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Farmer's perception of climate change and responsive strategies in three selected provinces of South Africa

Zelda A. Elum [a,*], David M. Modise [a], Ana Marr [b]

[a] College of Agriculture and Environmental Sciences, University of South Africa, South Africa
[b] Natural Resources Institute, University of Greenwich, United Kingdom

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ABSTRACT

The world has responded to climate change phenomenon through two broad response mechanisms (mitigation and adaptation strategies) with the aim of moderating the adverse effects of climate change and/or to exploit any arising beneficial opportunities. The paper aims to examine the trend in climate parameters, farmers' perception of climate change, constraints faced in production and to identify the strategies (if any) that farmers have adopted to cope with the effects of changing climate. A one-way analysis of variance, percentage analysis and Garrett ranking technique were applied to a set of primary data collected from 150 randomly sampled farmers with the aid of questionnaires in three purposively selected provinces through the months of June to August 2015. The analytical results of obtained recent weather data revealed that the climate parameters have significantly changed over time and these were substantiated by farmers' experiences. The farmers are engaging in various climate-response strategies, among which, the planting of drought-tolerant varieties is most common. Therefore, it is important to enhance farmers' access to improved drought-tolerant seeds and efficient irrigation systems. Also observed, is that the lack of awareness of insurance products and inability to afford insurance premiums were the principal reasons majority of the farmers did not have insurance. These present a need to strengthen insurance adoption among farmers through various supporting programmes that may include premium subsidies and media outreach. The paper under one platform provides evidence of changing climate, farmers' responses towards mitigating perceived adverse effects of the changed climate, and South Africa's national policy on adaptation and mitigation.

1. Introduction

Climate change mitigation and adaptation issues have become subject of intense global discussions in the past few decades. Mitigation entails all anthropogenic interventions or policies aimed towards reducing greenhouse gas (GHG) emissions or enhancing the sinks for GHGs (Chambwera and Stage, 2010; IPCC, 2001). Mitigation is regarded as a crucial long-term solution to addressing ongoing climate change and minimising its negative impacts in the future. Adaptation, on the other hand, refers to all adjustments or moderation in natural or human systems in response to actual or expected climate change as well as taking advantage of new/arising opportunities (Adger et al., 2003; IPCC, 2001). More so, the United Nations Frame-

* Corresponding author at: Department of Agricultural Economics and Extension, University of Port Harcourt, Nigeria.
E-mail address: zeldaforreal@yahoo.com (Z.A. Elum).

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work Convention on Climate Change UNFCCC (2007) presented adaptation as a process through which societies make themselves better able to cope with an uncertain future by taking appropriate measures and making right adjustments to minimise the adverse effects of climate change. Rightly put, the impending impacts of climate change can be addressed only through adaptation since mitigation cannot reverse an already changed climate. Thus, mitigation and adaptation cannot substitute for each other but one greatly complements the other. Without doubts, the need for adaptation in the long term can be reduced by current mitigation practices. Certainly, when required adaptive measures are not put in place, climate change could impair economic growth and other aspects of human and natural wellbeing (Chambwera and Stage, 2010).

Although climate change is a global problem, the need for adaptation is higher among developing countries where vulnerability is presumably higher (Adger et al., 2003). It is expected that Africa's agricultural production will be greatly affected by climate change. Considering that the agricultural sector is a source of livelihood for many people especially the poor in rural communities (Bryan et al., 2009), it becomes imperative to protect the livelihoods of farmers to sustain food security. Remarkably, the extent to which a system will adapt is a function of its vulnerability to climate change which is in turn influenced by its level of exposure and sensitivity to the climate change impacts. For instance, frequent occurrence of flood hazards can lead to great production losses thereby increasing risk awareness and need for adaptation measures such as increase demand for insurance among farmers. Apparently, access to insurance and access to credit have been identified as important for autonomous adaptation (Maddison, 2007). However, studies (Tobey et al., 1992; Adger et al., 2005) have shown that there are numerous adaptation strategies available to farmers.

Climate change is intertwined with weather although there are subtle differences between the two (IPCC, 2007a). Climate is defined as average weather condition over a long period and which can affect cropping area and intensity whereas weather is a climate-related event that occurs in any one time. However, climate and weather (individual atmospheric condition) both affect cropping area, intensity and yield but in different ways (Iizumi and Ramankutty, 2015). The local impacts of some weather extremes (e.g., hail and heavy rainfall) on crop, work calendar and field workability could be substantial (Cooper et al., 1997; Vorst, 2002). Subsequently, three broad strategies of examining the impacts of climate change have been identified by Mendelsohn and Dinar (1999) and they are the agronomic modelling, agro-economic and the Ricardian modelling technique (Maddison, 2007). Although serious effects of climate change across sectors and scales have been predicted, Adger et al. (2003) argue that all societies are fundamentally adaptive; although, some groups and sectors might be more vulnerable to climate risk than others. As such, assessment of adaptation to climate change often involves an examination of the vulnerability of the individuals and places to impacts of natural catastrophes (Grothmann and Patt, 2005). For instance, it is estimated that by 2020, about 250 million people in Africa could be exposed to greater risk of water stress (IPCC, 2007b). Like many African countries, South Africa has been identified as being highly vulnerable to the impacts of climate change (Republic of South Africa (RSA), 2011) and would therefore need supportive policies and framework to enhance climate change adaptation process among farmers especially considering that the agriculture sector is a major employer of labour in the country. In this regard, an understanding of current effects and response to climate variability at all levels of social organization and sectors will help in future studies of the effects and responses to climate change and in identifying effective adaptation strategies (Adger et al., 2003).

The broad aim of this paper is to provide a platform of summary on climate change effects to stimulate discourse on the applicability of various response mechanisms such that individuals and societies, especially in developing countries, can become more resilient to the impacts of changing climate. The specific objectives of the study was to study the trend in climate parameters, examine farmer's perception of climate change and to identify the responsive strategies (if any) that farmers have adopted to cope with the effects of changing climate. The study aims to provide current data-base evidence on the extent of climate change and the adaptation measures adopted by farmers involved in cabbage and potato production in three selected provinces of South Africa. It is hoped that the study will contribute to existing literature on climate change response practices undertaken in Africa and that researchers would find the work useful for further research. The paper is organized as follows. This first section introduces the focus of the research. The next section presents a theoretical overview of the concepts of mitigation and adaptation in addition to discussing the implication of climate change for South African agriculture and the government response policy. This is followed by the methodology employed in the study and the presentation of results of data analysis. The final section distills the findings of the study to conclude.

2. Theoretical overview of adaptation and mitigation strategies

Notably, there is a vast body of knowledge on the assessment of vulnerability to climate change, mitigation and adaptation strategies. However, mitigation had received much greater focus in the scientific community and political perspective (Füssel, 2007) before recent times, and this is most probably due to its universal applicability unlike adaptation which is more locationally-defined. There is a school of thought that is of the opinion that mitigation has received more focus because of the business opportunities it offers developed countries through investments in developing countries as in the case of the Clean Development Mechanism (CDM) project activities in South Africa (United Nations Industrial Development Organization UNIDO, 2003). In a similar vein, Roberts (2008) opines that the international community has paid less attention to adaptation when compared to the focus on mitigation. However, adaptation discourse has in recent times become a preoccupation of climate change researchers and experts that have previously dwelt on mitigation politics and economics of global climate change before its inclusion in Article 2 of the UNFCCC (Adger et al., 2009). On the one hand, researching adaptation strategies has become necessary as climate change threatens food security through the occurrence of natural hazards such as drought, flood and fire, etc. On the other hand, reducing the contribution of agriculture in producing greenhouse gases is also important. Apparently, agriculture (including food systems and land-use change) produces about 31 percent of the world's greenhouse gas emissions (FAO, 2015). In addition, formulating policies that can help ensure food security requires an understanding of farmers' perception of climate change and the adaptation strategies adopted (Bryan et al., 2009). Adaptation in the context of climate change is viewed as a means of strengthening resilience of individuals and systems to climate change and climate variability.

Furthermore, among the numerous explanations for adaptation given in the literature, include the view that adaptation could be either anticipatory, concurrent or reactive based on their timing, and based on the degree of spontaneity, it could be autonomous or planned (Smit and Wandel, 2006). Adaptation to climate change is planned when the actions that are taken are meant to reduce risks and utilise new opportunities brought about by global climate change (Füssel, 2007). Furthermore, adaptation could be classified into spatial scope in terms of being localised and widespread and also into form-adaptation in terms of technological, behavioural, financial, institutional and informational operations (Smit and Wandel, 2006). The IPCC and the Kyoto Protocol have also recognised adaptation in its different forms (Adger et al., 2003) and agreed that some form of intervention is needed to support adaptation adoption in societies. Apparently, adaptation has most often been assessed in the context of vulnerability to climate change. As a result, adaptation to climate change is usually preceded by an analysis of perception of climate change as this is what spurs an individual or group to want to respond to perceived climate change or not. One's perception is shaped by experiential and or indigenous knowledge of the climate as well as given the observed impacts of climate change. For example, Maddison (2007) observed that farmers across 11 African countries planted different crop varieties, increased water conservation and switched activities from farming to non-farming when temperatures changed. On the other hand, changing planting dates was of more focus to them when precipitation and times of rains varied. Likewise, in a study involving 1800 farming households in South Africa and Ethiopia, it was observed that commonly adopted adaptation strategies among the farmers included, the planting of different crops and crops varieties, tree cultivation, soil conservation practice, irrigation and change of planting dates (Bryan et al., 2009). It was however, observed that farmers who did not engage in any coping mechanism cited lack of credit, lack of access to land and information for their inability to adapt to perceived climate change (Bryan et al., 2009).

Although, there is a long and multidisciplinary history of scientific research associated with adaptation and the definition of adaptation has varied by fields and practice (Moser and Ekstrom, 2010), this paper however, defines adaptation in the context of agricultural vulnerability to climate change. Consequently, in the context of this study, adaptation is explained as activities adopted or practiced by farmers in the selected provinces in order for them to cope better with increasing climate variability. These associated farm activities apparently help to reduce the production risk faced by the farmers. The need for adaptation has often risen from extreme weather events experienced in a specific region or sector rather than from average climate conditions. Thus, adaptation is often context-specific as it varies from place to place among individuals and groups and also over time depending on the available resources (Smit and Wandel, 2006); as such, it is relevant for all climate-sensitive domains such as agriculture, forestry, water resources, health etc. (Füssel, 2007). The increasing focus on adaptation of agriculture to climate change indicates the need for climate-smart agricultural practices which could see to the reduction of GHG emissions and their adverse effects. The adoption of climate-smart agricultural practices to reduce emissions such as nitrous oxide (from applied fertilizers) and methane (from livestock operations) can halt the perpetuation of climate change. Although, the choice of adaptation interventions depends on a country's peculiar circumstances, Vincent (2007) identified the main factors constituting the adaptive capacity of a country to include, economic wellbeing and stability, demographic structure, global interconnectivity, institutional stability and wellbeing, and natural resource dependence. Believably, most African farmers would easily adapt to changed climate if they had unfettered access to markets, new technologies, extension agents and credit services among other needs (Hassan and Nhemachena, 2008).

As reported by the Department of Environmental Affairs DEA (2013a), the agriculture sector plays an important role in the economy of Southern Africa including South Africa. It contributes about 4–27 percent of GDP of the Southern African Development Community (SADC). Reportedly, there has been a gradual drop in cereal production in South Africa; however, the use of water in agriculture has not reduced as it is observed that water is being increasingly used in other crops such as high-quality fruits and vegetables that give more value per unit of water used. Evidentially, Southern African region including South Africa is experiencing increasing number of hot days, decreasing frequency of cold days and higher variability of rainfall. Certainly, the most significant climate parameter that has affected human activities is rainfall (Thomas et al., 2007). Flooding and drought are water-related climate impacts often experienced across the globe. These impacts are seen as detrimental to the agriculture sector which is highly sensitive to climate variables. The SADC believes that adaptation would require the combination of individual farmer's response at the farm level. Adaptation measures that have been identified under the Climate Change Adaptation Strategy (2011) of the SADC include research and development of indigenous knowledge and technology; identification of groups and communities most vulnerable to climate change impacts; sensitisation of the public on climate change; improvement of irrigation and drainage system; ground water management and sustainable farming systems among many others (DEA, 2013b). Other adaptation strategies being employed by farmers in South Africa to reduce production risk include the planting of varieties with a shorter growing period, changing planting times as dictated by rainfall, collection of water in furrows near plants and increasing use of irrigation. In addition, it has been reported that farmers are adopting climate-smart agriculture practices such as conservation tillage practices to reduce soil moisture loss, reduce erosion and control weed (DEA, 2014a).

This paper deals with planned adaptation as it assumes that farmers are currently engaged in practices based on their experience of changed weather conditions although, Adger et al. (2003) opined that farmers, fishers, coastal dwellers and large city residents will most often undertake autonomous adaptation. Without doubts, the ability of farmers to engage coping mechanisms are greatly dependent on their economic resources (Smit and Wandel, 2006). It is agreed that costs and benefits do come with adapting to climate change. These costs may arise from the implementation of adaptation strategies such as purchase of drought resistant seeds which may cost more, purchase of irrigation facilities etc. while the benefits may include reducing climate change impact and utilising new opportunities brought about by changed climate. Basically, adaptation strategies will vary but the agronomic technology available to farmers would determine how climate affects the different components of production. However, farmers in developing countries select their crops based on the many challenges they face and not just climatic and agronomic but also institutional, social and economic.

Equally important is mitigation strategies. Mitigation is more often viewed from the lens of GHG emissions reduction or the enhancement of the earth carbon sinks to limit global warming which is a major cause of climate change. Mitigation is a proactive process that involves making efforts to lessen GHG emissions and eventually stop global warming while adaptation as explained earlier is mostly reactive, that is, undertaking activities that protect society and ecosystems against the impacts of the changes of climate that are unavoidable. Mitigation is not independent of adaptation as both are driven by the same climatic stressors and between the two, there could be trade-offs or complementarities depending on the situation (Smit et al., 2000). Nevertheless, mitigation and adaptation respond to different problems caused by climate change on different scales (Grothmann and Patt, 2005). More so, there is a wide spread view that mitigation must take place on a global scale to be effective while adaptation can address climate change issues on different scales ranging from local to global and it would still be effective (Adger, 2001). This may explain why many adaptation studies have focused on examining the adaptive capacity of specific groups or individuals or locations in understanding the barriers to adaptation. Examples of mitigative strategies include changes in livestock practices that include adding a greater proportion of legumes to animal feeds to reduce methane emissions, implementing rotational grazing (Mcintyre, 2012), less use of inorganic fertilisers as well as fermenting animal waste in biodigesters and converting them to biofuels (Koneswaran and Nierenberg, 2008). In the context of this study, mitigation is viewed as those farm practices engaged upon by farmers with the hope of minimising the negative effect of the increasingly unpredictable weather conditions (inadequate rainfall and high temperature) on crop yield. In this study, farmers were asked about the mitigation and adaptation strategies they had undertaken to minimise the effects of the perceived changing climate with regards to temperature and rainfall.

2.1. Climate change and South African agriculture

Extreme weather conditions such as drought and flood which are closely intertwined with climate change can affect agriculture and livelihood in many ways that include total failure or reduced harvest and severe livestock deaths (CARE, 2009; Müller, 2009; Stringer et al., 2009). More so, climate change impacts are mostly felt by those whose livelihoods depend on natural resources as characterised by many African population of which South Africa is not exempted and this therefore, creates a need for supportive policies that can aid adaptation among farmers (Stringer et al., 2009). In other words, there is a momentous potential for adaptation in the agriculture industry. South Africa's agricultural sector contributes just about 2.6 per cent (DAFF, 2013) to the country's GDP, yet it is still considered a very important sector because it is a source of livelihood for more than 70 per cent of the country's labour force (Akpalu et al., 2008). Reportedly, more than a million people are directly dependent on agriculture for their livelihood in South Africa (Durand, 2006). More so, the agriculture sector employs a greater proportion of women than men. Majority of sub-Sahara African farmers operate at the subsistence, smallholder level and majority of them are women (Ogunlela and Mukhtar, 2009). In South Africa, it has been observed that the majority (almost two-thirds) of those involved in rural agriculture especially household food production are women even though the share of men and women in commercial-oriented small-scale agriculture are relatively equal (Hart and Aliber, 2012). In addition, studies have indicated that in developing countries, more women experience poverty and suffer the effects of environmental degradation than women in developed countries (Rosen, 2009). In a study of South African farmers' adaptation to climate change (Bryan et al., 2009), it was observed that 95 per cent of the farmers believed the temperature had changed over time while 97 per cent of them thought there has also been a change in rainfall. Extreme weather events have been projected to increase in the Southern Africa region which is frequently besieged by frequent drought occurrences due to its characteristic low rainfall index and variability (Rakgase and Norris, 2015; Stringer et al., 2009) and most notably, South Africa with an annual average rainfall of less than 500 mm is regarded as a dry country whereby, about 1.3million hectares of farmland is under irrigation, thereby making South Africa the largest 'irrigation country' in the southern African region (Durand, 2006).

South Africa is highly vulnerable to climate change impacts (Republic of South Africa (RSA), 2011). The country has recorded climate-related disasters in recent times that have often caused enormous damage and sometimes deaths. One of the most serious climate-related catastrophes occurring in Africa is flood. Floods can be caused naturally by high rainfall or induced through human activities such as deforestation, land degradation and poor drainage structures etc. (Mulugeta et al., 2007). Some of these climate-related events are presented in Table 1 and to these effects; the South African government has recognised the need for climate change mitigation and adaptation measures. Part of this process is the formulation of the Strategic Plan for South African agriculture which takes into cognisance that agriculture is a major contributor to climate change as well as a sufferer of changed climate impacts. Therefore, government seeks to manage the synergies between

Table 1
Chronology of climate-related events in South Africa.

Date	Event
2014	Orkney earthquake
2013	Earthquake in Barberton and Nelspruit Flooding in Jozi Wildfire in Paarl Storm in Free State
2012	Storm in Mahikeng Heavy Storm in Cape Town Floods in Eastern Cape Storm in Mpumalanga Tornado in Kestell
2010–11	Floods in provinces along Orange River
2003	Drought in Western Cape

Source: Disaster Report (2015), National Disaster Management Centre (2009).

adaptation and mitigation by identifying climate-resilient land uses, promoting the development of climate-smart agricultural practices, promoting the development of biofuels and afforestation among other facets (RSA, 2011).

Furthermore, considering that climate change do not act on farmers in isolation, it therefore implies that the farmers collectively face similar challenges and would likewise adopt similar response measures (DEA, 2014a). Adaptive measures that have been identified include improved transport infrastructure, improved irrigation efficiency and water management. A high proportion of surface water is allocated to agriculture in South Africa (DEA, 2013b). Irrigation is inextricably linked with the issue of agriculture adaptation to climate change. The South African National Water Resource Strategy 2004 reports that available water in South Africa is already being over utilised by some industrial and residential areas unlike water management areas where available water can be used for agriculture. However, Studies (DEA, 2014b) have shown that South Africa has a well-planned and integrated water supply system that provides a certain level of resilience to potential climate change impacts on larger water supply systems. This is in addition to making available drought resistant varieties, improved drought planning and support for farmers as well as modifying design standards that include regulatory requirements for water sensitive urban design and flood operating rules for areas susceptible to flood. More so, it has been observed that flood irrigation has the efficiency of 55–65 per cent which is lower than sprinkler irrigation (75–85 per cent) and micro-irrigation (85–95 per cent). As such, it would benefit farmers to adopt the best efficient irrigation (micro-irrigation) method especially for horticultural crops that requires water. Without doubt, smallholder farmers are less adapted to climate change as they more often lack the means to improve their adaptive capacity. These constraints include lack of access to credit and insurance to hedge against climatic risk among others.

3. Methodology

The study area was made up of three purposively selected provinces of South Africa namely; Gauteng, Limpopo and Mpumalanga. The sampling frame of the study was the lists of farmers in the various communities that were obtained from each provincial Department of Agriculture and/or Rural Development. Farmers were randomly selected from these lists. To achieve the study objectives which were to: examine farmers' perception of climate change, investigate the numerous coping strategies practiced and the production challenges faced by farmers, primary data was collected with the aid of structured questionnaires that were randomly distributed to farmers across five communities in each of the selected provinces in the months of June to August 2015 when the farmers were harvesting. However, some farmers who had not harvested gave information based on previous (2014/2015) production. A total of 150 farmers made up of 75 cabbage farmers (25 farmers from each of the three provinces) and 75 potato farmers (45 farmers from Gauteng and 30 farmers from Limpopo). These numbers of farmers were chosen due to resources constraint. Weather data (rainfall and temperature) for the three selected provinces was obtained from the South African Weather Services. These provinces were purposively chosen because studies have identified them as being vulnerable to climate change impacts (Gbetibouo et al., 2010). The study was also limited to the three provinces due to resource and time constraints. Gauteng is South Africa's smallest province. It is regarded as the financial capital of Africa. The capital of the province is Johannesburg which is the biggest city in South Africa as well as the commercial hub of the country. Its annual precipitation averages about 713 mm. Average maximum temperature is about 26 °C in January and 16 °C in June. Mpumalanga is the second smallest province after Gauteng. Its capital is Nelspruit where the average maximum temperature is 29 °C in January and 23 °C in July with an annual precipitation of 767 mm. Agriculture occupies more than 68% of the province area. Limpopo is the country's northernmost province. The capital of the province is Polokwane. Limpopo though blessed with year-round sunshine, experiences wide climatic variations (RSA, 2015). The map of the surveyed locations is presented in Fig. 1.

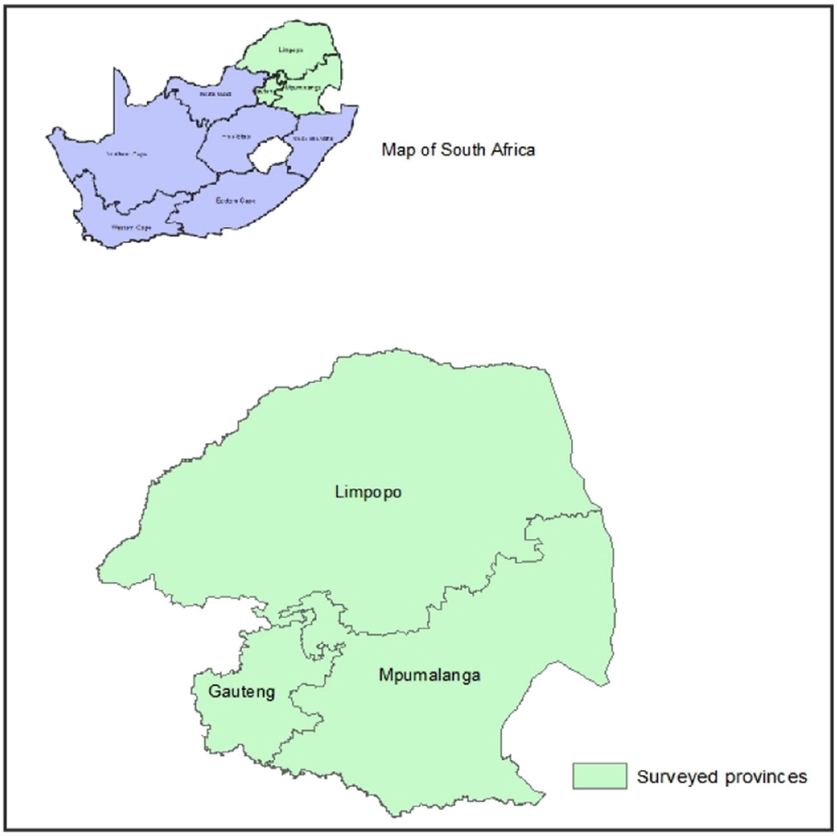

Fig. 1. Location map (South Africa).

With regards to the selected crops, cabbage and potato support many livelihoods across South Africa. Cabbage is a popular vegetable in South Africa and it is grown nation-wide, though its production is concentrated in some places like Mpumalanga and the Camperdown and Greytown districts of Kwazulu-Natal. The crop grows best in a relatively cool and humid climate at optimum temperatures of 18–20 °C and water requirements of about 380–500 mm. Cabbage is propagated from seeds. It is mostly produced for domestic consumption and marketed through the national fresh produce markets, the informal market and chain stores (DAFF, 2015). On the other hand, potatoes are tubers (although regarded as vegetables), with white, brown, purple or red skin with a white or golden flesh. The crop requires a lot of expertise to cultivate due to their sensitivity to temperature. For instance, too much sun exposure cause them to turn green during growth while cooler than normal temperature cause them to bruise during harvest.

Furthermore, a review of the literature reveals some of the methodologies used in adaptation studies and these include the following. Maddison (2007) used Heckman's sample selectivity probit model to examine the determinants of adaptation among farmers in 11 African countries. Grothmann and Patt (2005) employed a socio-cognitive model of private proactive adaptation to climate change (MPPACC) based on Protection Motivation Theory (PMT) to explain the varying adaptive behaviour/response among individuals in urban Germany and rural Zimbabwe. In Bryan et al. (2009) a probit model is used to examine the factors influencing farmers' decision to adapt to perceived climate changes in Ethiopia and South Africa. In addition, Hassan and Nhemachena (2008) analysed determinants of farm-level climate adaptation measures in Africa using a multinomial choice model applied to a cross-sectional data collected from 11 African countries. Furthermore, Deressa et al. (2009) employed the multinomial logit (MNL) model to analyse the determinants of farmers' choice of adaptation strategies in the Nile basin of Ethiopia. The methodology employed in this study included analysis of variance (ANOVA), descriptive and percentage analyses which were used to examine the climatic stressors, sample farmers' socioeconomic characteristics and perception of climate change. In addition, to analyse the production constraints faced by the farmers, a list of challenges researched from the literature were included in the questionnaire. Farmers were asked to rank the challenges in the order of importance as it affected them. The rankings provided were quantified through the application of the Garrett's ranking technique formula:

$$\text{Percentage Position} = \frac{100(R_{ij} - 0.5)}{N_j}$$

where R_{ij} is the rank given to *i*th factor by the *j*th farmer and N_j is the number of factors ranked by the *j*th farmer. The calculated percentage position of each rank was then converted into scores by referring to the table given by Garrett and Woodworth (1969). The study regarded the first five constraints with the highest scores as the most pressing issues facing the farmers.

4. Results and discussion

The result of the descriptive analysis of the climatic stressors is presented in Table 2. It is evident from the result in Table 2 that South African Weather had undergone significant changes in the period under study. A close observation of the descriptive statistics of the climate variables for the selected provinces in the period under consideration (1985–2014) as presented in the table reveals that Gauteng province has the least variability in minimum temperature while Limpopo had the highest maximum temperature. However, the province of Mpumalanga has received the highest amount of rainfall, although average precipitation has declined over time from that of the base period (1985) by 6.9 per cent. It was also observed that the maximum temperature of Limpopo reduced by 0.3 per cent in the same period. Further analysis showed that average rainfall decreased while mean temperature was on the increase in the provinces between the sub-periods I (1985–1999) and II (2000–2014). Increasing variance noticed in Gauteng and Limpopo provinces for the second sub-period was an indication that the climatic variables became less predictable even as they increased and decreased in absolute terms. The risk in crop production increases as climate parameters become highly unpredictable and unreliable (Garg et al., 2007; Winkler et al., 2013). It is also shown from Table 2 that on the average, Gauteng had 57 mm less rainfall in 2000–2014 than 1985–1999,

Table 2
Descriptive statistics of climatic stressors in the selected provinces.

Variables	Pooled data (1985–2014)		
	Gauteng	Limpopo	Mpumalanga
Mean annual rainfall (mm)	701.806	635.408	803.990
Rainfall variance	19245.498	31491.416	22495.166
Change in rainfall (%)	2.594	2.724	−6.862
Mean annual maximum temperature (°C)	22.921	25.497	24.216
Maximum temperature variance	0.497	0.340	0.575
Change in maximum temperature (%)	3.284	−0.332	10.719
Mean annual minimum temperature (°C)	9.772	13.283	10.979
Minimum temperature variance	0.221	0.629	1.742
Change in minimum temperature (%)	2.867	−3.878	53.054
	Sub period I (1985–1999)		
Mean annual rainfall (mm)	730.487	613.536	812.497
Rainfall variance	18809.922	16625.337	16471.639
Change in rainfall (%)	−22.404	−1.655	−4.081
Mean annual maximum temperature (°C)	22.671	25.339	23.942
Maximum temperature variance	0.429	0.275	0.570
Change in maximum temperature (%)	3.260	−3.940	3.284
Mean annual minimum temperature (°C)	9.760	13.501	10.425
Minimum temperature variance	0.225	0.148	2.693
Change in minimum temperature (%)	17.462	3.679	66.987
	Sub period II (2000–2014)		
Mean annual rainfall (mm)	673.126	657.280	795.483
Rainfall variance	19293.091	47581.780	29970.405
Change in rainfall (%)	−30.806	−46.736	−37.198
Mean annual maximum temperature (°C)	23.170	25.655	24.490
Maximum temperature variance	0.468	0.375	0.461
Change in maximum temperature (%)	7.246	5.032	10.142
Mean annual minimum temperature (°C)	9.783	13.062	11.532
Minimum temperature variance	0.233	1.052	0.259
Change in minimum temperature (%)	−6.642	−8.856	−8.675
	ANOVA		
Change in annual mean rainfall between 1985 and 1999 and 2000–2014	−57.361	43.744	−17.014
Change in average maximum temperature between 1985 and 1999 and 2000–2014	0.499	0.316	0.548
Change in average minimum temperature between 1985 and 1999 and 2000–2014	0.021	−0.437	1.107
Variance test for rainfall (P (F <=f) one tail)	0.481	0.029*	0.137
Variance test for maximum temperature (P (F <=f) one tail)	0.437	0.285	0.348
Variance test for minimum temperature (P (F <=f) one tail)	0.473	0.000**	0.000**
Covariance for rainfall and maximum temperature (1985–1999)	−54.484	−32.989	−28.893
Covariance for rainfall and maximum temperature (2000–2014)	−72.860	−101.122	−32.078
Covariance for rainfall and minimum temperature (1985–1999)	−3.498	−13.298	−4.328
Covariance for rainfall and minimum temperature (2000–2014)	−0.740	−3.501	−22.079

Source: South Africa Weather Services (2015). *Significant at 5% and **Significant at 1% level of testing.

Limpopo had 43 mm more rainfall in the last decade while Mpumalanga mean rainfall reduced by about 17 mm. The test of analysis of variance in rainfall between the sub-periods for Limpopo province was statistically significant. This implied that the province had experienced a significant effect of climate change in the amount of rainfall. Average maximum temperature changes in Gauteng and Mpumalanga provinces were shown to be about 0.5 °C higher in 2000–2014 than in 1985–1999 while that of Limpopo was 0.3 °C higher in the same period (Table 2). In addition, the test of variance for minimum temperature was significant for Mpumalanga and Limpopo.

Further, it was observed that the covariance of rainfall and maximum temperature in the second sub-period (2000–2014) in absolute terms was higher than the first sub-period. While, the covariance of rainfall and minimum temperature were lower in the second sub-period except for Mpumalanga. The implication of these results is that, just as rainfall has been declining, the temperature has been getting hotter in the provinces. The result supports the findings of Rakgase and Norris (2015) in which farmers in Limpopo acquiesced that the province is receiving less rainfall and getting warmer with greater occurrences of drought. Should this trend continue as evidently shown in this study, it could be rightly inferred that the selected provinces will face increasing challenges from climate change in the future. The results also support Oki and Kanae (2006) that climate change will exacerbate precipitation and the risks of floods and droughts. Thus, these selected provinces face increasing challenges from climate change as asserted in Gbetibouo and Ringler (2009).

The farmers' descriptive statistics and the one-way ANOVA employed are presented in Table 3. It was observed that cabbage farmers had lower number of labourers just as this group of farmers also had a higher amount of net crop revenue. The ANOVA result indicated significant differences in the portion of farm size irrigated, number of labourers and net revenue between the cabbage and potato farmers but further posthoc test (see Appendix A) to confirm the observed differences using the Bonferroni multiple comparisons procedure (Sincich, 1992) revealed that these observed differences were due to chance. This implied that there was no significant disparity between the two crops production among the sample farmers. Therefore, farmers' choice of which crop to produce may have been influenced by other numerous factors not captured in the survey.

The percentage analysis of farmers' perception of climate change and the responsive strategies undertaken across the two selected crops is presented in Table 4. It could be observed that the farmers mostly got to know about climate change issues through various news media and majority of them indicated that they had experienced higher temperatures, drought and lower crop yield due to changed weather conditions over time. A higher proportion (77.3 per cent) of potato farmers suffered from high/extreme temperature across the provinces than the cabbage producers (66.7 per cent) and expectedly, a greater share (81.3 per cent) of the potato farmers experienced shortfall in yield in contrast to 74.7 per cent for cabbage farmers. The result indicated that both cabbage and potato farmers were facing similar adverse effects of climate-related events. However, while cabbage farmers planted drought-tolerant varieties, potato farmers laid more emphasis on integrated pest management and the planting of different crops as a strategy to mitigate the impact of climate variability. Reportedly, the experience of the farmers corroborated with the higher levels of temperature observed from the weather data analysis. Consequently, farmers' awareness of climate change through various media and by their observation could help them to plan easily for future mitigation strategies (Rakgase and Norris, 2015).

Furthermore, the popularity of insurance as an adaptation option among the farmers was examined and the results revealed that just 13.3 per cent of potato farmers had insurance coverage while a mere 6.7 per cent of the cabbage farmers had cover. Apparently, lack of awareness of insurance products and inability to afford insurance premiums were the principal reasons majority of the farmers did not have insurance. It was observed that 40 per cent of the cabbage farmers were ignorant of the existence of insurance products in contrast to 17.3 per cent of potato farmers who claimed lack of awareness. The implication of this result is that although the experience of the farmers corroborates with the higher levels of temperature observed from the weather data analysis and the farmers exhibited awareness of changing climate and the potential effects, they did not find insurance an appealing adaptation option like other strategies. This supports the general notion (Iturrioz, 2009) that agricultural insurance market is very limited in developing countries, and therefore creates the need for measures that can make insurance an attractive option among farmers.

Table 3
Socioeconomic characteristics of sample farmers.

Variables	Cabbage		Potato		ANOVA p-value	B test
	Mean	SD	Mean	SD		
Age (years)	45.36	10.58	44.95	10.76	0.81	–
Education (categorical)	1.79	0.78	1.77	0.65	0.86	–
Farming years	6.86	5.06	7.76	5.36	0.30	–
Cultivated farm size (ha)	3.49	7.50	2.57	2.80	0.32	–
Irrigated farm size (ha)	2.79	2.22	2.09	2.00	0.05**	NS
Number of labourers	7.18	4.59	9.55	7.99	0.03**	NS
Net revenue (R.)	23446.31	36216.05	13376.87	38469.15	0.10*	NS
Gender: Male	56%		57%			
Female	44%		43%			
Number of observations	75		75			

B = Bonferroni critical difference statistic; ** and * significant at 5% and 10% level of testing respectively; NS = Not significant.

Table 4
Farmers' perception of climate change and responses.

Perception	Cabbage farmers		Potato farmers	
	Response	Percent	Response	Percent
Awareness of climate change	Yes	94.67	Yes	90.67
	No	5.33	No	9.33
Means of awareness	News media (radio, newspaper, internet)	53.33	News media (radio, newspaper, internet	74.67
	Public extension agents	34.67	Own observation and experience	38.67
	Own observation and experience	32.00	Public extension agents	32.00
Major climate events experienced	High/extreme temperature	66.67	High/extreme temperature	77.33
	Storm	54.67	Drought	46.67
	Drought	49.33	Storm	44.00
Effect of climate-related event	Reduced crop yield	74.67	Reduced crop yield	81.33
	Experienced crop failure	69.33	Higher incidence of pest and diseases	65.33
	Higher incidence of pest and diseases	32.00	Experienced crop failure	57.33
Response strategies	Planted drought tolerant variety	49.33	Applied integrated pest management	66.67
	Changing of planting time	44.00	Planted drought tolerant variety	58.67
	Increased access to extension agents	37.33	Diversified and relocated crops	49.33
Insurance adoption	Yes	6.67	Yes	13.33
	No	93.33	No	86.67
Reasons for not having insurance	Ignorant of insurance policies/products	40.00	Ignorant of insurance policies/products	17.33
	Unable to afford the cost	22.67	Unable to afford the cost	17.33
	No reason	5.33	No reason	5.33
Number of observations		75		75

Source: Survey data (2015). Multiple responses recorded.

The major constraints to the adaptive capacity of the potato and cabbage farmers were analysed with the Garrett ranking technique and are presented in Table 5. It was observed that both groups of farmers indicated facing challenges related with gender issues. It was shown earlier in Table 3 that about 56 per cent of the total respondents were males while 44 per cent were females. Also, while the majority of cabbage farmers viewed inadequate rainfall as their second most challenging need, the potato farmers thought that not having access to markets was a more serious barrier among other challenging issues. In providing logic to this result, we posit that it is common knowledge that more women are involved in agricultural production in Africa than men. In South Africa; almost two-thirds of those in agriculture are reportedly women; apparently, women are more vulnerable to the adverse impacts of changing climate as they are most often disadvantaged by societal norms that limit their access to financial services and land ownership (Hart and Aliber, 2012; Ogunlela and Mukhtar, 2009). Women are more often than men confronted with cultural and socioeconomic challenges that can impede their adaptive capacity (Steady, 1998). For instance, a study of South Africa's black farmers revealed that male-headed households received more agricultural support than female-headed households (Hart and Aliber, 2012). Thus, women, despite their heavy presence and participation in agriculture do not often benefit from agricultural incentives and innovation (Ogunlela and Mukhtar, 2009). Notwithstanding, women are not alone in gender discrimination as it has also been reported that the traditional dominance macho-role of men sometimes make it difficult for them to compete with women in marketing their vegetable produce in informal/unorganized market (Asomani-Boateng, 2002). Further, it was not surprising that the farmers had indicated lack of adequate rainfall as a pressing challenge; water is very significant for horticultural crops like cabbage and potato (Blignaut et al., 2009), it affects the farmer's ability to produce seasonally or through the year and also enables farmers to grow diversified crops instead of practicing single cropping (Asomani-Boateng, 2002; Nambi et al., 2015). More so, the weather data analysis had earlier shown (Table 2) decreasing precipitation and increasing temperature, thereby supporting a well-established fact that South Africa is getting hotter and drier (Blignaut et al., 2009); an indication that farmers are

Table 5
Constraints faced in production by sample farmers.

Cabbage farmers			Potato farmers		
Constraints	Mean score	Rank	Constraints	Mean score	Rank
Gender issues	82.59	I	Gender issues	81.31	I
Inadequate water/rainfall	77.38	II	Lack of access to market to sell product	78.83	II
Inadequate farm size	76.53	III	Absence of extension services	78.22	III
Absence of extension services	75.70	IV	Inadequate water/rainfall	76.84	IV
Lack of access to market to sell product	75.17	V	Inadequate farm size	76.70	V

Source: Survey data (2015).

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increasingly challenged. In addition, the result agrees with past studies that lack of access to market is a major constraint among other challenges faced by African farmers including South African farmers in production and in adapting to climate change (Bryan et al., 2009; Deressa et al., 2008, 2009). The result is also in line with Mpandeli and Maponya (2014) study of South African small-scale farmers in Limpopo Province which found that farmers were highly constrained by lack of market access and it led to the perishing of their produce in storerooms. In addition, it has been observed that migration within South Africa is mostly from the provinces of Limpopo, North West and Eastern Cape towards Gauteng and Western Cape provinces (DEA, 2013).

5. Conclusion

The essence of this paper was to provide evidence of the climate change response strategies of farmers in selected provinces of South Africa. In order to achieve its objectives, the paper first, set out to ascertain the change of climate in the selected provinces and then investigates farmers' perception of the changing climate through questions that included asking farmers about their experiences on the type of climate-related events they had encountered. The study revealed that there had been a significant change in rainfall and minimum temperature over time and there was corroboration between farmers' experiences and the analysed scientific weather data. There has been a decrease in average amount of rainfall and an increase in mean temperature across the provinces. Subsequently, farmers engaged in various climate-response strategies. Among the strategies adopted by the farmers; the planting of drought-tolerant varieties was most common. In addition, majority of the farmers did not have insurance due to lack of awareness and sometimes inability to pay the premiums. Based on the literature and analytical findings of the study, this paper argues that with respect to the surveyed provinces, potato and cabbage farmers' access to improved seeds which are tolerant to drought, access to formal market as well as the use of efficient micro-irrigation systems should be enhanced. It also stresses the need to strengthen the popularity of insurance as an adaptation option among farmers through various supporting programmes that may include premium subsidies and insurance sensitisation through media outreach. Conclusively, the paper provides empirical data to support the perceived assertion of climate change and farmers' responses. It also agrees with the DEA (2013) that South African farmers are already adapting to climate change, although, an integrated approach that addresses multiple stressors and combines indigenous knowledge and experience with scientific insights is required.

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Appendix A

Table A. Comparing two samples using one-way analysis of variance.

Variables	Degrees of freedom within group	Alpha/2 * 3	t score	Mean square	Bonferroni critical statistic	A–B
Age	145	0.025	2.26492	113.9199847	3.947631	–
Farm size	148	0.025	2.26444	32.02128288	2.092491	–
Years of farming	143	0.025	2.26525	27.23252747	1.930386	–
Irrigated farm size	143	0.025	2.26525	4.45869863	0.781096	0.7
Labourers	141	0.025	2.2656	43.49268808	2.43991	2.37
Crop net revenue	148	0.025	2.26444	1395738896	13814.86	10069.44
Education	146	0.025	2.26475	0.514140239	0.265183	

A = Cabbage farmers' mean; B = Potato farmers' mean.

B (Bonferroni) = $t_{(alpha/2g)}$ * SQRT(MS within groups) * SQRT[$(1/n_1) + (1/n_2)$].

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