Exploring farmers' perceptions and lessons learned from the 2015–2018 drought in the Western Cape, South Africa

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Highlights

- Farmers learnt from the 2015–2018 (*Day Zero*) drought and changed certain practices.
- Drought led more farmers to prepare for climate change.
- Farmers are adapting regardless of their beliefs of climate change.
- Highlight the strength of information and social networks in adaptation planning.

Abstract

The agricultural sector is one of the most vulnerable sectors to the impacts of climate change. Between 2015 and 2018, the Western Cape Province of South Africa experienced a multi-year severe drought. Projections show that the Western Cape is likely to experience hotter and drier conditions, with more frequent droughts. Without appropriate adaptation actions, climate change is likely to increasingly constrain agricultural activities in the province. Commercial farmers represent a considerable population of decision-makers, which are fundamental to climate change adaptation. Understanding farmers' perceptions is important to develop effective policy, support structures, and communications. This study aimed to understand wheat farmers' and apple producers' perceptions of climate change and adaptation in the Western Cape, South Africa, and establish whether the recent drought offered lessons for adaptation. Study methods included the use of an online questionnaire as well as several in-depth interviews with farmers and producers. Results showed that most farmers and producers agree that climate change is real and is caused by human activities. Most farmers and producers in the region are already actively (or intend to start) preparing for climate change (69%). In response to climate change, apple producers view on-farm water management (such as irrigation management and water recycling) as the most important strategy. Wheat farmers strategies are focused on crop management (including cultivar selection and conservation agriculture). Many farmers and producers further agreed that they had learnt from the past 2015–2018 drought. Notably, results showed that farmers and producers who rely a great deal on weather forecasts were more likely to feel that their farm's response was effective. Furthermore, it was found that farmers and producers who felt they learned from the drought were also more likely to be actively preparing for climate risks. It is recommended that investments into climate change adaptation focus on research and development, particularly with regard to cultivar development, irrigation management, tailored weather forecasting, and localised risk assessments. Policy should prioritise the more vulnerable farmers and producers while focusing on integrated risk reduction measures which account for multiple stressors.

Keywords: Climate change; Adaptation; Drought; Random forest; Risk reduction

1. Introduction

Climate change and agriculture are irrevocably connected. Agricultural practices contribute considerably to climate change both directly via greenhouse gas emissions and indirectly through land-use change (European Environmental Agency, 2015; OECD, 2016). While the agricultural sector is a major driver of climate change, it is also one of the sectors most vulnerable to the adverse effects of a changing climate (Fujisawa et al., 2015; Rockström et al., 2017). The effects of climate change on agriculture are numerous and widespread, including, but not limited to, changes in; rainfall patterns (increased droughts or flooding, seasonality), length and timing of the growing seasons, minimum and maximum temperatures, and the carbon cycle (Linderholm, 2006; Wreford and Adger, 2010; Arora, 2019). Recent studies have shown that climate change is increasing the severity of extreme events (Swain et al., 2020). For example, Otto et al. (2018) found that the likelihood of an event such as the observed 2015–2018 drought (often referred to as the Day Zero drought) experienced in the Western Cape Province was exacerbated by anthropogenic climate change. These results were echoed by Pascale et al. (2020).

Between 2015 and 2018, the Western Cape experienced a multi-year severe drought which negatively impacted numerous sectors of the local economy. The rarity of such a drought event occurring is indisputable, with a return period of more than one hundred years (Otto et al., 2018). At its peak, residents in the metropolitan City of Cape Town were limited to 50 L of water per day. These severe water restrictions were placed to avoid the city reaching Day Zero, the day city would run dry (Ziervogel, 2019). While much of the research focus of the Day Zero drought has been on the effects on Cape Town, the agricultural sector was also severely affected (Pienaar and Boonzaaier, 2018; Theron et al., 2021). In addition, climate change projections show that the Western Cape is likely to experience hotter and drier conditions, with more frequent drought (Jack et al., 2016; Western Cape Government, 2018). Without the appropriate responses and adaptations, climate change and increased drought frequency are likely to constrain economic development and exacerbate the already pressing difficulties of limited water resources (Midgley et al., 2005; Acquah, 2011). It is, thus, becoming clear that climate change will create new risk management challenges for farm-level adaptation and decision-making (Findlater et al., 2018).

According to the IPCC AR5 (2014 p1758), adaptation is defined as “the process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate harm or exploit beneficial opportunities.” Adaptation has been widely studied in recent literature, and many agricultural adaptation strategies have been recommended (Jiri et al., 2017). These strategies cover a variety of scales from local, regional to global as well as agents: farmers, businesses, government; and categories: micro-level decisions, such as crop diversification and shifting the timing of activities; market responses, such as income diversification and credit or insurance schemes; institutional changes, improved access to agricultural markets; and technological advances or development and promotion of new crop varieties and improvements in water management practices (Jiri et al., 2017). Adaptation can take place both after experiences of extreme events or based on predictions of future scenarios (Johnston et al., 2016; Raaijmakers and Swanepoel, 2020).

Commercial farmers and producers represent a considerable and understudied population of decision-makers, which are fundamental to climate change adaptation (Findlater et al., 2018). Importantly, they represent an autonomous, adaptive, and resourceful private actor (Findlater et al., 2019). Adaptation experts have encouraged farmers and producers to combine climate change risks with current decision-making processes to align climate risk management with other farming goals (Findlater et al., 2019). Understanding the various farmers' and producers' perceptions of climate change and how it ranks in their overall risk landscape is, therefore, key to minimising the impacts on agriculture (Johnston et al., 2016; Jiri et al., 2017). Climate change adaptation necessitates that, farmers and producers first recognise the climate is changing, then decide on practical adaptations and finally implement the required adaptation responses (Jiri et al., 2017).

At a national level, South Africa has drafted the National Adaptation Strategy, which identified agriculture, among others, as a priority area for climate change adaptation (Department of Forestry, Fisheries and the Environment, 2020). South Africa has also drafted Long Term Adaptation Scenarios (LTAS) for various sectors, including agriculture. The LTAS identified numerous adaptation options for agricultural water supply and sustainable farming systems (Department of Environmental Affairs, 2013a). The SmartAgri program has compiled a status quo review of climate change and the agricultural sector in the Western Cape (Midgley et al., 2016). The review illustrates current climate risks and impacts across the various agricultural sectors, as well as how climate change is expected to alter these risks. Ziervogel et al. (2014) reviewed approaches and advances in research on climate change and adaptation in South Africa. The study found that most adaptation responses focused on reducing current vulnerability to climate exposure rather than future risks. While research on climate change adaptation is rapidly expanding, its behavioural dimensions remain understudied (Bassett and Fogelman, 2013; Findlater et al., 2018). Talanow et al. (2021) conducted interviews with grain and wine farmers to assess climate change adaptation behaviour in the Western Cape. Their results showed that most farmers have observed long-term climate changes. Furthermore, the study found that most farmers have already employed adaptive strategies such as adjustments to soil and crop management, changes to the harvesting and planting times, crop rotations, and water conservation techniques. However, the study found that farmers have planned fewer adaptive strategies for future climate change impacts than currently implemented strategies (Talanow et al., 2021). Recent literature has stressed the importance of understanding farmers' perceptions on climate change and adaptation if effective policy, support, and communication are to be established for the agricultural sector (Hyland et al., 2016; Eitzinger et al., 2018; Mitter et al., 2019; Findlater et al., 2019).

This study aimed to understand commercial wheat farmers' and apple producers' perceptions of climate change and adaptation in the Western Cape, South Africa, and establish whether the recent drought offered lessons for adaptation. The aim was achieved using an online questionnaire of Likert-type questions as well as several in-depth, semi-structured interviews with farmers and producers in the province. This research paper seeks to enhance the current discussion on drought in this region, expanding on the work already undertaken. Yet, it aims to go further by considering the drought from an agricultural perspective as well as how experiences of extreme events shape perceptions and adaptation options.

2. Methodology

2.1. Study site

The study was conducted in the winter rainfall region of the Western Cape Province (Fig. 1). Cape Town, South Africa's second-largest city, is the capital and economic hub of the province. The province has three distinct rainfall regions. The western region extending from the ocean to the western Rûens experiences a Mediterranean-type climate, with hot, dry summers and cool, wet winters (Archer et al., 2019). The south-east or eastern Rûens experiences rainfall more evenly spread throughout the year (Engelbrecht et al., 2015). Finally, the province's north-eastern region (not part of this study) is more typical of a summer rainfall region.

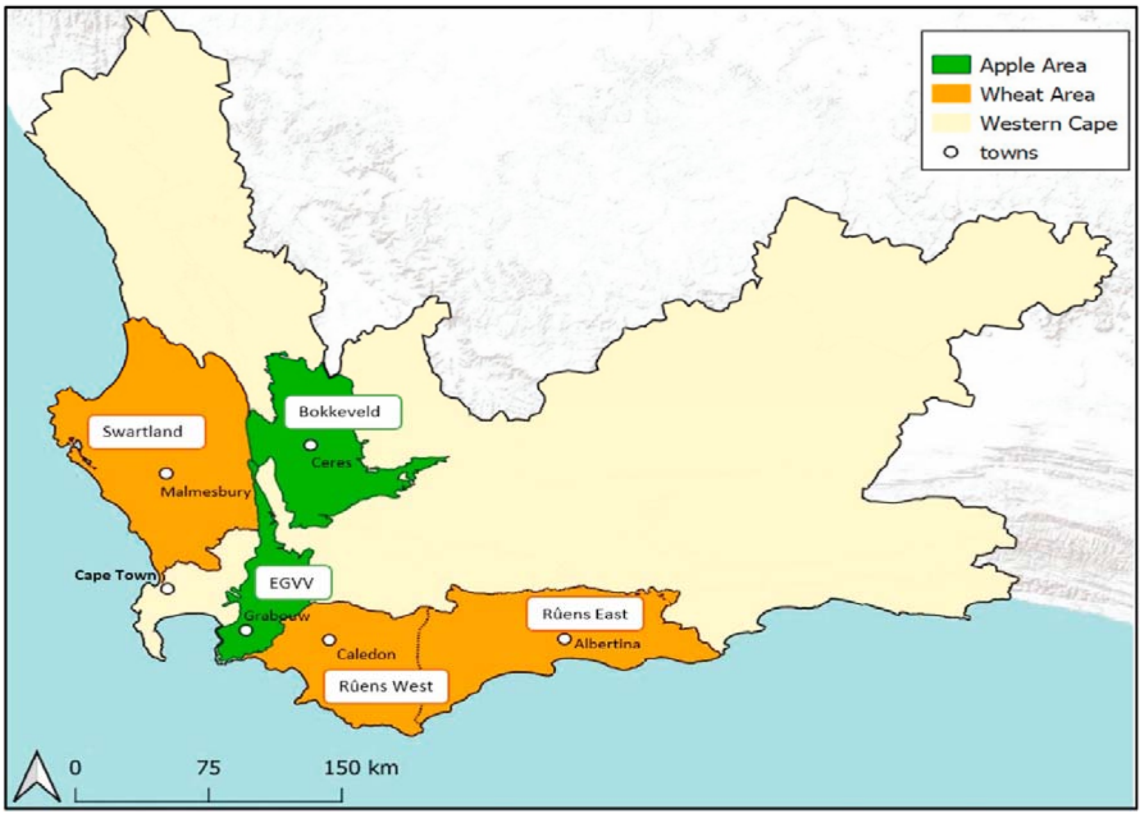

Fig. 1. A map of the Western Cape Province showing the two wheat producing areas and two apple producing areas according to the SmartAgri agro-climatic zones adapted from Midgley et al. (2016).

Wheat is grown in two main areas in the Western Cape - namely the Swartland around Malmesbury and the Rûens stretching from Caledon (western Rûens) to past Albertina (eastern Rûens) (Wallace, 2018). Wheat grown in the province is rainfed. Thus, the growing season coincides with the rainfall season, running from late autumn (May) through winter (June-July-August) and is harvested in spring (September–November).

Apples are grown on medium to large commercial farms in two main areas -namely the Bokkeveld near Ceres and Elgin-Grabouw-Villiersdorp-Vyeboom (EGVV) region near

Grabouw. Apples are the largest and most profitable of the deciduous fruits (excluding table grapes) grown in the province and are primarily produced for export markets (Hortgro, 2020). The apple-producing regions have well-developed irrigation infrastructure, which to a certain extent provides a buffer against the impacts of drought.

2.2. Data collection and analysis

Production data for 2008–2018 for apples were obtained from Hortgro and wheat production data was obtained from GrainSA. The period 2008–2018 was chosen as it was the period with the most complete data for the production regions and commodities. An online survey questionnaire was distributed to irrigated apple producers and rainfed wheat farmers in the winter rainfall region of the Western Cape. The questionnaire consisted of 37 questions divided into four sections as follows: Section 1 focused on farm characteristic data such as the number of years farming, location, farm size. Section 2 focused on the respondent's views on climate change; Section 3 centred on the respondents' drought response; and Section 4 aimed to understand perceptions on future risks and adaptation options. Questions were predominantly a Likert item, with respondents answering their agreeability to certain statements on a scale from 1 (Strongly Disagree) to 5 (Strongly Agree), 3 was neutral. There were also several questions which required Yes/No, a list of options or text responses. For certain questions respondents had the option to provide their own answers in addition to the options provided. Respondents were also given the opportunity to add more information that the study may have missed at the end of the survey. The questionnaire was developed using Google Forms and sent via e-mail to 150 farmers across the region. Participants were selected through advice from Stellenbosch University as well as those whose contact details were available on Farmers Weekly. One reminder email was sent out approximately four weeks after the original email. The surveys were also advertised in the Western Cape Department of Agriculture newsletter. A total of 51 (30 wheat and 21 apple) responses were collected.

For several questions which were not a Likert item, the responses were coded on a scale numerically, or 0–1 (Yes/No) in order to analyse them against the other responses. An essential part of this study was to understand respondents' views on climate change adaptation or preparedness and whether the recent drought influenced their perceptions. Thus, four questions were dedicated to assessing the various layers of preparedness. These included: acknowledging risk (*I need to be preparing specifically for climate change risks*); intent to prepare (*I will modify my farming practices to prepare for climate change*); action (*I am actively modifying my farming practices to prepare for climate change*); and business as usual (*I prepare for climate change risks as they arise*). The Likert Type questions, and their IDs are shown in Appendix 1.

Before statistical tests are used on a Likert scale, it is important to test the quality of the scale. Cronbach's alpha is an established method to assess the reliability of a Likert scale. A Cronbach's alpha of 0.7 is usually deemed an acceptable level for reliability (Taber, 2018). Using the R Psych package version 2.0.8, a Cronbach's alpha of 0.73 was obtained for this dataset.

A challenge exists to statistically analyse Likert scales because these scales comprise of ordinal data, and the assumptions made with parametric tests may not hold up when using ordinal data (Endresen and Janda, 2016). Thus, descriptive statistics could not be used to analyse the responses in this study. In order to avoid the assumptions of parametric tests, the study made use of a machine learning algorithm, Random Forests (RF), for classification to analyse the response data. While both statistics and machine learning can be used for prediction and inference, the strength of machine learning is that it is able to find patterns in often rich and unmanageable data by using general-purpose learning algorithms (Bzdok et al., 2018). In addition, machine learning makes minimal assumptions about the data and is often effective even in the presence of complicated non-linear relationships (Bzdok et al., 2018; Fromont et al., 2020). The RF algorithm can integrate numerous variables with comparatively few cases while accounting for the relations and interactions between the variables (Fromont et al., 2020). RF also remains more robust in the presence of collinearity between variables (Fromont et al., 2020). Importantly for the analysis, it allows for the ranking of importance predictor variables in explaining the data (Fromont et al., 2020). Another benefit of RF is that they are able to analyse small datasets (Qi, 2012; Luan et al., 2020; Xu et al., 2021). The R-package RandomForest version 4.6–14 was used in this analysis.

Since the data was limited to 5 responses per item, regression was not possible. Therefore, the 1–5 agreeability scale was converted to factors in R to do classification. Since this data was not used for prediction and the study only aimed to use RF to extract variables of importance or clusters of respondents, there was no concern about overfitting the data, and therefore, the data was not split between a training and validation dataset (Breiman, 2001; Matsuki et al., 2016). The tune function was used to establish the optimal values to run in the RF. Number of trees was set to 1000 while mtry (number of variables sampled at split) was set to 3. The algorithm randomly chooses subsets of the input data and simulates the influence of each predicting variable in every subset to assess the variable of importance. Accuracy of each prediction is then compared to the remaining data. The strength of a predicting variable is computed by randomly grouping its levels and which removes its importance: a predictor is considered important if the model becomes weaker after erasure (Fromont et al., 2020). Mean accuracy was used to gauge the variable of importance. This methodology also provides the out of bag (OOB) error which gives the prediction performance of a RF (Breiman, 2001).

RF can also calculate a proximity matrix. The RF-obtained proximity measure can then be utilised to create a multi-dimensional scaling (MDS) plot, where the differences between the data return a group of points in low dimensional Euclidian space, similar to principal component analysis (Ainali et al., 2012). This means that the proximities matrix of a RF can be visualised by MDS in order to identify patterns within the dataset (Ai et al., 2014). The questionnaire contained two questions that were not a Likert item but rather a list from which respondents could choose several items. These were; *My biggest concern relating to climate is* and *Which of the following practices are you most likely to employ in order to effectively respond to climate change?* In order to analyse these using RF, each item was given an arbitrary numerical value (not related to rank or weight) which was then converted to a factor in R.

Analysis of the online questionnaire was supplemented by semi-structured interviews with farmers (n = 11) to get a more nuanced understanding of farmer perceptions. The interviewees were selected through recommendations from Stellenbosch University. Of the 11 interviews, there were 9 wheat farmers, 1 apple farmer and 1 from an apple co-op. Here, it is important to note that most apple farmers can be categorized as co-op farmers where they operate under a larger company that decides on production strategies and then instructs the farmers on which strategies to employ (Fujisawa et al., 2015). Interviews were conducted between February and March 2020 and lasted between 30 and 120 min. Unfortunately, interviews were halted as a consequence of restrictions in place due to Covid-19. Questions covered topics such as climate change, drought response, risks to agriculture, as well as access to information. A cellphone voice recorder was used to record the interviews, and once completed, they were transcribed verbatim.

3. Results

The results of Section 1 of the survey (n = 51) provide an overview of the respondents which helps inform the results are the following Sections. Results from Section 1 showed that most respondents had been farming for between 21 and 35 years (Fig. 2). The average farm size was 1300 ha, with the largest farm around 5300 ha and the smallest 40 ha. Respondents were almost equally distributed across the four farming regions. Wheat farmers relied on rain as their water source, while the apple producers secured water resources through farm dams, boreholes as well as extraction from rivers and municipal dams. In terms of income diversification, 42% of respondents sampled have businesses or income outside of farming.

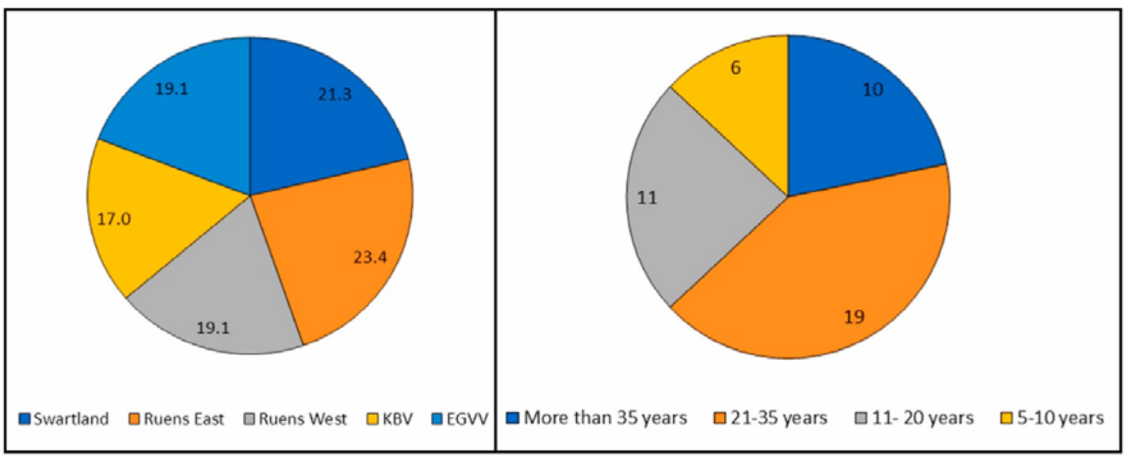

Fig. 2. The spatial distribution of respondents as a percentage (left). The years of farming experience of respondents as a percentage (right).

It is important to understand the impacts of the drought on apple and wheat yields to contextualise the responses. Fig. 3 shows that apple yield was more consistent than wheat production over the drought years with the effects of the drought only impacting production in 2018. Impacts of the 2015–2018 drought on wheat yield was highly variable. Yield increased in 2016/2017 and 2018/2019. However, the 2015/2016 and 2017/2018 seasons had a marked decrease in yield.

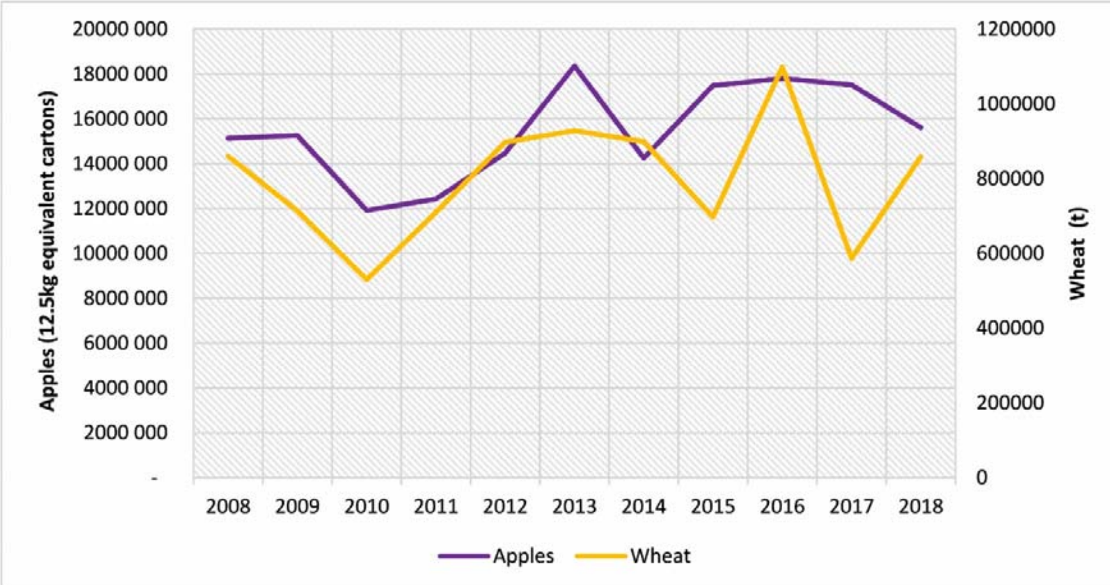

Fig. 3. Western Cape apple (purple) and wheat (yellow) yields from 2008 to 2018.

3.1. Climate change perceptions

In terms of perceptions of climate change, most respondents (76% of which 40% strongly agree) agree that climate change is real and is caused by human activities (69%), although fewer respondents (20%) strongly agree that it is caused by anthropogenic activities (Fig. 4). In terms of risks and opportunities, there is strong agreeability that climate change will cause more risks to their farm than opportunities. Results also show that climate change ranks high on their list of priorities. However, narratives from the interviews showed that both input costs and political challenges were cited as greater risks to their farming.

"[Biggest Risk?] I will still say politics, but you can't separate politics from economy because those, for me goes hand in hand. I won't say drought is not an issue, but the thing is drought has always been there."

"We are still optimistic, but government is always in the back of your head."

"Everything goes about the money we make on the farm because it is a business, and so if I want to do anything that I plan on the farm, it must be profitable; if there's no money to do it, you can't do it."

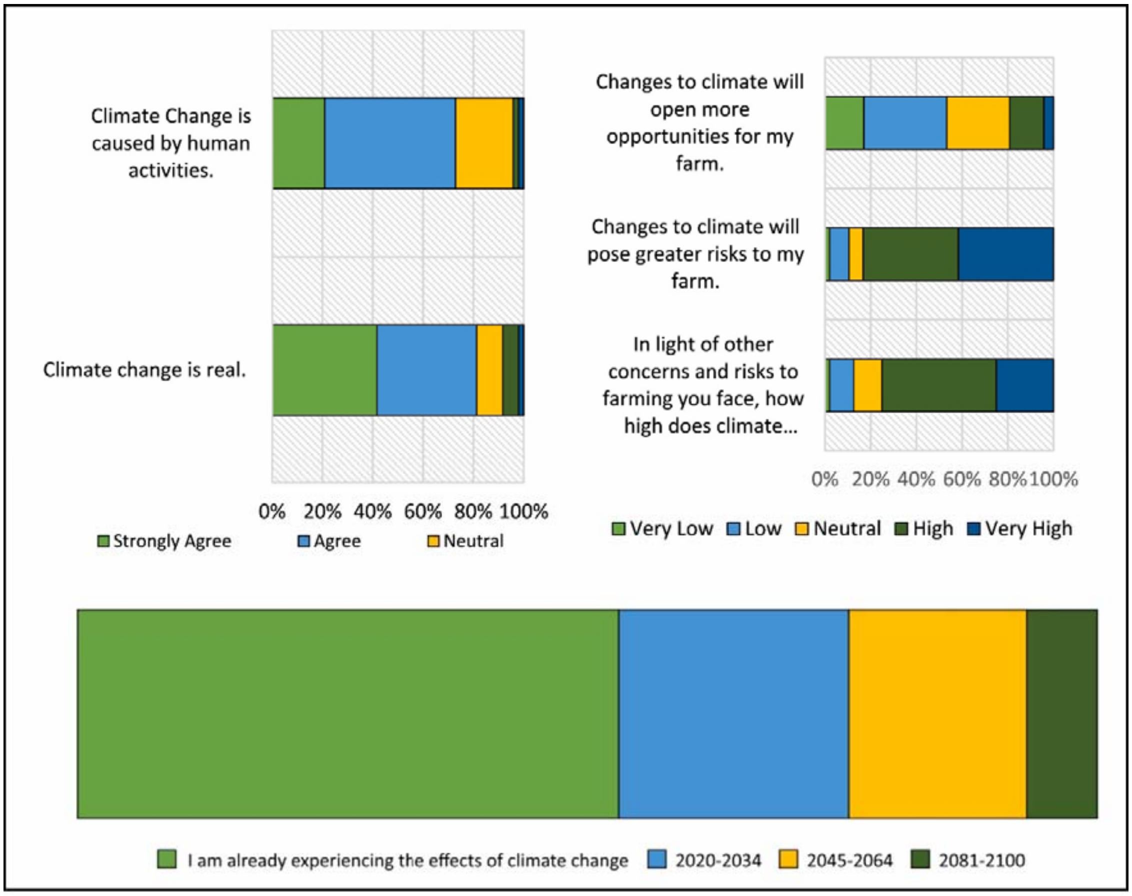

Fig. 4. Farmers' perceptions of climate change, timing of climate change impacts, and climate risks. The majority of respondents (53%) say they are already experiencing the effects of climate change, while 22.6% believe climate change will affect their farm in the next 15 years (2020–2034). According to Fig. 5, the biggest weather concern respondents have about climate change is more variable rainfall, less rainfall and higher maximum temperatures in summer. Wheat farmers are more concerned with less rainfall, more variable rainfall and rainfall arriving later. In general, apple producers are more concerned about increased temperatures than wheat farmers. Specifically, apple producers are concerned about higher maximum summer temperatures, as well as more variable and less rainfall. Higher summer temperatures are a risk to apple farming as it results in sunburn damage.

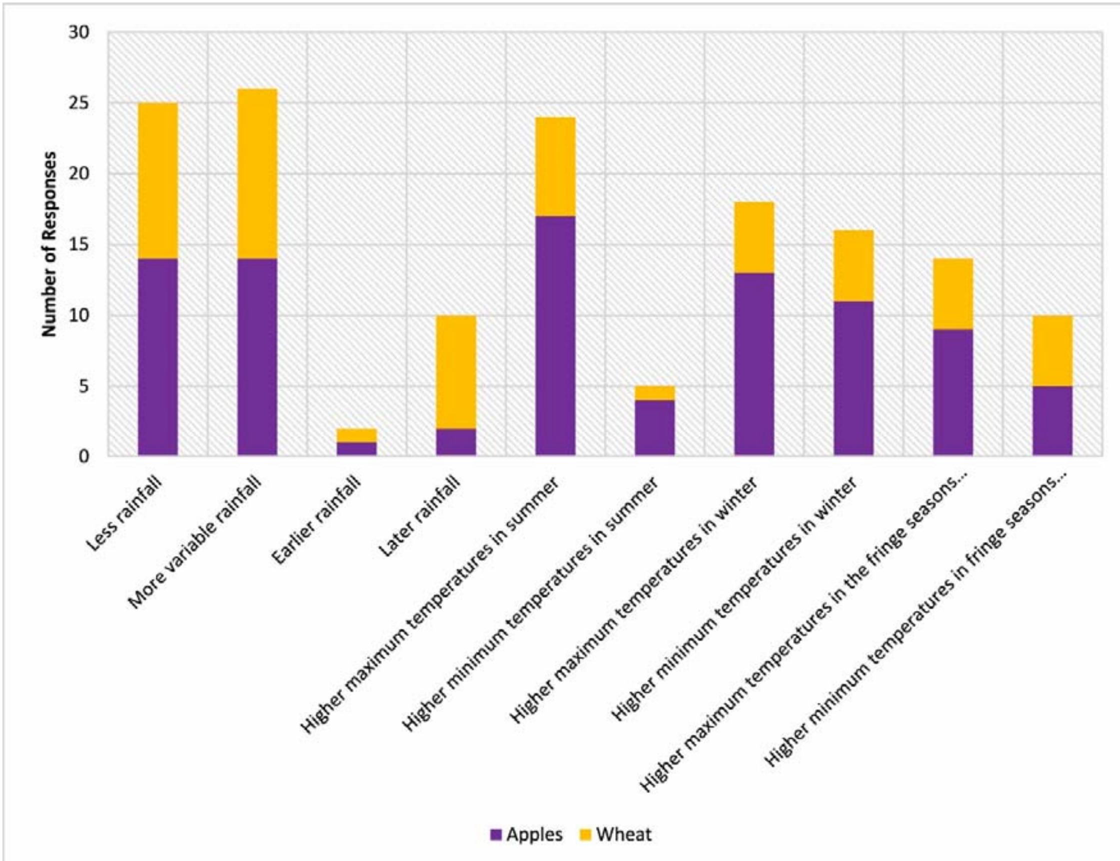

Fig. 5. Apple producers (purple) and wheat farmers (yellow) perceived weather risks and concerns relating to climate change.

The majority of respondents (69%) agree that they need to be preparing for climate change - however, they differ in the phases of action (Fig. 6). Most respondents are already actively preparing for climate change (68%) or indicated that they will be actively modifying their farming practices in the next five years (64%). Respondents also need adequate knowledge to prepare for climate change - the results show that the respondents agree less that they have adequate information to adapt to climate change. From the interviews, respondents cited sustainability as the biggest benefit of adapting to climate change. However, being better prepared for climate risks was also frequently cited as a benefit of adaptation.

"Hopefully give the business a better chance at being sustainable as well as mitigating and softening the contribution of our business to climate change."

"Be more prepared and adapting with it as it progresses allows you to follow the curve and not be behind. You might have to change what you farm with. For example, if you irrigate cereal crops which are relatively low income per hectare and per cubic meter of water, you might have to utilise some of the available resources, like irrigation water, for higher-income farming practices like citrus, avos or nuts."

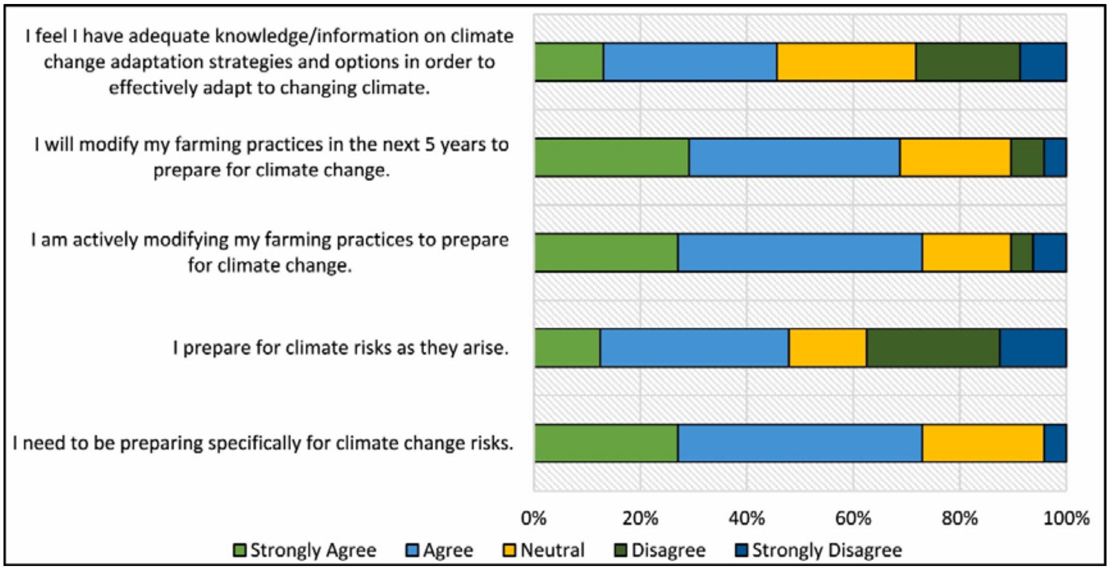

Fig. 6. Farmers' perceptions on adaptation to climate change.

The questionnaire also gave respondents options for those adaptation measures they are most likely to employ in response to climate change (Fig. 7). This question also allowed respondents to add their own responses if they were not satisfied with the provided options. Crop management practices were the most popular adaptation measure, including the use of quality seeds and planting materials, creating a genetically diverse portfolio of crop varieties, integrated pest management, nutrient cycling, and soil protection (particularly increasing the carbon content). Diversified farming (which could extend to businesses outside of agriculture or farm simultaneously with livestock) was the second most popular measure while changing farm type and adopting indigenous species was the least popular adaptation measure. Apple producers were most likely to adopt irrigation management practices, crop management practices and implement water recycling techniques. Wheat farmers were most likely to diversify their farms, adopt crop management techniques and adopt or expand conservation agriculture.

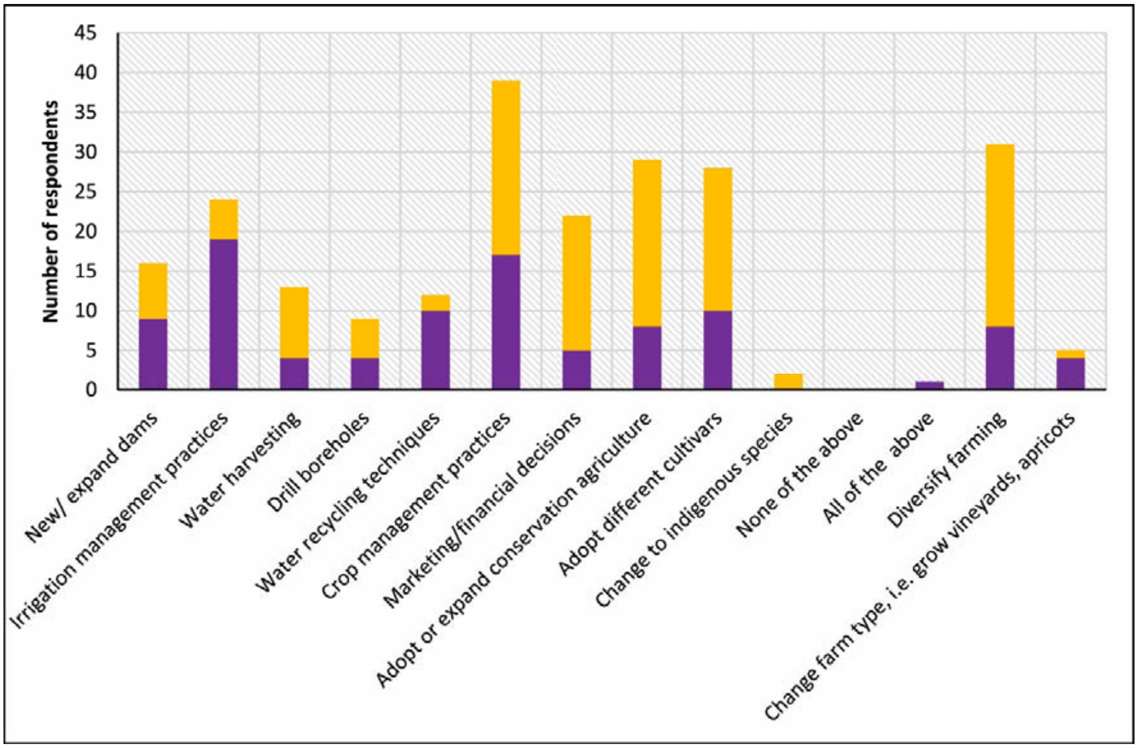

Fig. 7. The adaptation strategies most likely to be employed by apple (purple) producers and wheat (yellow) farmers in response to climate change. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

The survey also sought to understand who farmers and producers felt was responsible for driving climate change adaptation (Fig. 8). Responses show that the majority believe everyone is responsible for climate change adaptation- ranging from the public, government to industry and farmers themselves. Most respondents cited financial barriers to climate change adaptation. Institutional barriers were cited as the second biggest barrier to adaptation. In terms of support, respondents cited industry bodies as providing the most support, with research institutes cited as the second.

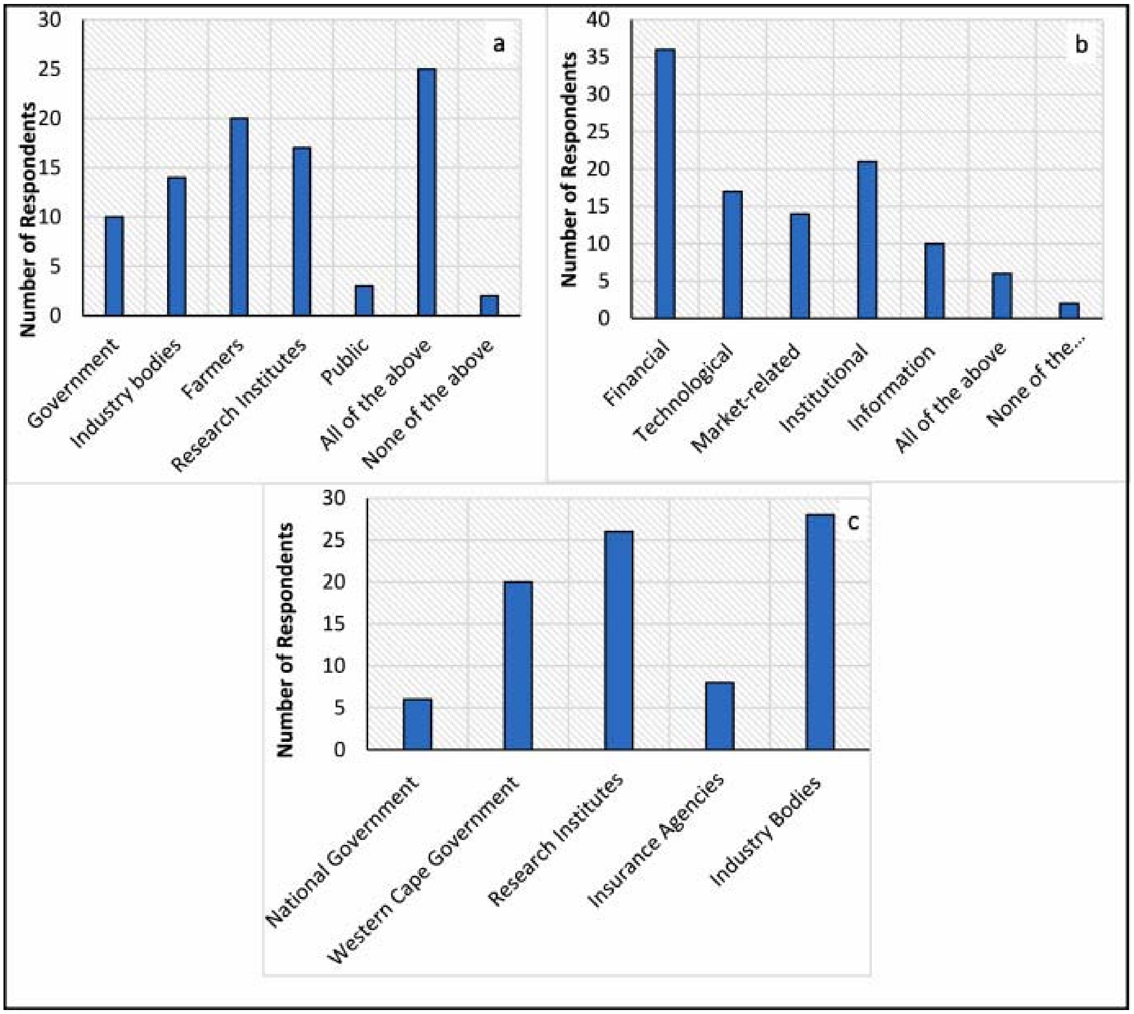

Fig. 8. Respondents' perceptions on (a.) who is responsible for climate change adaptation; (b.) perceived barriers to adaptation; (c.) who provides support to farmers regarding adaptation.

3.2. Drought response

The majority (72%) of respondents agreed that they had learnt from the past 2015–2018 drought and had changed some of their farming practices in response to the drought. They also mostly agreed (59%) that their farm's response to the drought was effective (Fig. 9). 84% of apple producers felt their farms response to the drought was effective while only 53% of wheat farmers felt their response was effective. In addition, 85% of apple producers and 66% of wheat farmers felt they had learned from the drought.

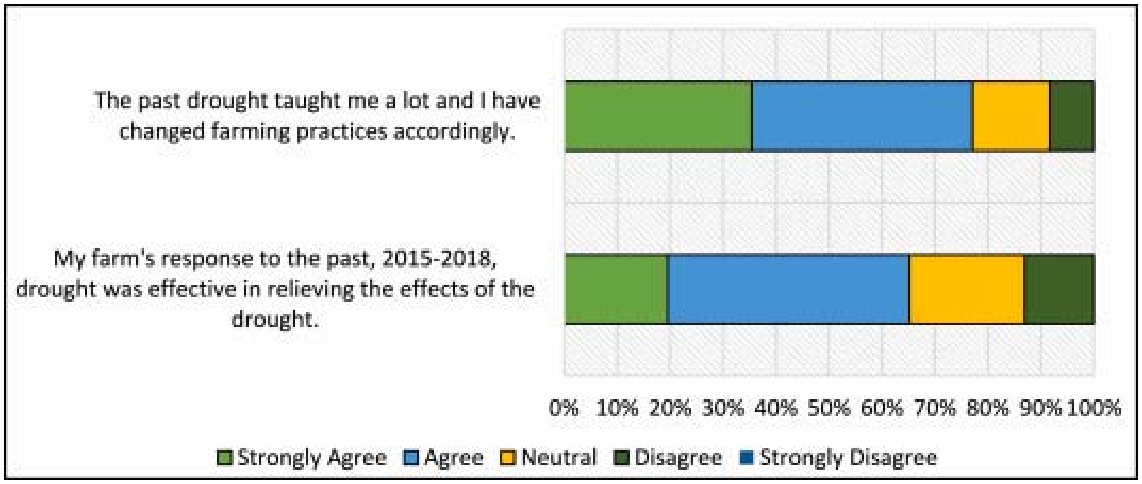

Fig. 9. Respondents' perceptions on the recent 2015–2018 drought.

The study attempted to understand what strategies farmers and producers employed to respond to the drought. This question also allowed respondents to add their own responses if they were not satisfied with the provided options. The majority of respondents employed crop management practices to respond to the drought. The adoption and expansion of conservation agriculture (CA) and the use of short season wheat cultivars were also highly cited as drought management strategies (Fig. 10). The biggest lessons reported from the interviews and surveys were better irrigation (for apples) and water resource management, such as using mulch and soil probes; managing input costs; and diversifying farming, which could extend to businesses outside of agriculture or farm simultaneously with livestock. Apple producers cited irrigation management as the biggest lesson, while wheat farmers cited input cost management and diversifying activities as their biggest lessons. In terms of strategies adopted to respond to the drought for apple producers, the dominant strategy was irrigation management, followed by crop management and drilling new boreholes. Wheat farmers employed crop management strategies, adopted, or expanded CA and adopted different cultivars.

“Water is your most precious resource and should be managed efficiently and effectively.”

“Manage my inputs carefully and stick to and keep on applying the basic principles of conservation farming.”

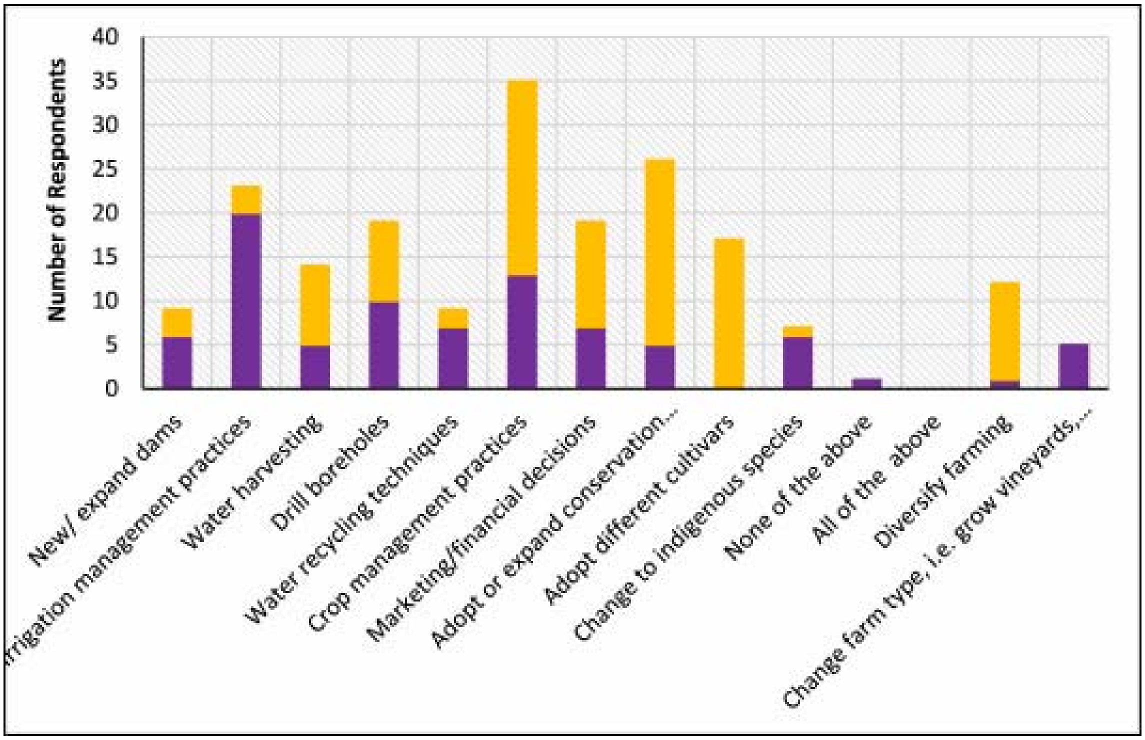

Fig. 10. The response strategies apple (purple) and wheat (yellow) farmers employed in response to the recent 2015–2018 drought

3.3. Lesson learned and preparedness

RF was used to understand the relationship between farmers' and producers' experience of the recent drought and their preparedness for climate change. The variable of importance plots for Fig. 11 were created using Q11 (*I am actively modifying my farming practices to prepare for climate change*) as the independent variable. The relationship was generally weak, with an OOB error of 45%. The main predictor variable was Q12 (*I will modify my farming practices in the next five years to prepare for climate change*). However, since Q12 and Q11 are similar, having Q6 (*The past drought taught me a lot, and I have changed farming practices accordingly*) as the second highest predictor variable is arguably more important. This suggests that respondents who felt they learned from the drought are more likely to be actively preparing for climate change. Another notable observation is the low importance of Q2 (*Climate change is real*). This indicates that respondents' beliefs regarding climate change do not influence their preparedness for climate change. This may suggest a cognitive disconnect between climate change preparedness and climate change.

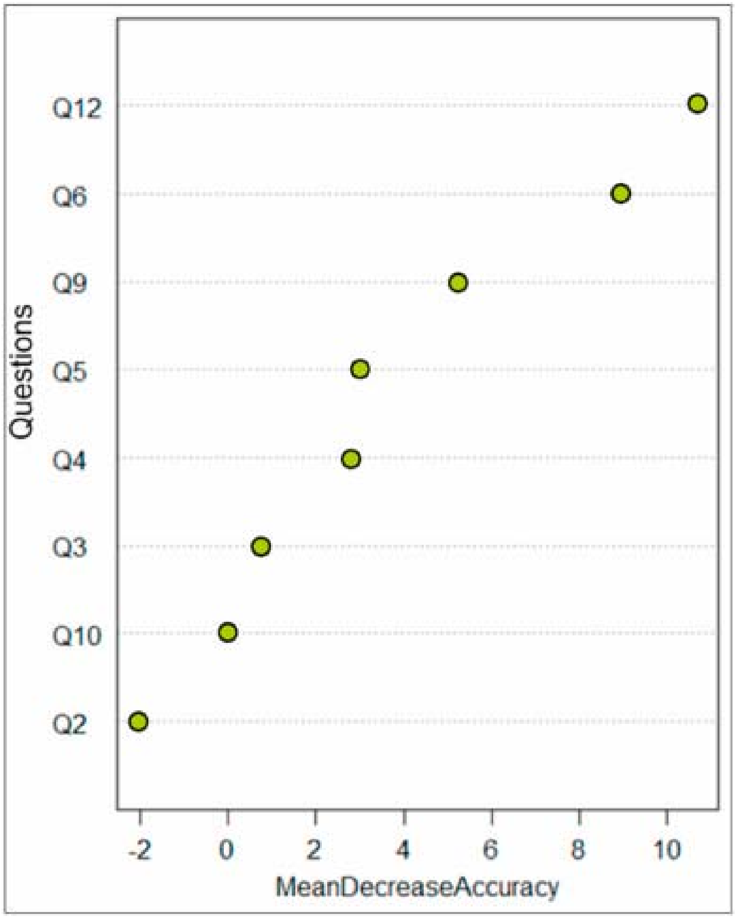

Fig. 11. Variable of importance plot for mean decrease accuracy for Question 11 (Q11): I am actively modifying my farming practices to prepare for climate change. Higher mean decrease accuracy represents variables that contribute to greater predictability of the model.

To better understand the lessons learned from the drought, the study attempted to unpack which adaptation strategies farmers and producers were most likely to employ (Fig. 7), given their main concerns surrounding climate change. The top three concerns (Fig. 6) and adaptation strategies (Fig. 7) were identified, and MDS plots were made (Fig. 12). Several clusters can be identified from the figure. First, there are strong clusters representing respondents who are concerned about less rainfall and rainfall variability. Concerns over summer daily mean maximum temperature (Tmax) have less defined clusters. The figure suggests that respondents who are concerned about less rainfall, as well as rainfall variability, are likely to adopt crop management practices, diversify farming and practice CA. However, in terms of their concern about an increase in summer Tmax respondents do not have a defined coping method. These clusters may be a consequence of wheat farmers vs apple producers and the varying risks each face with regards to rainfall and increased temperature.

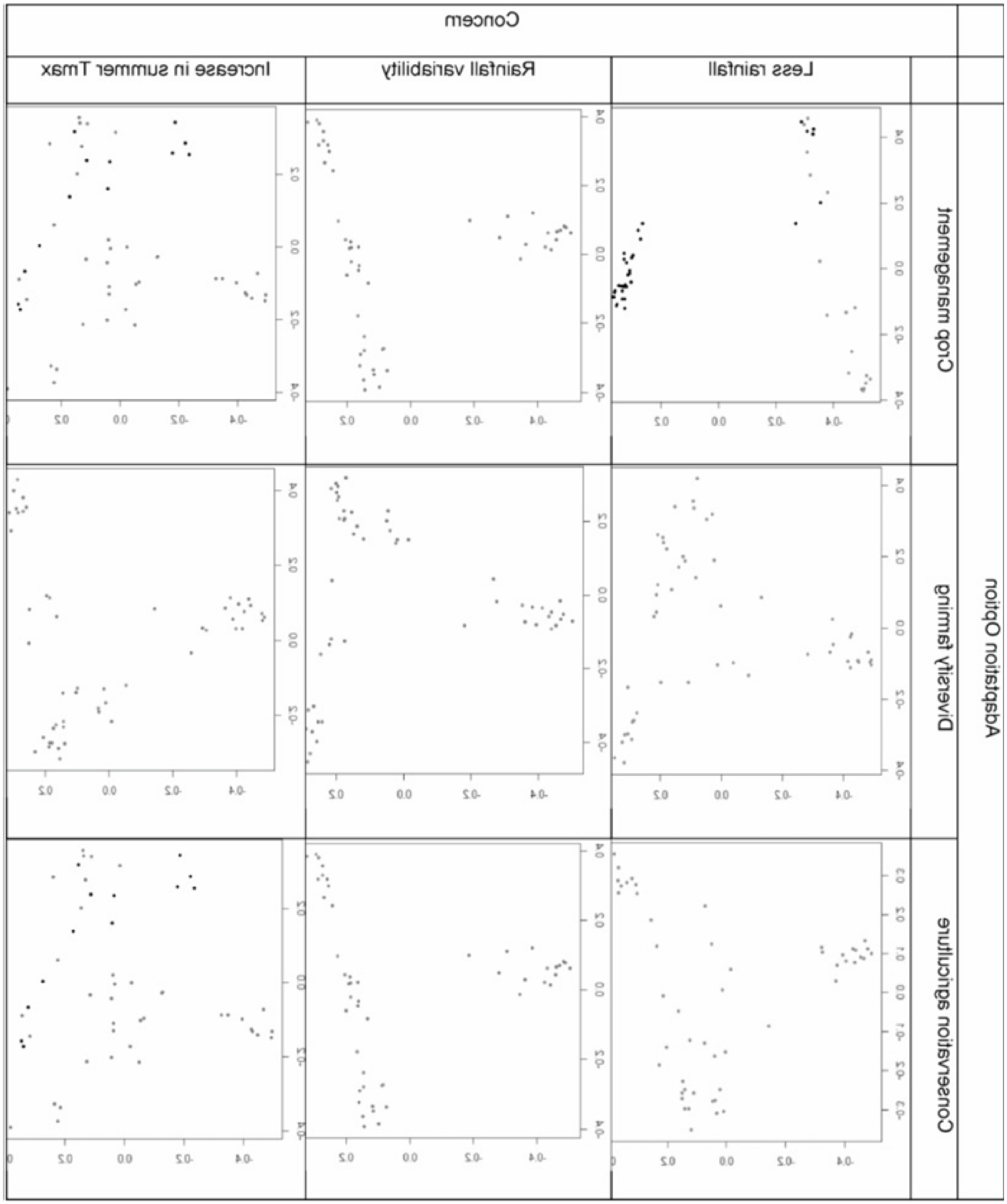

Fig. 12. Multi-dimensional scaling (MDS) plots of respondents' concerns and likely adaptation strategies. Variables on the x-axis represent the respondents' concerns, while variables on the y-axis represent the adaptation response. Tmax = maximum temperature.

RFs were run on the wheat farmer dataset (n = 30) in order to determine which questions (or variables) had the most robust relationship with other variables. The three questions with the strongest relationships were Q8 (*Changes to climate will pose greater risks to my farm*), Q11 (*I am actively modifying my farming practices to prepare for climate change*) and Q14 (*I rely a great deal on weather forecast tools*) (Fig. 13). A strong predictor of farmers feeling climate change would pose greater risks to their farm (Q8) was their acknowledgement that climate change is real (Q2) and that they need to be (Q9: I need to be preparing specifically for climate change risks) or are already (Q11) preparing for climate change. The OOB for Q8 was 36%. Q11 had unsurprising results as it was closely related to a similar question Q12 (*I will modify my farming practices*) and Q8 as described previously, and Q3 (*climate change is caused by human activities*). The OOB for Q11 was 33%. Relying greatly on weather forecasts (Q14) was most strongly related to Q5 (*my farm's response to the drought was effective*) and Q11.

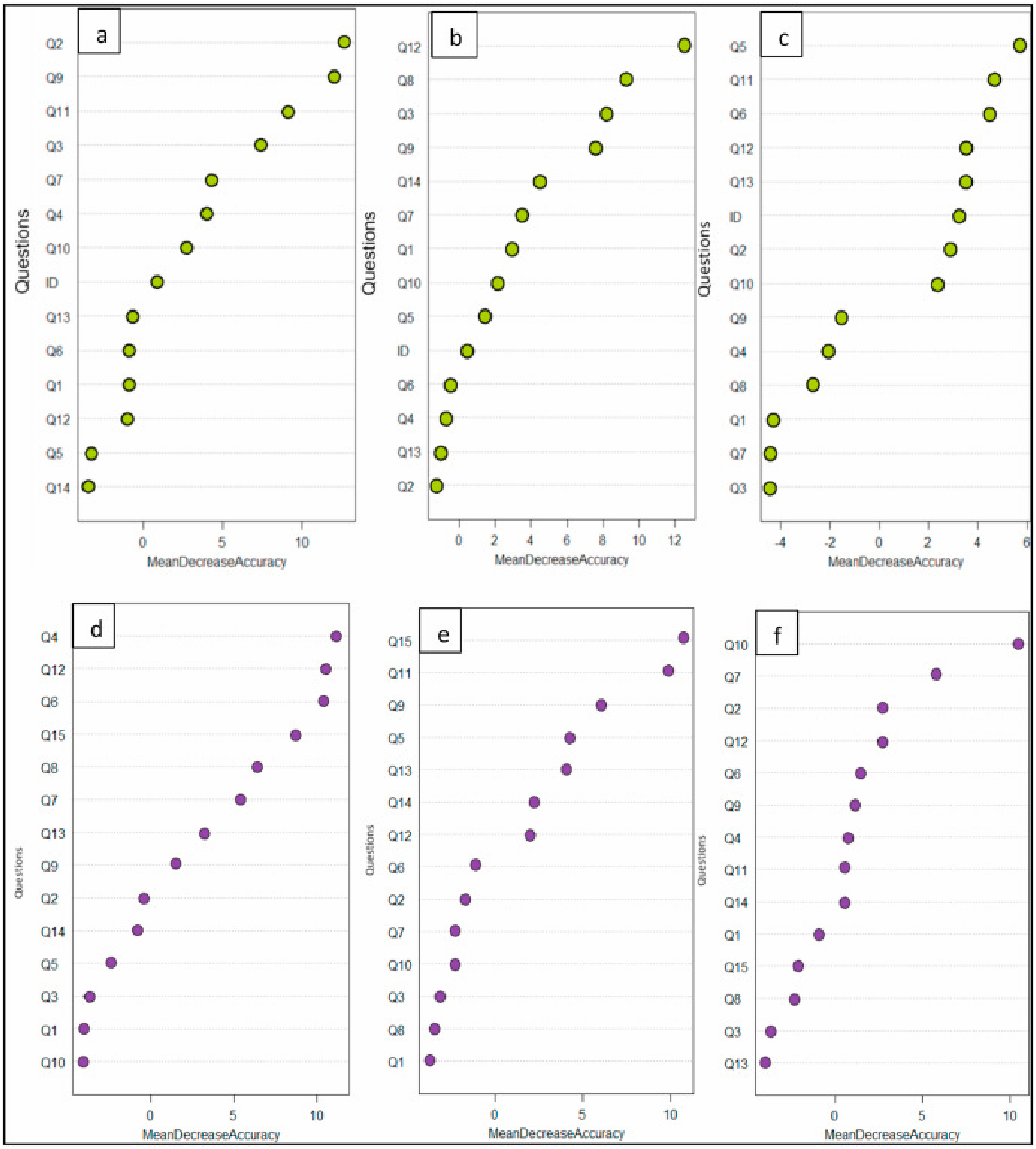

Fig. 13. Variable of importance plots for mean decrease accuracy for wheat farmers (top) and apple producers (bottom). (a) Q8: Changes to climate will pose greater risks to my farm; (b) Q11: I am actively modifying my farming practices to prepare for climate change.; and (c) Q14: I rely a great deal on weather forecast tools; (d) Q11; (e) Q4: In light of other concerns and risks to farming you face, how high does climate change rank in your priorities? and; (f) Q5: My farm's response to the past, 2015–2018, drought was effective in relieving the effects of the drought.

RFs were also run on the apple producer dataset (n = 21) in order to determine which questions (or variables) had the most robust relationship with other variables. The three questions with the strongest relationships were Q11, Q4 (*In light of other concerns and risks to farming you face, how high does climate change rank in your priorities?*) and Q5 (*My farm's response to the past, 2015–2018, drought was effective in relieving the effects of the drought.*). A strong predictor of apple producers actively preparing for climate change (Q11) was how they ranked climate risks amongst other risks (Q4), that the drought had provided some lessons for response (Q6) and similar to wheat farmers also Q12. The OOB was 38%. Lessons learned from the drought for apple producers was associated with preparing for climate risks as they arise (Q10), that climate change might open opportunities for their farm (Q7) and that climate change is real (Q2). These results reflect some of the lessons reinforced by the drought for apple producers. Apple farmers response to the drought kept production steady which likely increased their confidence in responding to climate risks as they arise. In addition, more apple producers than wheat farmers felt their farms response to the drought was effective. Referring to Fig. 7, Fig. 10, apple farmers cited changing farm type more than wheat farmers which may be seen as leading to new opportunities.

4. Discussion

After three abnormally dry growing seasons in the winter rainfall region of the Western Cape, farm-level adaptation for both rainfed and irrigated farms became essential (Raaijmakers and Swanepoel, 2020). Production data shows that apple production was more consistent than wheat production over the drought period with apple yields only deceasing in 2018. This decrease was likely due to constrained water availability and the compounded impacts of three years of drought (PPECB, 2019). The consistency of apple production over the drought can be attributed to irrigation as well as orchard management strategies which focussed on preserving high value orchards and cultivars. Irrigation to some extent can mitigate the impacts of drought on production, however, after prolonged droughts farm dams may not have sufficient water to counter drought effects. Irrigated agriculture is also vulnerable to water restrictions especially in areas where water for irrigation is sourced from dams shared with urban users (Flörke et al., 2018; Rawlins, 2019). Rainfed wheat is vulnerable to drought and low rainfall or inconsistent rainfall over the growing season may lead to large variations in wheat production from one season to the next. These results reinforce the adaptation priorities of wheat farmers and apple producers. Wheat farmers are focused on crop management but cited financial decisions (effective use of inputs) as the biggest lesson. Apple producers cited water resources and irrigation as their biggest lesson and aim to employ better water management strategies as a climate adaptation strategy.

The results presented here indicate that most sampled wheat farmers and apple producers in the Western Cape acknowledge that climate change is real and is caused by human activities. This supports the results of Findlater et al. (2019), who found that South African farmers show greater acceptance of climate change and are more willing to adapt than most commercial farmers in higher-income countries. Moreover, a large majority of respondents say they are already experiencing the effects of climate change. This is an important observation since adaptation is determined by farmers' or producers' recognition of the issue and their perceptions of risks that it may bring (Hyland et al., 2016).

In terms of risks, respondents are most concerned that climate change will result in less rainfall, more variable rainfall and higher maximum temperatures in summer and winter. These results are consistent with those found by Fujisawa et al. (2015), who studied apple producers in the

Elgin region and found producers biggest concerns were warmer winter temperatures. The respondents' concerns are also aligned with evidence presented in the LTAS for agriculture, as well as many other studies on the effects of climate change in the region (Engelbrecht et al., 2015; DEA, 2013a, 2013b; Midgley et al., 2016; Davis-Reddy and Vincent, 2017; Naik and Abiodun, 2020). The LTAS states that in the intermediate future (2040–2060), annual temperatures are projected to increase by 1.5–2.5 °C. In terms of rainfall, relatively little change in mean annual precipitation is expected in the shorter term (2015–2030); however, in the intermediate- to long-term (2080–2100), a decrease in rainfall is expected in the Western Cape. From the mid-term onwards, inter-annual variabilities of rainfall show standard deviations to be intensifying in South Africa. This suggests that the farmers and producers in the Western Cape have good knowledge about the weather risks climate change will bring, although many feel they would like more information regarding weather, climate change and adaptation.

"*There is no one that tells us [about climate change] we have to go look for the information ourselves, and we don't always know what is true.*"

"Not unless I'm gonna google it, it's not information coming to me; I must go and look for it. 'Climate change', it's a Sci-Fi, word kind of. [Some people are] kind of afraid of the word, so you are not going to look for it, and if you got a mail about climate change, it's the last one you are going to look at. You are gonna look at the stuff that's happening now."

Results also showed that respondents acknowledge that they need to prepare for climate change, that they are preparing for climate change and/or that they will start preparing within the next five years. This further supports the results of Elum et al. (2017) and the DEA (2013a, 2013b), who found that South African farmers are already adapting to climate change. Adaptation strategies did not differ too much from the current drought response. This suggests that the farmers and producers in the Western Cape are not considering strategies beyond those tried and tested, confirming the results of Talanow et al. (2021). It also shows that farmers and producers are still focused on short term coping or recovery mechanisms rather than longer-term resilience building. This is consistent with results from Holman et al. (2021). The preferred strategies identified for adaptation are crop management practices, adoption or expansion of conservation agriculture, adoption of different cultivars, and diversified farming, which could extend to businesses outside of agriculture or farm simultaneously with livestock. Fujisawa et al. (2015) found that producers in the Elgin region are already planting cultivars and crops (such as pears) which require lower chill units. It is important to note that the identified adaptation strategies were also the dominant strategies respondents used during the drought- except that cultivar choice was cited more frequently than diversify farming for drought response. Talanow et al. (2021) suggested that such preferences in response strategies may be attributed to other influences such as farmer information networks. Such results have implications for information dissemination, highlighting areas where government or policy may need to tap into for effective communication. According to Findlater et al. (2018), conservation agriculture and crop management practices are most profitable when implemented without livestock. However, findings by both Johnston et al. (2016) and Findlater et al. (2018) show that many wheat farmers in the Western Cape's adaptation strategies include diversifying with livestock. This is due to the uncertainty over the performance of CA practices during severe droughts events (Findlater et al., 2018). This is further supported by the results of Johnston et al. (2016), who found that farmers are growing more medics and less wheat to provide grazing. The results may suggest that may be a lesson for farmers which was reinforced during the drought. Many farmers cited lessons learned with regards to livestock feed and grazing.

“[Biggest lesson?] Grow more cover crops for grazing.”

“Diversify into activities that are less rainfall dependant.”

The higher importance of “diversify farming”, which could extend to businesses outside of agriculture or farm simultaneously with livestock over cultivar choice for adaptation, may be due to the time needed to plan and prepare for diversification. In contrast, cultivar selection occurs at the start of the season (long-term vs short term-responses). Results showed that 42% of respondents (n = 51) have businesses or income outside of farming which may be a long-term adaptation strategy. It may also suggest the respondents' frustration with the limited availability of new cultivars. Indeed, cultivar development was frequently cited in the interviews, particularly with wheat farmers, as an urgent need for drought and climate change response.

“If you just look at the maize industry [and] what they've done in the last 10 years with the development of new varieties and with GM [genetically modified] maize, they've increased the yield immensely. Perhaps we can develop wheat that is more drought-tolerant. We've just got that one that I told you [about (SST 88)], and that's been with us since 1988, and it's still with us; it's still our banker for the dry years”.

It was found that most respondents felt that they had learnt from the 2015–2018 drought and had changed some of their farming practices since then. Furthermore, it was found that respondents who said they learned from the drought were also more likely to be actively preparing for climate risks. These results confirm findings by Weber (2006), who reported that actual exposure and awareness increase proactive behaviour. The large difference between wheat farmers and apple producers with regards to drought response and lessons learned are interesting and may indicate that increased support is needed for wheat farmers with regards to climate risk management. As mentioned earlier, most apple farmers are part of a co-op and often receive information on farm management from the co-ops. Large co-ops have dedicated researchers and consultants which help guide farmers. Wheat farmers do not have the same structural support, while there are several farmer days held annually the advice provided during these are often general and not farm specific. Another cause of the observations could be due to favourable export markets, the value of the rand and inflation; this was cited in the PPECB Reports 2017 and 2018 (PPECB, 2018, 2019). Wheat is produced for local consumption and, is thus, sold in South African Rand. While many apples produced are exported and sold in Dollars or Euros. It should be noted that there was an increase in processing tons of apples over the drought period (Hortgro, 2020; Theron, 2022). Apples selected for processing are of lower quality than those destined for export and local markets. Shifting fruit meant for the export market to the local or processing market because of quality problems puts prices under pressure and considerably decreases profitability of apple production (Midgley, 2016). This may have implications for apple production and supply as results show that farmers/producers do not have a defined coping method for increased temperatures (which often lead to lower fruit quality through sunburn).

Notably, results showed that most respondents (84%) rely on weather forecasts and respondents who rely a great deal on weather forecasts were more likely to feel that their farm's response to the drought was effective. This is a promising result, as it shows the importance of weather forecasts in strengthening responses to climate variability. It should be noted here that there was no definition of "weather forecast tools" in the survey that was distributed which leaves this question open to interpretation by the respondents. This is a weakness in this study. Nonetheless, the survey questionnaire was complemented by the interviews. In the interviews respondents describe that although they do read long-term seasonal forecasts, they do not make many decisions based on those forecasts due to their inaccuracy. Instead, they used short-term forecasts including 3–5 day and hourly forecasts (including rainfall, temperature, and humidity) in order to guide their farm management decisions. Such decisions include when/if to spray fungicide, when/if to apply nitrogen or other fertilizers and when to harvest among others. While none of these decisions are directly linked to drought, short-term forecasts can and do guide management response to prevailing conditions which can help ensure good quality (or best quality possible) wheat is still harvested. Furthermore, these short-term forecasts help farmers and producers decide on whether to purchase inputs which is a financial decision. Guiding farmers and producers on whether and which inputs to purchase is critical during droughts as they need to ensure they do not overspend. Thus, short-term weather forecasts are a crucial asset to farmers and producers, they guide crop management practices which was cited as one of the most employed adaptation strategies currently and will continue to be in the future and they guide decisions to help maintain and balance the farms financial capital.

"We use the weather all the time. We always joke, the farmers, [that] the cell phone's screens always got scratches where the app is… Um the short-term forecast but ja …. the long term is good to know what the next month, if its gonna rain, do they predict a drought for the next 3 months or a good season it helps position you over the short term. But the hourly forecast knows what you have to do now if you can go and spray now [and] the weekly one helps you plan your week."

"You look every day at the [weather] systems, you get a feeling you know that they are not always right, but you have a feeling more or less what is going on. It influences me when I must buy my extra nitrogen or my extra chemical spray which I want to spray on my wheat."

An interesting observation was that respondents' beliefs on climate change do not influence their preparedness for climate change. This suggests that farmers and producers are adapting regardless of their beliefs which may indicate a cognitive disconnect. It may also suggest the strength of information networks in driving decisions. Farmers and producers may be more likely to adopt the practices of their peers in the fear that they may get left behind. This was suggested in the interviews:

"The other farmers they spent [money] because they had the hope that it will rain better than the forecast. So a, emotionally, it is a big deal, your neighbour is spending right next to you, and a few of us, we decide no, we are going the other way. But you are scared that maybe he is right."

When studying farmer perceptions and decision making, it is important to understand that weather and climate variability are inseparably linked with other risks in farmers' perceptions, such as agronomic, economic, political, and personal. As a result, farmers and producers do not necessarily attempt to reduce weather risks but rather manage them as just one factor in a complex landscape of risk (Fujisawa et al., 2015; Johnston et al., 2016; Findlater et al. 2018, 2019). In fact, weather and climate risks are rarely the most important concern for farmers and producers. The respondents in the Western Cape frequently cited politics and input costs as greater concerns. Therefore, weather and climate risks may just be the "backdrop" against which other more direct risks play out. This may be due to the natural, unpredictable and "has-always-been-there" nature of climate and weather.

"A farm will always be vulnerable because of climate. We never know how the year will turn out."

There is much uncertainty surrounding climate change effects and impacts, including their direction and amplitude, particularly at the local level. This is compounded by uncertainties in the effectiveness of specific adaptive responses, as well as who is actually responsible for adaptation. Although the results show that respondents feel everyone is responsible for climate change adaptation, a considerable number believe farmers/producers themselves are responsible. Climate change will present unprecedented risks to food production and security, and indeed the responsibility of adapting belongs not exclusively to farmers/producers. However, a challenge exists in how to spread the responsibility of adaptation across society. These uncertainties make it difficult for farmers and producers to include climate change risks in conventional risk assessments and multicriteria decision-making (Dittrich et al., 2016).

"It's not enough known about this climate change stuff and how it really impacts us all."

It is recommended that to address the risk of climate change and facilitate farmer and producers' adaptation in the Western Cape; investments need to focus on several core areas. These include research and development into drought-resistant cultivars specifically for conditions faced in the Western Cape; strengthening of weather forecasting and improvement of information dissemination; research strategies that will address local risks; and aid the implementation of effective irrigation practices. The results further suggest that policy that aims to reduce climate change risks needs to be developed in the overall context of risks farmers/producers face (Johnston et al., 2016; Eitzinger et al., 2018). Such policies should take an integrated approach to address specific climate risks at the local level aiming to combine indigenous/local knowledge and experience with scientific results (Johnston et al., 2016; Elum et al., 2017; Eitzinger et al., 2018); ensure the risks addressed are embedded in other risks farmers and producers feel are important (in this case addressing land-reform and adaptation together may be a successful starting point); and aim to target farmers and producers who are more vulnerable to climate risk (Eitzinger et al., 2018). The results also show that wheat farmers and apple producers have different risks and strategies to mitigate those risks. Policy to support farm-level adaptation should take account of these differences and allow for flexibility in farm response to climate change. Furthermore, it is important that policy address the institutional and financial barriers farmers experience. The research demonstrates that understanding farmers' and producers' perceptions and drought response can improve climate risk communication and policy development.

5. Conclusion

Understanding the farmers' and producers' perception of climate change and adaptation is key in developing policies and guidelines aiming to minimise the impacts of climate change on agriculture. While several studies exist which analyse farmers perceptions of climate change in the Western Cape there is a gap in the research of farmers and producers' perceptions to climate change and drought after experiencing the recent Western Cape drought. Analysing farmers' and producers' responses to the recent drought and their perceptions on climate change can help inform strategies, which will support the sector's resilience under future climate. It can also help to understand how responses to extreme events may guide adaptation to climate change. This was achieved using an online questionnaire of Likert-type questions as well as several in-depth interviews with farmers and producers in the two apple and two wheat-growing regions of the province. In addition, there is limited research on the use of RandomForests for analysing survey data. This study shows that RandomForests is a useful tool to analyse Likert-type survey.

Results showed that most farmers and producers agree that climate change is real and is caused by human activities. Most respondents are already actively preparing for climate change, or they intend to start preparing within the next five years. In response to climate change, apple producers view on-farm water management (such as irrigation management and water recycling as the most important strategy). Wheat farmers strategies are focused on crop management (including cultivar selection and CA). Respondent's climate change response strategies do not differ significantly from drought response strategies, which indicate most respondents are still focused on short term coping or recovery mechanisms rather than long-term resilience building. The majority of respondents agreed that they had learnt from the past 2015–2018 drought and consequently changed some of their farming practices. Notably for a South African region, results showed that farmers and producers (especially wheat farmers) who rely a great deal on weather forecasts were more likely to feel that their farm's response to the drought was effective. Furthermore, it was found that farmers and producers who felt they learned from the drought were also more likely to be actively preparing for climate risks. However, respondents' beliefs on climate change do not influence their preparedness for climate risks. This may indicate a cognitive disconnect and suggest the importance of farmer information networks.

It is recommended that investments into climate change adaptation focus on research and development, particularly with regards to cultivar development, irrigation management, weather forecasting and early warnings, and localised risk assessments. Policy and guidelines should prioritise the more vulnerable farmers/producers while focusing on integrated risk reduction measures which account for other factors in farmers' or producers' risk landscape.

Author statement

The authors confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all of us.

Declaration of competing interest

None.

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Appendix.

Table A.1. The Likert type questions posed to the farmers; responses were graded on a scale of 1 (Strongly Disagree)−5 (Strongly Agree).

ID	Question
Q1	Income diversification other than farming?
Q2	Climate change is real.
Q3	Climate Change is caused by human activities.
Q4	In light of other concerns and risks to farming you face, how high does climate change rank in your priorities?
Q5	My farm's response to the past, 2015–2018, drought was effective in relieving the effects of the drought.
Q6	The past drought taught me a lot and I have changed farming practices accordingly.
Q7	Changes to climate will open more opportunities for my farm.
Q8	Changes to climate will pose greater risks to my farm.
Q9	I need to be preparing specifically for climate change risks.
Q10	I prepare for climate risks as they arise.
Q11	I am actively modifying my farming practices to prepare for climate change.
Q12	I will modify my farming practices in the next 5 years to prepare for climate change.
Q13	I feel that my farm will continue to be profitable in the next 30 years.
Q14	I rely a great deal on weather forecast tools.

Data availability

The authors do not have permission to share data.

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