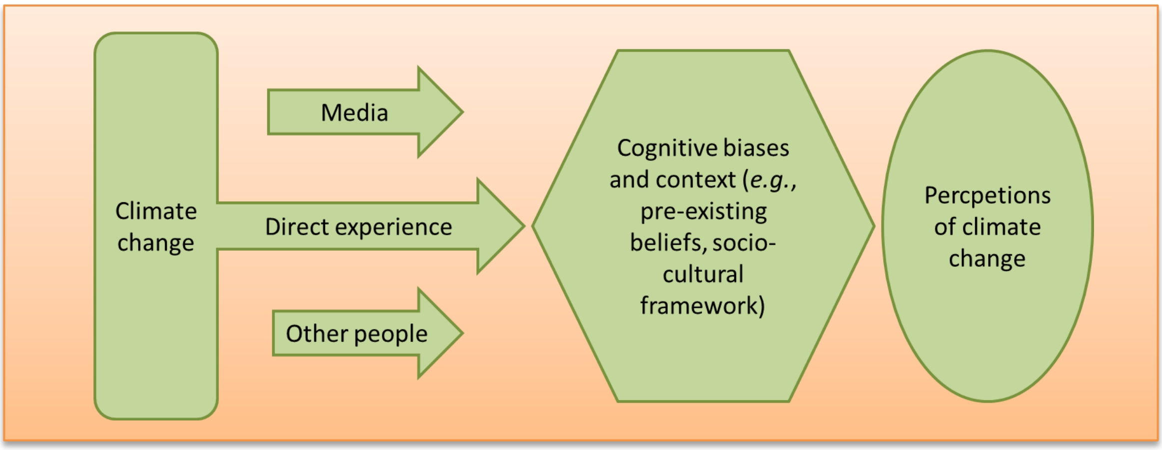


Fig. 9 A simplified model of the way people perceive climate change. Cognitive biases and the local context moderate the relationship between the direct and indirect experiences on the one hand, and perceptions on the other (based on Clayton *et al*., 2015).

Other studies confirm that while farmers report to be observing climate change, their perceptions of climate change are in fact more related to recent experience, as moderated by other factors (Hansen *et al*., 2004; Smit *et al*., 1996) (Fig. 9). Thus, one must also look to other sources of influence on beliefs and attitudes related to climate change. Ample research suggests that perceptions and experiences of risk are heavily moderated by cognitive and context-specific biases (*e.g.* socio-cultural framework) (Below *et al*., 2014; Clayton *et al*., 2015; Davis, 2011) (Fig. 9). Therefore, farmers' perceptions of climate change are influenced by personality characteristics, pre-existing beliefs, cultural (including the spiritual worldview) values, mental shortcuts, emotions, environmental cues, social experiences and other contextual factors (Battisti & Naylor, 2009; Clayton *et al*., 2015; Thornton *et al*., 2011). Furthermore, misperceptions persist because people interpret messages in light of previous experience, beliefs, values and expectations, and tend to filter new information through existing conceptual frameworks (Clayton *et al*., 2015). This implies that farmers within the same community may perceive climate change in different ways (Moyo *et al*., 2012).

3.2 Perceived causes of climate change

Local farmers' perceptions reveal a more complex picture of the causes and effects of climate-related change than suggested by the scientific viewpoint alone (Klintenberg *et al*., 2007). In some instances, the two viewpoints converge, as revealed by a study in Namibia, where farmers attributed local land degradation to overgrazing and low rainfall, which corresponded with the results of Namibia's national-level monitoring system (Klintenberg & Seely, 2004). Often, however, cultural and spiritual beliefs in addition to environmental factors are perceived to be associated with the causes of climatic variability (Gandure *et al*., 2013). Studies in Zimbabwe and Zambia, for instance, found that while a large proportion of farmers attributed weather changes to natural climatic processes, many also associated changes in climate with social and spiritual factors (Davis, 2011; Moyo *et al*., 2012). Farmers asserted that causes of climate change have been due to an erosion of religious values and beliefs and the wrath of cultural spirits and God who have meted out punishment to Zimbabwe: "[…] we are following the modern world so much that we no longer even go to '*Njelele*', the rainmaking shrine to pray to our ancestors for a good rainy season […]" (Moyo *et al*., 2012: 324). Similarly, a survey in southern Mozambique revealed that most respondents identified supernatural factors as being causes of climate change (Fig. 10), followed by the normality of change, their own farming practices and pollution from outside the community (Patt & Schröter, 2008).

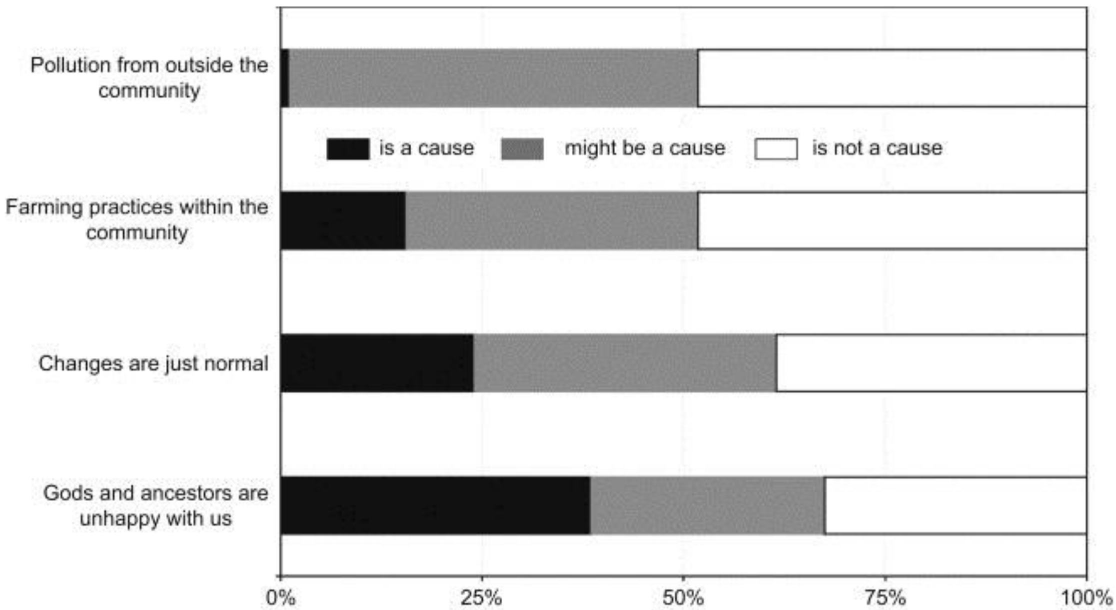


Fig. 10 Beliefs about causes of climate change in southern Mozambique. The question which participants answered was: 'Please indicate whether you believe each of the following is a cause, might be a cause, or is not a cause of any climate changes you have noticed' (Patt & Schröter, 2008).

3.3 Perceived changes in climate

While there is agreement that farmers often perceive the signs of climate change (Li *et al.*, 2013), the literature is less unanimous with regard to the nature of farmer perceptions. Some studies have found that farmers perceive a trend of worsening climatic problems (Silvestri *et al*. 2012; Tambo & Abdoulaye 2012), or that perceptions among farmers are heterogeneous, while others report that farmers witnessed no important long-term changes in climatic parameters (Reid & Vogel 2006). For example, a recent study covering a range of southern Africa countries found that all farmers across all the countries have observed a change in climate over the last 10 years compared with the 1990s. The most widespread observed change was unpredictability of rainfall– with changes in the timing, duration and intensity of rain. Lower rainfall was observed in some places, as well as higher temperatures (Vincent *et al*., 2013).

3.4 Scientific evidence compared to farmer perceptions

Smallholder farmers in Southern Africa often perceive climate change in a broader context, considering things such as agricultural practices, human actions and history- aspects that scientists do not generally consider (Newsham & Thomas, 2011). In Botswana, for example, Kinlund (1996) and Dahlberg (2000) compared scientific thinking with local land users' perceptions regarding climate-related environmental change and land degradation. Findings suggest that farmer perceptions can provide valuable insights into the extent and impact of changes, many times contradicting the common views held by other stakeholders, *e.g.* the scientific community and policy makers. It is important, therefore, to review discrepancies between local perceptions and scientific evidence with this in mind (without romanticising the latter, however, given concerns about contemporary farming practices as a driver of land degradation) (Newsham & Thomas, 2011).

3.4.1 Consistency between farmer perceptions and climatic data

Sometimes, farmers' perceptions of climate change appear to be in line with actual climate data. A study in Zimbabwe and Zambia, for example, found that the greater proportion of farmers interviewed have been aware of increasing climate variability over the past five years, with recent floods and excessive rains cited as evidence (Davis, 2011). It was found that the farmers' perceptions regarding flood incidence in the study area in the 1999/2000 season corresponded with available rainfall data which showed that the 1999/2000 season was a La Niña season (Davis, 2011).

3.4.2 Inconsistency between farmer perceptions and climatic data

There are also examples in the literature of instances where farmers' perceptions seem to differ from meteorological evidence. A study in South Africa's Free State, for example, found that farmers noted a delay in the onset of rains in recent years despite the fact that this was not demonstrated in the meteorological data (Gandure *et al*., 2013). Elsewhere, research in selected districts of Zimbabwe by Moyo *et al*. (2012) found that farmer perceptions contradicted available evidence, with the majority of the past seasons perceived as 'poor' by farmers, but 'good' according to climatology data (Fig. 11).

3.4.3 Causes of inconsistency

There are many possible explanations for the discord between farmers' perceptions and meteorological evidence. One is that the stakeholders involved use different underlying systems of reference. For example, in the study by Moyo *et al.* (2012), any season that negatively affected the farmers' livelihoods was described by them as 'poor'. Even though a total of 827 mm of rainfall was measured during the 2007/8 cropping season (classified as being 'average' in climatological records); long dry spells in the month of February managed to negatively affect crop yields, and the season was therefore classified as 'poor' by farmers (Moyo *et al*., 2012). Such anecdotes seem to indicate that land users do not necessarily consider poor seasons strictly in meteorological terms, but evaluate cropping seasons based on effects on harvests (*i.e.* livelihoods). Thus, even those seasons that might have good rainfall (in terms of climate data) can be termed 'poor' by farmers (Moyo *et al*., 2012).

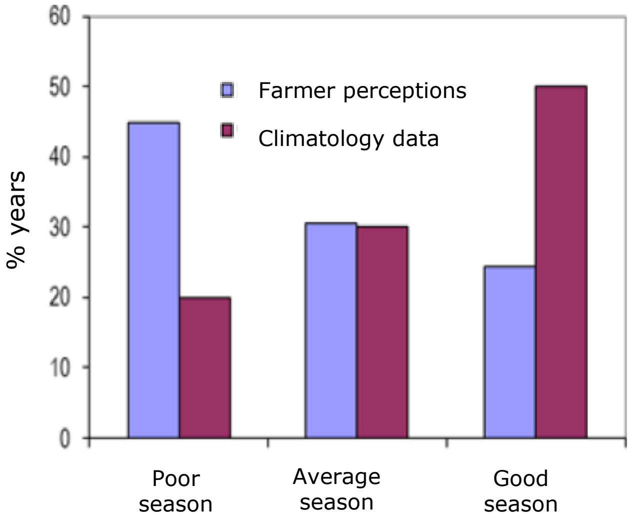


Fig. 11 Hwange district farmers' perceptions of the frequency of good, average and poor seasons compared with the reality of climate data for the past 10 years in semi-arid Zimbabwe (Moyo *et al*., 2012).

Similarly, a study in the southern highlands of Tanzania found differing reference systems among farmers and scientists. While farmers depended strongly upon the distribution of water flows during important stages of the cropping period, the trends of distributional parameters were not sufficiently captured by existing scientific climatological studies which model mean annual parameters (Below *et al*., 2014).

Studies also seem to show that farmers tend not to distinguish between climate change and climate variability (Moyo *et al*., 2012; Osbahr *et al*., 2011). Their views on climate change seem to be based more on recent, short-term variations and extreme events (years) with reduced crop productivity rather than long-term changes (Davis, 2011; Gbetibouo, 2009). The over-estimation of poor seasons in some cases insinuates that farmers perceive higher risk than actually exists within their localities (*e.g.* Moyo *et al*., 2012).

4. Farmers' responses to climate change

Farm-level responses to climate change are determined by the climatic stimuli and decision-making environment (Smit & Skinner, 2002). The decision-making context is influenced by opportunities and constraints that in turn are shaped by various factors beyond the farm household scale at the community, landscape, and regional levels (such as agro-ecological, economic, political and institutional circumstances) (Tittonell *et al*., 2010, 2014; Smit *et al*. 1999; Bryant *et al*. 2000). Farmers' responses to climate variability and change can be categorised as 'coping' or 'adaptation' (Eriksen *et al*., 2011; Vincent *et al*., 2013).

4.1 Coping *vs.* adaptation

Coping refers to short-term measures to cover immediate needs and ensure survival in times of crisis or stress (Ellis, 2000). As a response, coping is reactive rather than planned, and therefore does little to address underlying vulnerability (Vincent *et al*., 2013) (Box 4). While coping strategies may be appropriate if the farming system reverts to its usual state following a shock, this is unlikely with climate change-related stresses, which are projected to get worse. For this reason, adaptation has evolved as a process of adjustment to actual (reactive adaptation) or expected climate (anticipatory or planned adaptation) and its effects (Field *et al*., 2014). Unlike coping, adaptation therefore typically refers to longer-term changes in behaviour and practices which are more likely to reduce underlying vulnerability to climate change (Vincent *et al*., 2013) (Box 4).

Coping capacity is viewed as a prerequisite for adaptive capacity (Berman *et al*., 2012), even more so in Africa (Cooper *et al*., 2008). Studies show that without adaptation, climate change is generally problematic for agricultural production; but with adaptation, vulnerability can be reduced and opportunities may be exploited (Rosenzweig & Parry 1994; Fankhauser 1996; Smith 1997; Smit & Skinner, 2002).

***Box 4*. Responding to shocks: coping or adapting?**

A family suffering damage to their house after a flood might seek emergency assistance, diversify their income or migrate elsewhere to save money for rebuilding the same house. This would be a *coping* strategy for immediate survival purposes. However, rebuilding the house to the same specifications does not reduce the family's vulnerability to future floods, from which they would probably suffer the same adverse effects. Reactive *adaptation*, therefore, might involve rebuilding the house to new specifications which take into account flood risk; for example, by building on stilts, or using more resistant materials (bricks rather than mud).

Source: Vincent *et al*., 2013

4.2 Coping and adaptation in Southern African smallholder agriculture

Given the widespread recognition of climate change by Southern African farmers (Chapter 3), it is not surprising that a range of coping and adaptation strategies have been adopted. Farmer responses to cope with shocks such as drought (Kinsey *et al*.,1998; Roncoli *et al*., 2001) and floods (Few, 2003) have been widely covered in the literature, and climate-related coping strategies such as diversification, drawing on social safety nets and asset sales have been documented in rural communities across Southern Africa, for example in Malawi (Fisher *et al*., 2010), Mozambique (Eriksen & Silva, 2009), South Africa (Reid & Vogel, 2006; Thornton *et al*., 2007), Zambia (Mubaya *et al*., 2012) and Zimbabwe (Kinsey *et al*., 1998; Mubaya *et al*., 2012). Commonly documented agricultural adaptations include diversifying livestock and cropping activities, changing crop varieties and planting dates, using irrigation, planting trees, soil conservation and supplementing livestock feed (Bryan *et al*., 2009; Gbetibouo, 2009; Ringler *et al*., 2010).

Drawing heavily on the work of Below *et al*., 2010 and Vincent *et al*., 2013, this chapter divides farmer coping- and adaptation responses to climatic drivers into six broad categories: (1) crisis response; (2) modifying farming practices; (3) modifying crop and animal types, varieties and breeds; (4) natural resource management; (5) livelihood diversification and (6) knowledge management (summarised in Table 4). The relative importance of the categories is likely to vary given the differential constraints faced by farmers, the biophysical characteristics of their farms, and the variable effects of climate change, among other factors (Below *et al*., 2010). Nevertheless, it should be noted that the borders between coping and adaptation, and even between the categories themselves, are sometimes a bit fuzzy. There are in fact a lot of relationships and interconnections between the different strategies.

4.2.1 Crisis response

This category includes coping strategies undertaken by farmers in response to disaster. Ellis (1998) describes the coping behaviour of rural households as following a predictable sequence: when current consumption is compromised, the household first seeks to protect its future income -generating capability by (temporarily) pursuing new sources of income and only in the last resort are assets sold or abandoned to stave off starvation. Resource-constrained subsistence farmers are considered to be particularly likely to take extreme measures as a result of their vulnerability. When hit by a shock, they may be forced to adopt a 'survival strategy' simply in order to cover immediate needs (Devereux, 2008). Invariably, this may imply the sale of household valuables such as livestock, food rationing and withdrawal of children from school (Chamberlin, 2008; Harvey *et al*., 2014). Coping tactics such as these often result in a downward spiral, reducing even further any opportunities for poor farmers to save and invest and thereby climb out of the 'poverty trap' (Tittonell, 2014).

Income diversification

The pursuit of alternative income sources was identified as a crisis response in the literature. In Malawi, farmers were cited as seeking casual labour or piece work (Vincent, *et al*., 2013), while in Zambia and Mozambique farmers admitted to seeking food where paid employment was unavailable. This was done through, for example, emergency assistance schemes and participating in so-called 'food for work' programs run by NGOs to maintain roads, public facilities and irrigation systems (Osbahr *et al*., 2008).

Social support networks

Given the lack of formal safety nets in rural southern Africa, social relationships are particularly critical in times of crisis (Ellis, 1998, 2000). Drawing on reciprocal obligations was found to be the most significant mechanism to buffer disturbance in a study conducted in Mozambique, where most farmers used local connections and family ties to access critical resources (Osbahr *et al*., 2008). For example, the local *Kurhimela* labour exchange mechanism was cited as important for rebuilding houses after storm damage and helping to replant fields after drought (*Ibid*.). Similarly, in Madagascar, a study revealed that many farmers rely on their social safety nets for support, to borrow money or food and obtain post-disaster assistance in rebuilding houses or infrastructure (Harvey *et al*., 2014).

Food rationing

In Madagascar, farmers in three regions reported that one of the most common coping strategies for households dealing with negative impacts on agricultural production and food security was to ration their food or to switch their diet from rice to cassava and other tubers. Some farmers also rely heavily on wild, food plants from communal forests to supplement their diets in times of scarcity (Harvey *et al*., 2014).

Temporary migration

Often, a necessary part of the crisis response was to temporarily decrease the size of the household through temporary migration (Vincent *et al*., 2013) (section 4.2.5).

Table 4. Farmer coping- and adaptation responses in Southern Africa in relation to their main climatic drivers

Main climatic drivers	Risks/ impacts	Response category	Response measures	References
Extreme weather events (*e.g.* droughts and floods)	• Crop failure • Negative impacts on infrastructure • Pest- and disease outbreak	**(1) Crisis response**	Income Diversification	*Vincent et al., 2013; Osbahr et al., 2008*
			Social support networks	*Ellis 1998, 2000; Osbahr et al., 2008; Harvey et al., 2014*
			Food rationing	*Harvey et al., 2014*
			Temporary migration	*Vincent et al., 2013*
			Liquidation of assets	*Harvey et al., 2014; Vincent et al., 2013; Ziervogel, 2004*
			Infrastructural interventions	*Harvey et al., 2014*
Changing precipitation patterns (increased drying/ wetness) & **Rising temperatures** (warming trend)	• Water stress • Heat stress • Reduced crop productivity • Changes in production patterns (*e.g.* growing seasons) • Deteriorated rangeland quality • Shifting habitat ranges • Land degradation • Spread in prevalence of human diseases affecting agricultural labour supply • Increased risk of fire	**(2) Modifying farming practices**	Changing ploughing and planting dates	*Harvey et al., 2014; Stringer et al., 2009; Vincent et al., 2013; Ziervogel, 2004*
			Cultivation of new and/ or marginal land	*Harvey et al., 2014; Vincent et al., 2013*
			Intercropping	*Stringer et al., 2009; Vincent et al., 2013*
			Livestock movement	*Angula, 2010; Stringer et al., 2009; Ziervogel, 2004*
			Livestock feed supplementation	*Angula, 2010; Ziervogel, 2004*
			Pest and disease control	*Angula, 2010*
		(3) Modifying crop and animal types, varieties & breeds	Crop type diversification	*Vincent et al., 2013; Ziervogel, 2004*
			Planting different crop varieties	*Newsham & Thomas, 2011; Vincent et al., 2013*
			Livestock type diversification	*Behnke et al. 1993; IUCN, 2010*
			Rearing different livestock breeds	*Blümmel et al. 2010; Hoffman, 2010; Stringer et al., 2009*
		(4) Natural resources management	Water conservation	*Mbilinyi et al. 2005; Gandure et al., 2013; Vincent et al., 2013; Ziervogel, 2004*
			Soil conservation	*Rockström et al., 2009; Stringer et al., 2009; Vincent et al., 2013*
		(5) Livelihood diversification	Off/ non-farm work	*Angula, 2010; Harvey et al., 2014; Newsham & Thomas, 2011; Stringer et al., 2009; Vincent et al., 2013*
			Migration	*Gandure et al., 2013; Stringer et al., 2009; Tacoli, 2009*
		(6) Knowledge management	Indigenous early warning systems	*Below et al., 2010; Newsham & Thomas, 2009; Zuma-Netshiukhwi et al., 2013*

Liquidation of assets

Downsizing, abandonment and sale of mobile (*e.g.* agricultural implements, household possessions and livestock) or fixed assets (*e.g*. land, house) are extreme measures taken by farmers to deal with crises. Farmers in Malawi reported resorting to selling both mobile and fixed assets, including land (Vincent *et al*., 2013). In Lesotho, a study revealed that despite the high value placed on livestock by local farmers, a response to below normal rainfall was to sell animals rather than have them perish in the harsh conditions (Ziervogel, 2004). Similarly, pastoral communities in Botswana use their social networks to facilitate the sale of their livestock at onset of drought (Stringer *et al*., 2009).

Infrastructural interventions

In times of flooding, farmers in Madagascar reported to have built diversion ditches to remove water from fields (Harvey *et al*., 2014).

4.2.2 Modifying farming practices

Modifying farming practices and cultivation techniques is one response to try and maintain production levels under changing climate conditions. Particular practices observed included changing cropping habits such as planting dates, locations and techniques (intercropping) and animal husbandry practices such as migration and feeding (Vincent *et al*., 2013).

Changing ploughing and planting dates

To minimise the threat to their livelihoods, one of the most widespread farmer responses to increasing variability of the onset of rains is to adapt the timing of ploughing and planting accordingly (Stringer *et al*., 2009; Vincent *et al*., 2013). Studies have shown that in Swaziland, Zimbabwe, Zambia and Mozambique, for example, it has now become common to plant maize as soon as the rains arrive in order to increase the chances of the maize producing cobs before rainfall ceases (Vincent *et al*., 2013; Stringer *et al*., 2009). In Lesotho, crops are planted earlier in the case of above-normal rainfall (Ziervogel, 2004). In Free State, South Africa, some farmers have shifted their planting dates due to later onset of rains. For example, maize and beans are now planted in November instead of September/October. Coupled with this shift, the same farmers are also spreading risk by planting twice and only when it rains (Gandure *et al*., 2013).

Cultivation of new and/ or marginal land

With declining production levels, farmers are increasingly pushed to find new land to cultivate. In many cases, however, this is difficult to do without encroaching on ecologically sensitive areas. In Zimbabwe and in Mozambique, for example, farmers have been extending their fields to wetland areas and water ways in search of better soil moisture as a precaution against drought (Vincent *et al*., 2013). Similarly in Swaziland, extreme weather events are anticipated in advance and different fields planted at different times to minimize risk to the whole crop (Stringer *et al*., 2009). In Madagascar, farmers change the location of crop fields in times of drought (Harvey *et al*., 2014).

Intercropping

Intercropping is a cultivation technique whereby two or more crops are planted in the same field. It has the advantage of allowing greater production from the same land, while not causing additional soil degradation, as the two crops will require different nutrients and can be mutually beneficial to each other (Vandermeer, 1992; Vincent *et al*., 2013). Intercropping has been found to be a common response strategy in Malawi, where farmers are increasingly intercropping their tea with maize as a risk management mechanism, to ensure that even if one crop fails there is another one from which they can make a living (Vincent *et al*., 2013). In addition, increased pressure on land and vulnerability to climatic hazards such as droughts in Malawi has led farmers to intercrop field peas and pigeon peas to replace beans which cannot tolerate low rainfall (Stringer *et al*., 2009).

Animal migration

A strategy to both reduce sensitivity and increase resilience to climate change and drought through land degradation prevention or remediation is to move herds according to seasonal patterns. In Botswana, pastoral communities use their social networks to facilitate the movement of their livestock at onset of drought (*Mafisa* livestock movement system) (Stringer *et al*., 2009). Similarly, studies have revealed that lack of grazing forces farmers in Lesotho and Namibia to take their animals to other areas for better grazing and water (Angula, 2010; Ziervogel, 2004).

Animal feed supplementation

In times of drought, farmers in Namibia have been found to improve the chances of livestock survival by collecting pods from acacia trees for feeding (Angula, 2010). In Lesotho, some farmers cultivate lucerne and teff as fodder crops since they survive harsh conditions (Ziervogel, 2004).

Pest- and disease control

A worm outbreak associated with flooding in a village in rural Namibia destroyed crops and made it impossible for a majority of households to harvest anything. While farmers usually managed such outbreaks through de-worming and pest control methods of digging trenches around the field and manual removal of insects, it was reported that they were increasingly difficult to control (Angula, 2010).

4.2.3 Modifying crop and animal types, varieties and breeds

In the face of increasing climate variability and gradual changes in average climatic conditions, farmers may reassess the crops and varieties they grow. As the weather becomes warmer, farmers tend to shift towards more heat-tolerant crops. Depending upon whether precipitation increases or decreases, farmers will shift towards water-loving or drought-tolerant crops, respectively (Below *et al*., 2010). Increasingly, farmers may also consider shifting from crop systems to livestock systems or introducing different livestock breeds that are more resistant to drought (Below *et al*., 2010).

Crop type diversification

As with intercropping, farmers may diversify their crop choices in order to maintain production levels and minimize risk. For example, while it was traditionally only planted in the south of Zambia, cassava is increasingly widespread in the country due to its drought-tolerance compared to other common cereals such as maize. Similarly, in Zimbabwe, farmers have been partially returning to the cultivation of drought-tolerant small grains, such as sorghum and pearl millet (Vincent *et al*., 2013). Further south in Lesotho, a study found that in cases of below normal rainfall, farmers planted drought resistant crops, while in cases of above normal rainfall they grew more vegetables as cash crops (Ziervogel, 2004).

Planting different crop varieties

As a result of improved breeding technologies, more seed varieties are available now than in the past. A number of smallholder farmers are turning to hybrid and early maturing varieties in order to maximise yields in ever shorter and unpredictable cropping seasons (Vincent *et al*., 2013). For example in Namibia, one of the most effective documented adaptations to climate variability is the adoption of early-maturing crop varieties, such as pearl millet. Farmers highlighted two main advantages over other pearl millet varieties: a reduced length of time between seeding and harvesting allowing for two millet harvests in good seasons, and lower water requirements, making the variety suitable for low rainfall seasons too (Newsham & Thomas, 2011).

Livestock type diversification

Most Southern African livestock or mixed crop-livestock farmers manage herds that consist of a diversity of livestock species, including some combination of goats, sheep, cattle and donkeys (IUCN, 2010). A diverse herd represents a critical adaptation measure to climate-related changes in vegetation as the different animal types have different grazing preferences, enabling more efficient exploitation of diverse, yet scarce resources (Behnke *et al*. 1993). During drought periods, farmers may shift from cattle to sheep and goat husbandry, as the latter are more prolific and hardy (lower feed requirements and broader feeding habits) (IUCN, 2010).

Rearing different livestock breeds
Blümmel *et al*. (2010) consider traditional breeds and higher genetic diversity to be important for increased resilience of livestock production systems. A widely practiced strategy in the face of drought is for livestock farmers to change to more drought-resistant animal breeds (Stringer *et al*., 2009). Indigenous breeds such as the South African Nguni (Bester *et al*., 2003), which have co-evolved in Southern African systems over millennia and have adapted to the prevalent climatic environments show greater heat tolerance, productivity and feed efficiency, disease resistance (Hoffman, 2010).

4.2.4 Natural resources management
Given the observed changes in the distribution of rainfall across Southern Africa, water availability for agriculture has decreased; making more efficient use- and better management of scarce water resources critical (Harvey *et al*., 2014). Similarly, retaining or enhancing soil quality is essential to ensure nutrient availability for optimal production (Vincent *et al*., 2013).

Water conservation
A number of studies highlight examples of existing indigenous water management techniques. In Malawi, some smallholder farmers are engaging in micro-irrigation activities in their fields where they cultivate vegetables in the dry season (Vincent *et al*., 2013). Evidence from Tanzania and Lesotho indicate that rainwater is harvested to pour over crops (Mbilinyi *et al*. 2005; Ziervogel, 2004). In South Africa's Free State, local farmers use a technique called '*matangwana*' to collect in-field rainwater runoff to support plant growth and also apply mulch as a way of storing soil moisture (Botha *et al*., 2003 in Gandure *et al*., 2013).

Soil conservation
There is evidence that smallholder farmers across Southern Africa are practicing elements of conservation agriculture; a low-input approach based on three principles: mulching, crop rotation and minimum tillage (Rockström *et al*., 2009; Vincent *et al*., 2013). In Malawi, for example, small-scale tea farmers use mulching in the spaces between plants with grass to preserve moisture and reduce water stress for their tea fields (Vincent *et al*., 2013). In Swaziland, annual crop rotations to increase soil fertility and decrease weeds are implemented (Stringer *et al*., 2009). In the livestock systems of semi-arid areas such as Botswana, animal herds are separated to avoid over-grazing on degraded rangeland. In addition, farmers attempt to rehabilitate rangelands cleared of encroaching bushes by resting it and using whole uprooted bushes as fencing or laying broken up bushes on the ground to protect recovering grass from grazing, recycle nutrients and reduce wind erosion (*Ibid*.).

4.2.5 Diversification of livelihood activities
While agriculture is a key source of livelihood in Southern Africa, diversification as a risk management strategy is becoming increasingly important in the context of a changing climate (Bryceson, 2002; Ellis & Freeman, 2004; Vincent *et al*., 2013). The crisis responses mentioned in section 4.2.1 could be considered short-term and temporary examples of diversification. Other strategies outlined above, such as the adoption of different crop- and livestock types, could be considered elements of diversification too. This section, however, focuses on the longer-term diversification of livelihood activities beyond food production (Below *et al*., 2010).

Off/non-farm work
Diversification beyond on-farm activities (crop- and livestock income) into off-farm (agricultural income), and non-farm activities (non-agricultural income) (Ellis, 1998) is common across Southern Africa, with off/non-farm incomes contributing up to 60 to 80% of total incomes in some cases (Bryceson, 2002). The literature shows, for example, that in Zambia (Vincent *et al*., 2013), Malawi (Stringer *et al*., 2009) Namibia (Angula, 2010; Newsham & Thomas, 2009) and Madagascar (Harvey *et al*., 2014), the unpredictability of rainfall has caused farmers to shift away from reliance on agriculture as a key income source towards the development of non-farm activities such as micro-enterprise (*e.g.* tailoring,

handicraft-making in tourist areas and food processing) and off-farm activities such as inter-household labour exchanges and work as agricultural wage labourers on other farms.

Migration

Recent research in Africa shows that farmers have adopted strategies to cope with climate change (*e.g.* recurring drought) that incorporate migration (McLeman & Smit, 2006). The prevalence of short-distance, circular migration in the context of land degradation and desertification is effectively a form of income diversification that may involve the same activity– farming– in different locations, or a temporary engagement in non-farm activities (Tacoli, 2009). Migration decisions can be made as private adaptations at the farm household level or at the public level.

Farmers may also move to urban centres, especially where there is demand for migrant labour, and send home remittances on a regular basis (Tacoli, 2009). Rural youth from Swaziland sometimes seek employment abroad in South Africa (Stringer *et al*., 2009), while in South Africa the rural-urban migration trend is strong amongst the youth too (Grandure *et al*., 2013). In Malawi, on the other hand, intra-rural migration from southern Malawi further north as a result of population pressures on land availability and poverty has been documented (Stringer *et al*., 2009).

4.2.6 Knowledge management

Rural populations have always been deeply cognisant of environmental processes, thanks to indigenous and traditional knowledge systems (see Sillitoe, 1998, for a comprehensive discussion). In southern Africa, farmers have a long history of applying local knowledge in response to increasing climate variability and change (Below *et al*., 2010; Vincent *et al*., 2013).

Indigenous early warning systems

Before the initiation of modern scientific methods for weather forecasting and climate prediction, farmers utilized traditional ways and indicators of rainfall forecasting/prediction (Zuma-Netshiukhwi *et al*., 2013). Such 'indigenous early warning systems' use local indicators to interpret the weather/climate conditions to be expected. In parts of South Africa, for example, inhabitants use birds, toads, and white ants to predict the summer season and onset of rains as well as temperatures, while in Tanzania, they look at the behavioural patterns of birds and mammals (*Ibid*.).

A survey on early warning information available to farmers (Table 5) in northern Namibia found that 76% of respondents found local forms of such information more useful for making farming decisions than the widely available weather forecasts on radio and television. The latter were often deemed by farmers to be too general to be of use in decision-making processes (Newsham & Thomas, 2009).

Table 5. Early warning indicators used by farmers in Omusati region, Namibia.

Indicator type	Indicator	Indicates
Plant	• Uumpishi/ uutwishi, or mopane sugar, secretion on mopane leaf • Omhuzi tree produces fruit before start of rainy season • Trees and plants lose leaves slowly	Good rainy season Good rainy season Poor rainy season
Animal	• Oimote birds seen walking on the ground • Appearance of small, white butterflies • Goats give birth in April	Poor rainy season Army worm invasion next growing season Early onset of rains
Climate	• Continuous or east winds in summer	Good rainy season

Source: Newsham & Thomas, 2009

4.3 Disconnection between farmers' perceptions and responses

Perceptions of climate change are a necessary prerequisite for adaptation to climate change, as they determine the decisions in agricultural planning and management taken by farmers (Roncoli *et al*. 2002; Vogel & O'Brien 2006; Thomas *et al*. 2007). Yet, a number of studies show that there is often a disconnection between farmers' perceptions of climate change and on-the-ground responses (Smit *et al*., 1996; Brklacich *et al*., 1997; Granjon, 1999). For example, in Madagascar; while smallholder farmers generally perceive that climatic conditions have changed over the last 10 years, only a subset of farmers report having made changes in their farming practices to either reduce their future vulnerability to droughts and floods or to accommodate long-term shifts in climatic conditions (Harvey *et al*., 2014).

The limited uptake of adaptation strategies by the Malagasy farmers could be attributed to the high levels of household food insecurity, which make it risky for farmers to adopt new strategies that may affect their agricultural production and food availability. In addition, most farmers simply lack the resources needed to implement adequate response measures (Harvey *et al*., 2014). Furthermore, the same study also showed that the use of adaptation measures was positively correlated with farmer education level, use of diversified agricultural practices, diversified cropping systems and livestock ownership indicating that farmers who are better educated and already have more diversified systems are more likely to be willing to adopt new strategies (Harvey *et al*., 2014).

Elsewhere, factors which were found to affect farmers' ability to adapt to climate change have included: accessibility and usefulness of climate information (Roncoli *et al*., 2002), the policy and institutional environment (Eakin, 2005; Agrawal *et al*., 2008), and the socio-economic position of the household (Gandure *et al*., 2013; Ziervogel *et al*., 2006), among others.

5. Conclusions

Temperature and precipitation variability along with increased frequency of extreme weather events is projected to have significant direct and indirect impacts on the productivity of small-scale production systems in Southern Africa. Indeed, climate-related changes are already threatening food security in the region. A better understanding of the complex local knowledge systems and strategies for managing climate risk may contribute to more effective agricultural adaptation research and practical agricultural adaptation planning.

To this end, this report has reviewed the perceptions of- and farm-level responses to the challenge of climate change among smallholders in Southern Africa. It has shown that farmers' perceptions can provide multifaceted insights into the causes and effects of climate-related changes, despite the fact they are often disagree with scientific data. As has been further documented; smallholders are influenced in their decision-making and responses by their framing of climatic trends, their experiences and the local context. Therefore, farmers within and across communities and countries perceive- and react to climate change in different ways. The resulting wide variety of indigenous practices to deal with perceived climate risks can be classified as coping (short-term, reactive) or adaptation (longer-term, reactive or anticipatory) strategies. These can be further divided into six broad categories: (1) crisis response; (2) modifying farming practices; (3) modifying crop and animal types, varieties and breeds; (4) natural resource management; (5) livelihood diversification and (6) knowledge management.

To conclude, attention is drawn to the importance of conducting further research into farmers' knowledge and perceptions around climate change; because as has been shown, there is often a disconnect between farmers' perceptions of climate change and on-the-ground responses on the one hand, and farmers' perceptions and scientific/ policy viewpoints on the other. Using a baseline of existing responses, as reviewed in this document, new or improved adaptation practices can be developed that will potentially have the advantage of being both technically effective and socially accepted (Crane *et al*., 2011). Linked to the previous point; farmers' responses can be adjusted by incorporating lessons learned from other regions of the world as well as through the findings of innovative science (Below *et al*., 2010).

Finally, while it is acknowledged that local farm-level responses are expected to be helpful in dealing with climate change, there remains considerable uncertainty about their impacts (Challinor *et al*., 2014). Therefore, it is further recommended that efforts be made to understand a broader spectrum of rural society by including age and gender-disaggregated perceptions in the analysis, since climate change is an inter-generational challenge that will affect both present and future generations of men and women (Gandure *et al*., 2013).

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