Journal of Rural Studies 81 (2021) 203–219

Contents lists available at ScienceDirect

Journal of Rural Studies

journal homepage: www.elsevier.com/locate/jrurstud

Farmers' perceptions of climate change and adaptation strategies in South Africa's Western Cape

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ARTICLE INFO

Keywords:
Adaptive behaviour
Cape Floristic Region
Drought
Risk perception
South Africa

ABSTRACT

Climate change poses a serious threat to South Africa's agricultural sector. Implementing adaptation strategies is thus crucial to secure future agricultural production and rural livelihoods. To support effective adaptation, it is necessary to understand how farmers, as primary land-use decision-makers, perceive and respond to climate change. We conducted semi-structured interviews to examine climate change adaptation behaviour by commercial grain and wine grape farmers in a water-scarce, recently drought-stricken agricultural region of South Africa's Western Cape. Specifically, we investigated (1) how farmers perceive climate change, (2) which factors influence their adaptive behaviour and (3) which adaptation strategies they apply in their farming practices, and whether these are medium to long-term or short-term coping strategies. Through the resulting discourses, we found that most farmers have observed long-term regional changes in climate, such as changes in rainfall patterns, increasing temperatures and extreme climatic events. Farmers' adaptive behaviour is influenced by previous experience of climatic stresses and internal factors, including risk perception, perceived adaptive capacity and cognitive biases. Institutional and biophysical constraints including perceived lack of government support and soil composition are external barriers to adaptation. Most farmers have implemented adaptive strategies on their farms, including alterations to soil and crop management, such as changes of harvest and planting time, crop rotations and water conservation techniques. However, farmers have planned fewer adaptive strategies to future impacts of climate change than current implemented strategies. Current strategies are mostly technological and address direct impacts of climate stressors, although climate change impacts go beyond the farm scale into society. These findings may have important implications for future policy making and climate change adaptation in this region, given the place-specific institutional and biophysical barriers identified by farmers, and the strategic importance of the Western Cape in South African agriculture.

Authors contributions

KT: Conceptualization, Investigation, Writing - original draft Preparation. ET: Investigation, Writing - original draft Preparation. JL: Conceptualization, Supervision, Project administration, Funding acquisition, Writing - review & editing. BML: Conceptualization, Methodology, Supervision, Writing - review & editing.

1. Introduction

Climate change is one of the biggest challenges facing humankind to date. The severity of the future impacts of climate change is largely determined by peoples' present ability and action to adapt (Wolf and Moser 2011). Adaptation is particularly important in agriculture, given the climate sensitivity of the sector (Smit and Skinner 2002; Haden et al., 2012; Niang et al., 2014). To secure agricultural productivity and rural livelihoods, farmers need to adapt their farming practices to present and future impacts of climate change. However, the relationship between perception of and adaptation to climate change is not straightforward (Wiid and Ziervogel, 2012). Understanding the motivating factors leading to adaptive behaviour is key to promoting climate change adaptation to secure food production and farmers' livelihoods.

An important precondition to understand individual climate adaptive behaviour is to reveal farmers' cognitive processes (Bryant et al.,

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https://doi.org/10.1016/j.jrurstud.2020.10.026
Received 6 April 2020; Received in revised form 23 September 2020; Accepted 16 October 2020
Available online 6 November 2020
0743-0167/

2000), which are shaped by experiences and perceptions of climatic changes (Wiid and Ziervogel, 2012). Individual adaptive behaviour is strongly influenced by the perception of climate change, the appraisal of associated risks (Hyland et al., 2015), and the perception of one's own capacity to adapt (Grothmann and Patt, 2005; Woods et al., 2017). Furthermore, the perception of risks and adaptive capacity are affected by cognitive biases, such as the optimism bias, whereby people perceive their personal risk as lower than average (Grothmann and Patt, 2005) and which commonly appear under conditions of uncertainty (Woods et al., 2017).

While the perception of climate change and its impacts can motivate adaptive behaviour (Hyland et al., 2015), farmers' behaviours are also influenced by multiple external factors (Chiotti and Johnston, 1995; Smit et al., 2000; Smit and Skinner, 2002). These factors can either act as a barrier or support adaptation behaviour, and include the access to or lack of resources and capital, such as financial means, technology, information, societal and systemic support (Smit and Pilifosova, 2003; Grothmann and Patt, 2005; Darnhofer et al., 2010; Tessema et al., 2019). Farmers' behaviours are also strongly shaped by personal, environmental and socioeconomic contexts (Findlater et al., 2018; Takahashi et al., 2016). To better understand farmers' adaptation behaviour to climate change, it is necessary to investigate both internal (e.g., cognitive) and external (e.g., institutional and biophysical) influencing factors. This adaptation behaviour can be further differentiated between coping, which consists of immediate or short-term responses to impacts and hazards, and adaptation itself, seen as transformative medium and long-term change (Birkmann, 2011; Fischer, 2019). Determining whether farmers adapt or cope is important for developing policies that foster not only short-term, temporary adjustments but also enduring adaptation in the face of environmental change (Fischer, 2019).

South Africa is especially vulnerable to climate change and its impacts, as a semi-arid and water-stressed country (Botai et al., 2018). Mean annual temperatures have increased by at least 1.5 times the observed global average of 0.65 °C during the last five decades (Ziervogel et al., 2014), a trend which is projected to increase, along with reduced rainfall, increased rainfall variability, drier winters and high risks of severe droughts and extreme weather events in the southwestern regions of Africa (Niang et al., 2014; Nhemachena et al., 2014; Davis-Reddy and Vincent, 2017). These projected changes and associated water scarcity will exacerbate existing stresses (Midgley et al., 2005; Dennis and Dennis, 2012; Niang et al., 2014; Botai et al., 2018), leading to negative effects on agriculture, water and food security, ecosystem services and the South African economy (Hannah et al., 2013; Nhemachena et al., 2014; Ziervogel et al., 2014; Archer et al., 2019). Indeed, climate change-induced increasing water scarcity and insufficient irrigation are expected to lead to severe declines in agricultural productivity of up to 50% in South Africa, as well as other countries in the Southern African Development Community (SADC) region (Davis-Reddy and Vincent, 2017). Next to South Africa, Namibia and southwestern parts of Botswana are already facing high risks of water scarcity and are vulnerable to further climatic changes, especially in climate-sensitive sectors such as agriculture (Davis-Reddy and Vincent, 2017). The highly developed South African commercial farming sector contributes significantly to food security of the southern African region (Tibesigwa et al., 2017), while the spectrum of South African farmers also contains approximately two million subsistence-oriented, smallholder farmers and approximately 20,000 small-to medium-scale commercial farmers (WWF, 2018). South Africa's commercial farming sector has been largely deregulated since the end of apartheid and the transformation of South Africa's political system, meaning that commercial farmers had to respond to free global market conditions without subsidies, credit or trade protections (Hornby et al., 2018; Kheswa, 2013; Mapfumo et al., 2014; Schulze 2016). South African commercial farmers therefore operate under different conditions to other highly mechanized agricultural sectors in higher-income countries, potentially rendering them less resilient to climate change impacts (Findlater et al., 2019). This may be particularly pivotal in the wine industry, where South African farmers compete against developed regions with subsidies such as Europe, North America and Australia (Ashtenfelter and Storchmann, 2016).

In the years 2015–2018, South Africa's Western Cape province was subject to a rare and severe drought attributable to anthropogenic climate change (Wolski, 2018; Otto et al., 2018). The Swartland agricultural region in the Western Cape is the most productive agricultural region in the province, and the recent drought resulted in crop losses and associated economic impacts (Moseley, 2006; Archer et al., 2019). The region is dominated by large-scale commercial agriculture, with associated environmental and socio-political problems, including significant loss of native vegetation and economic inequality (Crane, 2006; Halpern and Meadows, 2013). Many grain farmers in the Swartland have adopted 'conservation agriculture' (CA) principles, such as practicing minimum tillage, introducing crop rotations with legumes and increasing permanent soil cover (Findlater, 2017; FAO, 2017; Western Cape Department of Agriculture, 2019). These principles are promoted in part to combat climate change impacts and diversify risk to farm operations, and are linked to climate change adaptation in the region (Findlater, 2017; WWF, 2018). Considering the region's distinctive climatic variability and the dominance of commercialized agriculture, the Swartland constitutes a unique area to investigate farmers' perceptions of climate change and factors influencing climate change adaptation, particularly in light of recent severe water stress.

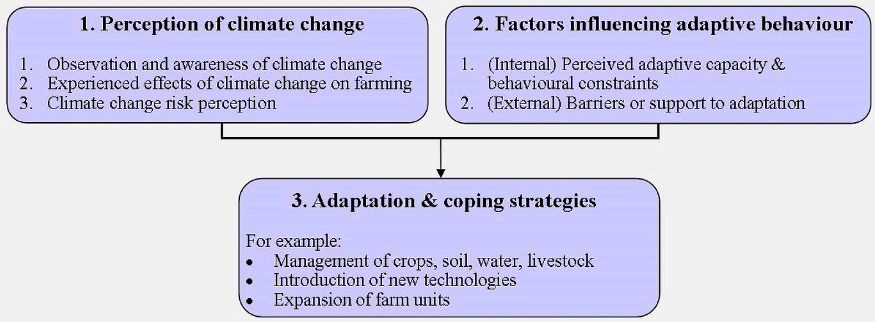
In this context, we aim to answer the following research questions: (I) How do Swartland farmers perceive climate change? (II) Which cognitive and external factors influence their risk perception and adaptive behaviour? (III) Which adaptation strategies do they apply in their farming practices and which do they envision applying in the future? To answer our research questions, we adapted the conceptual framework Model of Private Proactive Adaptation to Climate Change (MPPACC) created by Grothmann and Patt (2005) to study the individual response to climate change. The MPPACC-framework categorizes the variety of internal and external factors that determine a person's adaptation intention and resulting adaptive behaviour. We adapted the framework into three components, whereby (1) perception of climate change and (2) factors influencing adaptive behaviour lead to (3) strategies for current or planned adaptation. These three components are further described in Box 1. We also sought to distinguish between adaptation strategies and coping behaviour by interpreting the stated adaptation strategies according to approaches taken by Fischer (2018, 2019), and to identify the overlaps of these stated adaptation strategies with CA principles.

2. Methods

2.1. Study area

Our research area is the Swartland municipality and its close surrounding in the Western Cape province of South Africa (Fig. 1). The Western Cape accounts for 12% of South Africa's total agricultural area and provides 20% of the nation's total agricultural production output (Meterlekamp, 2011; Directorate Statistics and Economic Analysis, 2013), mostly in large-scale commercial enterprises (Findlater, 2013). The province is a Mediterranean-type, winter rainfall region with Atlantic ocean influence and fertile soils, rendering it especially favourable for cereal farming, including wheat, oats and barley, and viticulture (Midgley et al., 2005; Western Cape Government (WCG), 2015; Araujo et al., 2016). Additional farming types include fruit and vegetable production and livestock (Midgley et al., 2005; Meterlekamp, 2011; Department of Agriculture, Forestry and Fisheries, 2017). The region has experienced a mean annual temperature rise of approximately 1.0 °C over the last 50 years, as well as increased flooding, droughts and heat waves (WCG, 2015). Climate models project continued warming and a general drying trend in the next decades

Box 1
Conceptual framework of adaptive response to climate change in agriculture, including internal and external factors, adapted from Grothmann and Patt (2005).



Perception of climate change
1. Observation and awareness indicates whether, and to what extent, farmers evaluate observed changes in climatic parameters as a sign of ongoing, global climate change (Hyland et al. 2015). 2. *Experienced effects of climate related events on farming* refers to the impacts on farming that farmers ascribe to climatic stresses. 3. *Climate change risk perception* indicates farmers' individual appraisals of the probability of exposure to, and the level or harm of, climate-related risks (Grothmann and Patt, 2005).

Factors influencing adaptive behaviour (Internal and External)
1. Internal perceived adaptive capacity and behavioural constraints relates to the farmer's perceived own ability to take effective adaptive responses (Woods 2017; Grothmann and Patt 2005). *2. External barriers or support to adaptation* address the availability or lack of external resources, such as knowledge, money, and institutional support, as objective determinants of adaptive behaviour (Smit and Pilifosova 2003; Grothmann and Patt 2005; Darnhofer et al. 2010; Nhemachena et al. 2014).

Adaptation and coping strategies
We considered agricultural adaptation strategies as all measures, activities and changes in the agricultural system, at farm level, related to reducing the system's vulnerability to climatic stresses (Esham and Garforth 2013, Smit and Skinner 2002). We distinguished between long and medium-term adaptation strategies and short-term coping strategies according to Fischer (2018, 2019).

(WCG, 2014), increasing number of hot days and more frequent heat waves in the Western Cape (WCG, 2015). The western parts of the region in particular are projected to experience drier winters and high risk of droughts (Midgley et al., 2005; Niang et al., 2014; WCG, 2015).

Grain production covers approximately 60% of all cropland in the Swartland, while vineyards cover 6% (Western Cape Agristats Dataset, 2018). While wheat is the major grain under cultivation, crop rotations include medics (clover) and lucerne (alfalfa). Grain production in the Swartland is sensitive to higher temperatures and heat waves, reduced rainfall, longer dry spells and higher frequencies of intense rainfall events. The majority of wheat farmers in the Swartland grow rainfed wheat during the winter wet season and do not use irrigation (Findlater, 2017; Western Cape Agristats Dataset, 2018). Grape production is sensitive to climate variability, temperature changes and droughts (Hannah et al., 2013; Araujo et al., 2016). Wine grape farmers often have irrigation systems, and are hence less sensitive to changes in rainfall (Araujo et al., 2016), although some Swartland farmers also have dryland vines. The limited supply of water leaves little scope for expansion of irrigation (Archer et al., 2019). The projected climatic changes are thus likely to have negative effects on both grain and wine grape production in the region (Hannah et al., 2013; Araujo et al., 2016).

2.2. Data collection and analysis

We collected qualitative data by conducting face-to-face semi-structured interviews with 16 commercial farmers, of which eleven concentrated on wheat farming and five on wine farming in the Swartland. Farmers from a pool of participants of a previous study in the region (Topp and Loos, 2018) were contacted and asked if they would be willing and available to participate. From this pool, 16 farmers signalled their willingness and availability. Interviews were conducted between September and October 2018. Prior to each interview, we informed all participants about the purpose of the study and the interview process and obtained their written consent to participate in the research. All interviews were conducted in English, audio-recorded using voice recorders and later transcribed in full. The average length of the interviews was 40 min, ranging between 25 min and 1.5 h. The interview questions were designed to address each of our research questions, and informed by a scoping of literature on climate change adaptation in Southern Africa (Nhemachena et al., 2014; Elum et al., 2017; Filho et al., 2017; Callo-Concha, 2018). The full interview guide is provided in Appendix 1. We differentiated wheat (WH) and wine (WI) farmers in order to relate potential differences in farmers' perceptions of climate change and differences in the implementation of adaptation to farming systems. Such contextual information may help to improve understanding of farmers' observations and "ground" knowledge in place (Soubry et al., 2019). The transcribed interviews were coded and analysed with the software MaxQDA Version 2018. We applied qualitative content analysis (Mayring, 2002; Kuckartz et al., 2008) to uncover the components of the conceptual framework outlined in Box 1. In order to code for *climate change risk perception,* we coded statements into three categories; low, moderate or high. We coded for low risk perception where farmers expressed little concern for climate change and low perceived exposure to its impacts, whereas we coded for high risk perception when farmers expressed high concern and high perceived exposure to its impacts. Low risk perception also encompassed cognitive biases such as optimism and

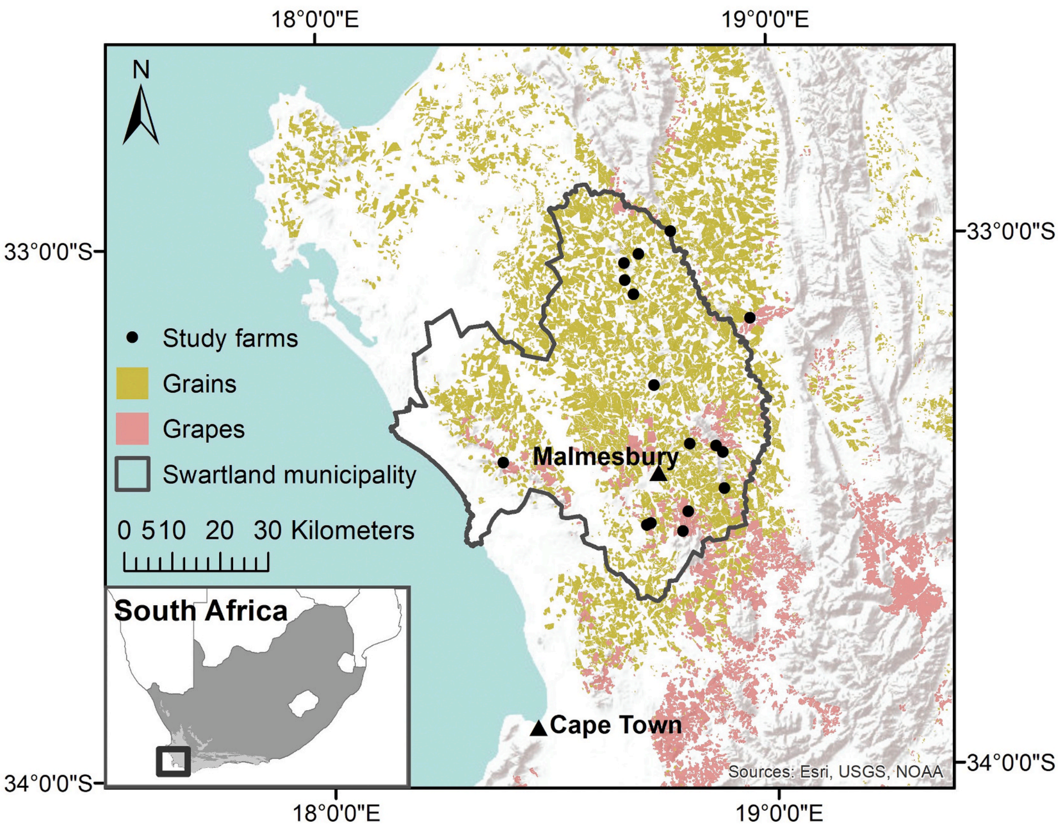


Fig. 1. Location of study farms in or within 5 km of the Swartland of South Africa's Western Cape province. The Swartland municipality is outlined in grey and the 16 farms represented in the study are identified with black circles. Spatial information on crop cover from the Western Cape Department of Agriculture, Forestry and Fisheries (2017), available at https://gis.elsenburg.com/portal/home/. 'Grains' includes primarily wheat and other grains such as barley. 'Grapes' includes both viticulture and table grape production.

avoidance of dealing with climate change. Moderate risk perception encompassed more measured statements which relativized the severity and urgency of climate change, and high risk perception encompassed statements of anxiousness and resignation towards the effects of climate change. *Perceived adaptive capacity* was not explored by direct questioning but identified from farmers' responses to other questions, such as those regarding problems caused by climatic changes, the availability of information and support towards climate change or the application of adaptation strategies. We identified strategies and interpreted whether they were short-term coping strategies or more medium and long-term adaptation strategies, evaluating the stated benefits of each strategy in order to better understand the purpose behind its implementation and assess if the practice may be considered adaptation (Fischer, 2018). We also categorized whether an adaptation strategy overlapped with CA principles based on recommendations for CA in a South African context (WWF, 2018). The CA principles are primarily for grain farming and therefore less overlap of CA principles with stated adaptation strategies in wine farming was expected. While our sample size was relatively small, our in-depth conversations with farmers allowed for expression and contextualization of perceptions and responses to climate change, with the potential for a rich dataset. The entire coding system, including a detailed description of all categories and codes, is available in Appendix 2.

3. Results

All interviewees were white, predominantly male (n = 15), and spoke Afrikaans as their first language, although the interviews were conducted in English (see Appendix 3 for full interviewee data). The average time spent farming was 24 years, ranging from 6 to 43 years. The area of arable farmland belonging to farmers ranged from 180 to 1800 ha, and the median average was 550 ha. The majority of wheat farmers (n = 10 out of 11) practiced dryland agriculture, whilst all wine farmers irrigated their vines (n = 5). Three farmers were hired managers, whereas the remaining thirteen were the owners of the land they farmed. We present our results according to the three components of the conceptual framework presented in Box 1.

Table 1
External and internal barriers to climate change adaptation as identified by all interviewed farmers (n = 16).

Barriers to adaptation		All farmers (n = 16)
External	**Institutional and political constraints**	**16**
	Lack of governmental support	14
	Inadequate municipal water management	5
	Insecurity of land rights	3
	Restrictions on building dams	2
	Lack of capacity of government institutions	2
	Biophysical constraints	**10**
	Dependency on nature and climate	4
	Local soil composition	2
	Farm topography	1
	Economic constraints	**9**
	Maintaining profitability	8
	Lack of financial means	2
	Increasing input costs	2
	Information constraints	**4**
	Technological constraints	**1**
Internal	**Low perceived adaptive capacity**	**5**
	Behavioural constraints	**5**
	Perceived exhaustion of adaptation possibilities	3
	Lack of motivation to plan for the future	1
	Lack of open-mindedness for change	1

3.1. Perception of climate change

3.1.1. Observation and awareness of climate change

The majority of interviewees (n = 12) were aware of climate change and ascribed the local climatic events they experienced within the last two decades to global climate change, for example: *"There is a climate change definitely happening. And the seasons have moved along with that as well."(F8_WI)*. Four interviewees expressed scepticism for anthropogenic climate change and whether natural weather variability and climatic cycles could be distinguished from long-term regional climate change, for example: *"It's very difficult to say that global warming has an effect on our farming, because last year was dry, it was a dry year, but this year it's more normal. And now the harvest is really good! So what can you say now? Is it now global warming, what is it? I don't know." (F10_WH)*. All interviewees reported that they had observed changes in climate throughout the last 20 years (Table 1). Whilst the majority (n = 12) related these changes to climate change, interviewees that were uncertain or sceptical about climate change considered them a natural phenomenon (n = 4). Reported changes included rainfall variability (n = 13), increased drought (n = 11), reduced precipitation (n = 8), shorter rainy seasons and increased intensity of single rainfall events (n = 3), and extreme weather events including floods (n = 2). Many interviewees (n = 9) stated they had observed a change of seasons, for example: "*It feels like it's getting later and later … the seasons probably moved on almost three weeks*" (F16_WH). Wheat farmers in particular evaluated the change and unpredictability of rainfall patterns as critical for the germination and grain filling period of the wheat, as illustrated by the next quotes: "S*ometimes we start early to plant and the seeds won't come up [or] they will come up but they only get 4.*5 mm *of water and come up and then die. So the next rain is taking too long to come*" (F14_WH) and "(…) *we plant in a dry season, the soil is very dry, we can't wait for the moisture because the timing [of rain] is of the essence."* (F15_WH).

3.1.2. Experienced effects of climate related events on farming

Twelve interviewees reported that they experienced climate-related problems on their farms, including reduced yields (n = 11), crop failure (n = 7), soil erosion (n = 2), and lower crop quality (n = 1). These effects were often considered to be interlinked, for example, reduced yields were linked to financial losses (n = 5). Crop failure and damage was associated with above-average heat events or extreme weather events such as hailstorms. One interviewee reported increasing pests in relation to climate change and two interviewees reported a shorter growing season. Four interviewees reported few or no problems due to climate related events.

3.1.3. Climate change risk perception

Of interviewees that expressed concern for climate change-related risk (n = 9), three demonstrated high risk perception. Concerns included the impacts of climate change on farmers' livelihoods and on those dependent on them, including family and employees, for example: "*Some of the farmers nearly lost their farms because it was so dry. Because you get so scared because it's not just [affecting] you and your family, it's the farm workers that work for 20, 30, 40 years for you*" (F1_WH). One interviewee expressed strong concern for the impacts of climate change on his ability to farm: *"But the climate change makes it more and more difficult [to farm]. So where does it stop?"* (F14_WH) and another respondent showed resignation towards the global consequences of a changing climate: "*I don't know what we can do, because I think it will be too late for the people in the world to do something*" (F13_WI).

Five interviewees expressed moderate risk perception and stressed the long-term, gradual occurrence of severe climatic impacts, for example: *"Climate in our region wouldn't turn overnight into a dry area. It will be 50 or 100 years. Or 300 years for that matter."* (F4_WH). Interviewees that expressed moderate risk perception were confident that there was sufficient time to adapt, or that addressing a fluctuating climate required a year-by-year approach. For example, interviewee F7_WI reported recent extreme weather events that had severe impacts on her farm but considered climate change to be too unpredictable to implement long-term adaptation strategies: "*Last year was a difficult year and this year it was normal again. So you don't know … you can maybe try to prevent stuff and then it's not necessary … so we basically just take it as it comes.*" (F7_WI). Four interviewees, while expressing awareness of climate change, hesitated to adapt as they did not feel affected to a degree that justified the economic cost of implementation of adaptation measures, for example: *"The changes are too small to make any huge strategies."* (F14_WH).

Four interviewees expressed low risk perception. Interviewees were either optimistic about not being affected by climate change in their lifetime, expressed hope that climate change would not happen, or that the extent of its impacts would be less severe than projections estimate. Three farmers attributed hope, optimism and confidence that climate change is a natural phenomenon to their religious beliefs and convictions, for example: *"I believe in God and I believe God won't let us down*" (F10_WH). In contrast, other farmers expressed an avoidant attitude, stating that although they were aware of climate change and did experience climate related yield losses, they did not want to know about the topic, for example: *"I just put a blanket over my head and don't worry about it."* (F9_WI). In three cases, interviewees presented moderated statements relating to risk perception, by assessing current risks as marginal but future risks as threatening (i.e. F14_WH) or by expressing belief in and anxiousness towards climate change but optimism about its impacts and their own ability to adapt (see 3.2.1) (F10_WH; F13_WI).

3.2. Factors influencing adaptive behaviour

3.2.1. Perception of adaptive capacity

In total, 13 interviewees expressed perceptions of their own capacity to adapt to climate change and different attitudes towards change and adaptation. Five interviewees revealed a low perceived adaptive capacity, referring to perceived superior forces of nature, for example: ***"You can't fight against nature.** So you can only do what you can do. If there is no water you can do nothing."* (F1_WH) and stating a lack of possibilities: *"All that I can think of, that we did already. We're out of options."* (F6_WH). This low perceived adaptive capacity was considered an internal barrier to adaptation (Table 1). Other interviewees characterized climate change as an antagonistic force they could not oppose, alongside a passive attitude towards their own action, for example: *"So somewhere you going to have to stop [farming] … Because climate change pushing you and that's a direction you can't farm."* (F14_WH). Adaptation was simultaneously framed as a necessity to survive: *"It's actually adapt or die. We need to adapt always. Thinking of new methods, new ways."* (F6_WH).

In contrast, nine interviewees expressed a high perceived adaptive capacity, presenting statements that revealed a proactive attitude towards change and adaptation. The ability to adapt was designated as an essential characteristic of a good farmer: "*But to be a good farmer you must change. So if the world changes, so you must change. If you don't change you lose your farm."* (F2_WH). One interviewee specifically attributed the capacity to solve problems as a distinctive characteristic of all South African farmers (F10_WH). Younger interviewees contrasted their own ability to adapt to the older generation of farmers, who were not willing to change their way of farming any more, and emphasized the necessity of being open-minded in order to have personal adaptive capacity: "*It isn't a challenge to change, you just have to make a mindset and be adaptable. My dad wasn't very [adaptable], but they are the older generation. So for us it's easier, we can adapt like that [snaps fingers]"* (F16_WH). Three farmers likewise expressed that the recent drought experience had caused an increased consciousness and behaviour change in their personal water usage and named this as beneficial for their future adaptive behaviour, for example: *"These dry seasons challenge [us] very much economically. We learn to save more in these years. But I think it makes us better farmers moving forward. We learn out of this* *dryness what we can be capable of. I think we didn't have such dry years in a long long time. So you learn how to work with what you have"* (F8_WI).

A similar yet more combative attitude towards climate change was expressed by two interviewees. This attitude contained statements of self-confidence and framed climate change as a challenge to be defeated, for example: *"I'm an extrovert and I will challenge everything. So I like challenges"* and: *"I will win. And I believe I will win. And I believe in myself and I hope that the climate will change."* (F13_WI). Likewise, one interviewee demonstrated a highly proactive stance: *"I can't sit and wait till the world [to] change, I want to change it myself."* (F11_WH). He perceived a high capacity to deal with climate change, not through climate-specific measures but by maintaining his current farming practice: *"I think we will … outperform maybe climate change; that is my aim. In 20 years' time, I want to sit back and say 'but climate change hasn't affected me'"* (F11_WH).

3.2.2. Barriers or support to adaptation

Farmers named few organizations which provided help or support to adapt to climate change, but identified institutional and political constraints as the major external barriers to adaptation (n = 16), followed by biophysical and economic constraints (n = 10) (Table 1). Interviewees expressed a negative and frustrated attitude to lack of governmental support (n = 14), and reported displeasure with water management by the municipalities during drought years (n = 5), stating: *"Government doesn't help us at all … They help pull us down. Not bring us up."* (F14_WH) and "*[water] you don't use they are going to take from you.*" (F7_WI). Three wheat farmers felt insecure about future land rights and perceived land tenure insecurity as a political barrier to adaptation, for example: "*We have bigger problems on this moment in South Africa than climate change … That's a big concern for us. Land … reconciliation … that means they can take your land without compensation.*" (F3_WH). This high perceived uncertainty was linked to behavioural constraints such as lack of motivation to plan for the future. One interviewee reported he felt insecure about changing land rights and the prospect of losing his farm in the future: *"It's a bit demotivating to build your soil and one day in a month you maybe go and say to yourself: Is this really worth it? Because are you going to have your farm? If I am building up my soil and they are taking the land, what I've been working for my whole life."* (F11_WH). Although three farmers were hired as land managers and were not landowners, this was not mentioned as a factor in choosing whether to implement adaptation strategies.

Biophysical and economic constraints were also identified as external barriers to adaptation. For example, two farmers identified the regional soil composition as a barrier to successfully reducing tillage and moving toward CA principles (Table 1). One farmer expressed his

Table 2
Climate change adaptation and coping strategies implemented by interviewed farmers (n = 16).

Implemented adaptation strategy	Stated benefits	All farmers (n = 16)	Coping strategy (short-term)	Adaptation strategy (medium to long-term)	Conservation Agriculture principles
Crop management		14			
Change of harvest and planting time	Match plant growth stages to rainfall variability	4	X	X	
Introduction of legume cover crops	Reduced loss of soil moisture; less application of chemical fertilizers thereby reducing production costs	3		X	X
Crop rotation	Improved soil moisture and structure	3		X	X
Crop diversification	Spread of financial risks and improved cash flow	3		X	X
Removal of unproductive crops	Water saving	2	X		
Reduction of fertilizer input	Lower production costs, leading to greater financial stability in drought years	2	X	X	X
Increase of fertilizer input	Increased yield despite climatic stress	2	X		
Introduction of cultivars with shorter growing seasons	Better adapted to changing seasons	1		X	
Crop protection with netting	Protection against weather extremes and decreased soil moisture loss through shade	1	X	X	
Introduction of drought-tolerant cultivars	More adapted to drought conditions	1		X	
Soil management		11			
Minimum tillage	Increase in yields, soil moisture and organic carbon; reduced energy input	7		X	X
Increased soil cover	Reduced water evaporation	5		X	X
Building topsoil	Improved fertility, organic carbon and water holding capacity	3		X	X
Composting	Soil improvement	1		X	X
Water management		6			
Water conservation techniques e.g. drip irrigation	Maximise water use efficiency	4	X	X	
Technological advancements e.g. computerized soil moisture meters and solar water pumps	Maximise water use efficiency	2	X	X	
Increase of water usage	Crops can be more frequently watered with available water	1	X		
Livestock management		3			
Abandonment of livestock	Reduced feed costs, leading to greater financial stability	2	X		
Change of grazing patterns	Prevention of overgrazing and soil protection	1		X	
Change of fodder	Increased likelihood of livestock survival through times of climatic stress	1	X		
Other		3			
Introduction of new technologies e.g. computerized soil mappings and GPS control systems	Reduced cost of agrochemical use, leading to greater financial stability	2			X
Expansion of farm units	Additional income from additional farmed land	1	X		

general willingness to adapt but named the unfavourable topography of his farm as a biophysical barrier to implement actual adaptation: "*In a perfect world, I would love to keep the stubble and prepare my soil better for when the big and quick rains come … and I have a very hilly farm, so it's a problem. If I had a flat farm, it would be much easier*" (F15_WH). Farmers also saw little potential in natural vegetation on their farms to contribute to climate risk mitigation. One farmer noted that the remaining natural vegetation on his farm may be a good location for a borehole to find more water: "*I have a good feeling about that spot in the renosterveld between the rocks. I think maybe there is some water down there*" (F12_WI). Undertaking climate change adaptation measures was seen as a challenge to remaining financially profitable. Identified economic constraints included the lack of government subsidies, price pressure due to subsidized grain imports, decreasing crop market values and increasing input costs for fertilizers and pesticides (Table 1).

Available information supported farmers to learn about climate change (n = 15) and adaptation strategies (n = 13), but a lack of reliable and long-term information was identified as an additional constraint to adaptation (n = 4). The most commonly stated source for climate change information was media, including the internet and weather forecasts (n = 11), followed by exchange with other people, such as self-organized farmer unions, other farmers and agricultural consultants (n = 7). The most commonly stated sources for information on adaptation strategies were institutions and agricultural companies, such as research farms, agrochemical companies and regional or national agricultural research boards (n = 9). Information constraints led to a reported lack of awareness of climate change (n = 4) and the need of accurate predictions for future decision-making: "*All that we saw about the long term predictions is that … you can't work with that, it's not dependable enough.*" (F5_WH).

3.3. Adaptation strategies

3.3.1. Implemented adaptation strategies

We found that all farmers (n = 16) adapted their farming practices in response to experienced climatic stresses. In total, 22 strategies were identified in five different adaptation groups: crop management, soil management, water management, livestock management and other (Table 2). Wheat farmers generally stated more soil management strategies than any other adaptation group, whilst wine farmers stated more water management techniques. Of these 22 strategies, 11 could arguably be identified as coping while 15 could arguably be identified as more long-term adaptation strategies, and these groups were not mutually exclusive (Table 2). For example, the change of harvest and planting time may be a short-term response in that a farmer can implement this change from one farming cycle to the next, but is also a long-term strategy in that this reflects gradual climatic changes and requires ongoing flexibility at farm level. Stated adaptation strategies such as minimum tillage, legume cover crops and extended crop rotations overlapped with CA principles (Table 2). These changes were also stated by farmers as beneficial for experienced climatic stresses, as illustrated here: "*I think the best precaution we did here for the drought is the no-till.*" (F5_WH). While 11 interviewees stated to have implemented adaptation strategies as a direct response to climate change, two farmers applied changes primarily for economic or agricultural reasons (F3_WH; F4_WH) and stated to have experienced fewer or no climatic stresses effecting their farms. These farmers also expressed uncertainty about the reality of climate change or the imminence of its impacts (see for example section 3.1.3, quote from F4_WH).

3.3.2. Future adaptation strategies

As well as identifying already implemented strategies, twelve interviewees identified adaptation strategies they may implement in future. The most commonly mentioned strategy was the introduction of cultivars with shorter growing seasons or better drought-tolerance (n = 11). Additional future strategies included crop diversification (n = 2), shifting to livestock husbandry if future wheat or wine grape profitability declined (n = 2), and netting for crop protection and shade (n = 1). Three interviewees stated no intention to adapt, as they perceived the range of adaptation possibilities to be exhausted (see 3.2.2). Two interviewees (F13_WI; F11_WH) who showed a high perceived adaptive capacity and combative attitude towards climate change listed fewer or no concrete future adaptation strategies (see 3.2.1).

4. Discussion

We found a range of perceptions and adaptations to climate change among Swartland commercial wheat and wine grape farmers. We discuss here our findings according to the three components of the applied framework: perceptions of climate change, factors influencing adaptation behaviour, and adaptation strategies.

4.1. Perceptions of climate change

The majority of interviewed farmers were aware of climate change and reported experienced climate changes consistent with long-term regional trends, including increasing mean annual temperatures, and short-term climatic events, such as severe drought (Davis-Reddy and Vincent, 2017; Otto et al., 2018). Farmers' perceptions are often affected by recent years' experiences (Bryant et al., 2000; Takahashi et al., 2016). Recent drought exacerbated some interviewees' anxiety about climate change, while interestingly, rather than seeing the 2015–2018 drought as evidence of the increasing need to adapt, some interviewees partly downplayed the reality or severity of climate change by ascribing the recent drought to natural climate fluctuations. Specific farming context also plays a role in farmers' perceptions (Wiid and Ziervogel, 2012), with wheat and wine farmers respectively emphasizing different impacts of climate change. Water stress can conversely improve wheat quality by concentrating proteins in the grain, potentially leading to satisfaction with 2017 and 2018 harvests for some wheat farmers, despite water scarcity (Archer et al., 2019). While only one wheat farmer we interviewed stated this potential benefit to wheat quality (F4_WH), the majority of wheat farmers mentioned the overall hardiness of wheat in drought conditions and their commitment to its cultivation. Drought conditions can increase pest, disease and physiological stress on grapevines, as well as yield reduction (Araujo et al., 2016), all of which were reported by wine grape farmers in our study. These stressors have been reported in other wine-producing regions such as California and southern Europe (Ashenfelter and Storchmann, 2016) and while at a district scale, impacts on the sector may be managed, the effects on grape yields may be critical for the individual farmer (Araujo et al., 2016).

We found a diverse mix of low, moderate and high risk perceptions among farmers. Farmers with low or moderate risk perception relativized climate change risks by pointing to the long-term uncertainty of climate change, which is in line with Woods et al. (2017), who state that risks with longer time horizons are perceived as smaller than those in the short-term. The dominance of perceived short-term risks to farm survival over long-term risks from climate can impede adaptation or uptake of other best practices, such as CA principles (Findlater et al., 2018). Many of the farmers we interviewed acknowledged the risk of climate change but used 'survival' or 'emotional' language, as found by Findlater et al. (2018), including optimism bias, avoidance, and ideologies to describe their perception of risk. These cognitive processes were prevalent among farmers with low risk perception. Previous research found that this low risk perception can hinder adaptation behaviour (Grothmann and Patt, 2005; Gifford et al., 2011; Wolf and Moser, 2011). Overall, farmers expressed multiple forms of uncertainty for the future, in which climate change risk was framed as part of the day-to-day challenges of farming rather than a concern requiring special or targeted consideration (Takahashi et al., 2016). Adaptation is therefore more incremental than transformative (Fischer, 2019). Concern for short-term farm survival can also hinder long-term adaptation behaviour (Findlater et al., 2018), but we found that some farmers named some strategies specifically for bridging low-income periods, such as crop diversification, which could sustain the farm into the longer term and potentially through more challenging climate conditions.

4.2. Factors influencing adaptive behaviour

Woods et al. (2017) found that farmers' perception of their adaptive capacity, along with external factors, can hinder or support an individual's adaptation intention. We found that perceived adaptive capacity varied among respondents. Interviewees with low perceived adaptive capacity referred to an exhaustion of adaptation possibilities or to their high dependency on climate and nature, whereas those with high perceived adaptive capacity had a positive attitude towards change and their ability to solve problems. Arbuckle et al. (2015) suggested that this problem-solving attitude means farmers are more open to adaptation than mitigation. We also identified an extreme version of this attitude to climate change adaptation, where climate change was viewed not only as a problem to solve, but as an opponent to defeat. While this combative approach shares some aspects with perceived high adaptive capacity, such as confidence in current farming practices, its proponents listed fewer future adaptation strategies and expressed a less adaptive mindset. We also found evidence that the interplay of external and internal factors can support adaptation intention, as some farmers identified that restricted water usage taught them that it was possible to work in highly challenging conditions, increasing their perceived adaptive capacity. Although the variables we considered in this study comprise a basic conceptualization of perception, the underlying processes of human cognition are deeply complex (Gifford et al., 2011), and these links between perceptions, adaptation intention and actual adaptation implementation in the Swartland context would benefit from further investigation.

Farmers consistently reported barriers to adaptation. We found that, similar to Findlater et al. (2018), perceived external barriers to adaptation were mostly institutional and political, although they often intersect with economic constraints; for example, a lack of government subsidies is related to a lack of financial means at farm level. These barriers also point to shared responsibilities at a regional scale for adequate water management. The commercial farmers we interviewed in the Western Cape did not list socio-economic constraints felt in other South African regions, such as poverty, lack of credit and gender issues, which were found to be important in previous research (e.g. Crane, 2006; Nhemachena and Hassan, 2007; Gbetibouo et al., 2008; Bryan et al., 2009). However, the farmers in our study expressed concern for potential changes to land ownership, which was named as a demotivating influence for farm investment, including implementation of costly strategies to deal with climate change. This perceived uncertainty demonstrates how external factors may override internal factors such as perceived adaptive capacity and limit adaptation behaviour. Farmers also acknowledged that this perceived uncertainty, along with related economic insecurity, affects future farm employment. Climate change adaptation at farm-level should also include risk assessment and mitigation to farm employees and dwellers (Hornby et al., 2018). It must be noted that our interviews reflect perceptions from farming decision-makers but do not reflect perceptions of the full spectrum of the Swartland agricultural society, including farm employees and dwellers. Further investigation into social interactions and the potential impact of land ownership changes on adaptation could also shed light on Swartland farmers' uncertainty and related implications for rural livelihoods.

Biophysical constraints, including dependency on nature and farm topography, were noted as additional barriers to adaptation. Here we found evidence that rather than supporting intention to adapt, external factors can limit internal perceived adaptive capacity. For example, hilly farm landscapes were identified as a physical constraint to effective soil management despite the farmer's willingness to implement soil conservation measures. Interestingly, natural vegetation was not identified by farmers to support climate risk mitigation. Notwithstanding, natural vegetation provides valuable grazing during drought conditions, when planted pasture is insufficient to provide enough fodder for cattle (Winter et al., 2007), and has been shown to reduce soil erosion (O'Farrell et al., 2009), which was attributed to climate change by farmers in our study. Farm locations with remaining natural vegetation were identified by farmers as areas which may provide extra water sources, which when coupled with increased grazing, potentially increases pressure on remaining fragments of natural vegetation. The combination of perceived uncertainty, barriers, and the related uptake of specific implementation strategies among Swartland farmers, illustrates the knock-on effects that farmers' responses to climate change have, not only on farming operations, but on the surrounding landscape and society. This underlines the need to embed the perception and adaptive behaviour of farmers in their specific social-ecological context (Soubry et al., 2019).

4.3. Farmers' adaptation strategies

Our interviews revealed that farmers with experience of climatic stresses were more likely to implement adaptation strategies, upholding the theory that risk experience influences response behaviour (Grothmann and Patt, 2005; Clayton et al., 2015). A wide range of adaptation strategies were implemented by farmers, but the most commonly mentioned strategies aimed to maintain crop productivity and soil quality, with reduced climate vulnerability a secondary benefit. For example, farmers mentioned the increased use of fertilizer as a response to climatic stress, although Tessema et al. (2019) found that farmers may attribute this strategy to climate change due to social desirability bias: the desire of the interviewee to tell the interviewer what they want to hear. However, some of these strategies are also implemented by farmers elsewhere in Africa to adapt specifically to climate change (Nhemachena and Hassan, 2007; Gbetibouo, 2008; Findlater, 2017; Archer et al., 2019).

The identification of strategies which may be termed short-term coping in contrast to long-term adaptation enables the differentiation of actions related to immediate impacts compared to those related to change (Birkmann, 2011). While many strategies named by farmers in our study may be termed short-term coping, proactive, long-term adaptation measures, such as diversification of crops, the introduction of drought-tolerant cultivars or technology and infrastructure investments were implemented less often and cited as potential future adaptive strategies. These future ideas differed little from current practices, suggesting that farmers do not consider approaches beyond their usual methods, an inclination which may be attributable to other influences such as farmer information networks (Wiid and Ziervogel, 2012), or a lack of external innovation influx. Indeed, the fact that some of our interviewees belonged to the same local community or farmed neighbouring parcels of land suggests that their perceptions of possible farming practices are likely to be similar, although we found suggested differences in attitudes between generations. However, some of these practices, such as experimentation with different wine grape varieties, are key parts of multi-faceted adaptive approaches to climate change risk in comparable wine grape-producing regions, such as South Australia (Bardsley et al., 2018).

Although wheat farmers perceived a wider range of barriers to adaptation than wine farmers, they identified more future adaptation strategies (Table 2). This may be in part due to the recognition of benefits of adopting CA principles in commercial grain production, and the development of an associated long-term outlook (Findlater et al., 2018). In addition, specific farming system context was found to be important for adaptation, since wheat farmers responded to ongoing water scarcity principally through soil management, whereas wine grape farmers noted adjustments to water management as a present and future response. We found confirmation that wine grape farmers apply recommended mitigation strategies, such as adjusting irrigation timing to grapevines' early growth periods (Araujo et al., 2016). Both wheat and wine farmers may also be aware of a wider range of future adaptation strategies due to regional promotion of climate-smart farming practices (WWF South Africa, 2018; Western Cape Department of Agriculture, 2019). However, all strategies listed were primarily technological in nature, although climate change was cognitively linked to wider societal concerns, and therefore technological adjustments alone do not address the full spectrum of impacts of climate change (Hornby et al., 2018). Tibesigwa et al. (2017) observed that the commercial South African farming sector may be as vulnerable as smallholder farming systems to climate impacts, particularly for highly specialised commercial production. Nonetheless, our findings on perceptions and barriers for commercial farmers also highlights the challenges for non-commercial, low-input, subsistence and smallholder agriculture elsewhere in southern Africa. These regions are among the world's most vulnerable and limited access to relevant information and technologies pose many challenges for future climate adaptation (Mapfumo et al., 2014).

5. Concluding remarks

Our study echoes Wolf and Moser (2011) in recognizing that no single theory can explain the variation in human perception and response to climate change. We found a mix of low to high climate risk perception and perceived adaptive capacity among Swartland commercial grain and wine grape farmers. All farmers perceived climate change impacts and acknowledged accessible sources of information about climate change, while noting institutional, political and biophysical barriers to adaptation, which are shared and place-specific. The combination of particular internal cognitive factors, including optimism bias, avoidance and ideologies, with these external barriers, can limit Swartland farmers' perceived adaptive capacity and influence their adaptation behaviour. Our conversations with farmers illustrated how climate change transcends environmental issues and how this is often contextualized in other socio-political issues (Wolf and Moser, 2011). Farmers' strong perceptions of uncertainty regarding climate change impacts, and related implemented strategies, have knock-on effects for rural livelihoods and the Swartland landscape. By recognizing enabling and limiting factors for climate-adaptive behaviour, as well as alternative attitudes held by decision-makers, we can understand dynamics at play in agricultural systems contributing to food production. The effects of climate change are already being felt in the Western Cape and are likely to be exacerbated in future (Archer et al., 2019; Otto et al., 2018; Midgley et al., 2005). Climate resilience in the province is important not only for South Africa but for southern Africa more widely due to the region's strategic importance for export and its contribution to regional food security. By assessing both grape and grain farmers, our study reveals how neighbouring producers may experience and respond differently to climate change impacts in the climate-vulnerable Western Cape. We found farmers tended to list strategies which were in keeping with widespread farming practices and which overlapped with conservation agriculture principles. This tendency reflects the capacity, both perceived and external, of farmers to respond to incremental changes in climate with the set of approaches they use day to day. While these approaches are largely technological, they do not address the aforementioned broader socio-economic impacts of climate change, which highlights the cognitive challenges of land management in the face of uncertainty. In differentiating between coping and adaptation strategies we enhance the understanding of farmer responses to climate impacts and identify which strategies are more likely to support farm resilience. Our findings may help to assess policy objectives for climate change adaptation, including technical recommendations, with asserted experiences of commercial farmers in South Africa.

Funding

This study is funded by the German Research Foundation (grant number DFG, LO 2323/1–1.).

Declaration of competing interest

The authors declare that they have no known competing interests.

Acknowledgements

We are thankful to the participants of the study for their time and willingness to share their experiences, to Friederike Sieve for research assistance, and to Bregda and Teubes Mostert for sharing their insights into Swartland life. We also thank two anonymous reviewers who provided comments on an earlier version of this manuscript. We conducted our study with ethical clearance from the University of Göttingen Ethics Commission, approved on November 15, 2017.

Appendices.

A1: Interview guideline

Main Category	Variable	Questions
Personal Context and Farming Practices	1. Length of time spent farming 2. Cultivation of crops 3. Change of farming practices	1. For how long have you been farming the land? 2. Which crops do you grow on your land? 3. Have you changed your farming practices over the years? (If yes, how?)
Perception of Climate Change	1. Observation and awareness of climate change 2. Effects of climate related events on farming	4. Have you perceived a change in climate and the environment throughout the last 20 years? Which changes have you experienced in the climate and environment over the last 20 years? 5. Which problems arise on your farm because of these changes in climate?
Factors influencing adaptive behaviour	1. Perceived adaptive capacity 2. Barriers to adaptation 3. Availability of knowledge and information (sources) 4. Accessibility to information, external help or resources	(inferred from responses, see article section 2.2) 6. What are the major challenges for you in order to deal with climate change? 7. From where or whom have you gotten your knowledge about climate change? Do you get any information about adaptation strategies towards climate change? From whom do you get knowledge about adaptation strategies? 8. Do you receive any other external help to adapt to climate change? Can you name specific people or organizations that inform you about the impact of climate change?
Response and adaptation strategies	1. Implemented adaptation strategies 2. Influence of natural vegetation 3. Future adaptation strategies	9. Have you taken any strategies to adapt to these climate effects in your farming practice? (y/n) Which strategies have you taken to respond to climate change? 10. Does the natural vegetation on your land, such as the renosterveld, influence your ability to adapt to

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Main Category	Variable	Questions
		climate change?
Future	1. Challenges and Opportunities in the future 2. Future Coping Mechanisms	11. Are you planning to take further adaptation strategies in the future? If yes, which ones? 12. Which challenges and opportunities do you see in the future of your farm in terms of climate change? 13. What would you need in the future to better cope with the current situation of climate change?

A2: Coding system Coding system: 1. Perception of climate change Major category encompassing (1) Observation and awareness of climate change, (2) experienced effects of climate change on farming and (3) climate change risk perception

Minor category	Code	Description of code	Representative quote
Awareness of climate change	Awareness of climate change	Statements of awareness of climate change that indicate that farmers understand observed changes in climate as an indication of on-going climate change	*"There is a climate change definitely happening. And the seasons have moved along with that as well." (F8_WI)*
	Scepticism towards climate change	Statements of scepticism or uncertainty about climate change that indicate that farmers do not understand changes in climate as an indication of on-going climate change	*"I'm not a what you call it, a climatologist, but (…) in my 35 years that I can say it's a long term climate change I would more say it's like cycles, like cycles, it's like you get wetter periods and drier periods. (…) so the climate is changing all the time. But I can't confirm that it's going in a certain direction." (F3_WH)*
Observation of long-term changes of climate	**Changes of rainfall**		
	Change of rainfall patterns and variability	Observed changes of rainfall patterns and rainfall variability	*"When I was a little boy we would have rain for 7 to 10 days on end, light rains. But that has changed totally. It's at the most we get 3 to 4 days of that kind of rain but it's shorter bursts and more at a time." (F15_WH)*
	Lack of rainfall	Observed decrease of amounts of mean annual or seasonal rainfall	*"Yeah the winters are more drier[sic]. The last three years we didn't have a lot of rain. Like last year was very bad". (F12_WI)*
	Rainfall intensity	Observed changes of rainfall intensity such as changes in quantity of rainfall on single rainfall events	*"In recent years I think the raining season got shorter and the quantity of rain was more intense at a time." (F15_WH)*
	Drought events	Observed changes of amounts, intensity or duration of drought events	*"But the intensity of the drought is increasing." (F6_WH)*
	Changes in temperature		
	Increasing temperature	Observed increase of mean annual or seasonal temperatures	*"I as a child was born up here, 35 degrees was quite hot. Now we're getting 40 degrees. 40 degrees I want to run out into the dam and I want to swim. So it's getting really really hot, so that scares me." (F13_WI)*
	Increasing number of hot days	Observed increase of number of hot days during summer months	*"Because when I was younger it was very very rare and I'm speaking about much summer that the temperatures was above 40 degrees. These days you can get like a week or two weeks that the temperatures is 44, 45, 46." (F3_WH)*
	Seasonal extremes (hot summers, cold winters)	Observed changes in seasonal temperature extremes, i.e. warmer summers and colder winters	*"Or I am seeing on my farm is that it's getting colder in the winter and also hotter in the summer." (F13_WI)*
	Change of seasons	Observed changes in onset, duration and/or length of (agricultural) seasons	*"It's just the seasons I think it's a bit … summer starts month later and winter starts a month later." (F7_WI)*
	Extreme weather events	Observed extreme weather events such as hail storms, floods	*"It (hail storm) was two or three times this year (…)it's just like thunder and 5 min hail and gone (…) we didn't see that often here. Like … this size balls (laughs) falling out of the sky." (F8_WI)*
Experienced effects of climate related events on farming	Reduced yields	Experienced climate-related yield losses or reductions of yield	*"The wheat that's … that harvest was not so good. The tons were about 500 instead of 1000, maybe. So … so … that is one thing that definitely was bad." (F10_WH)*
	Crop failure and damage	Experienced climate-related crop failure and damage	*"Young vines might die, I lost about, what's it about 30% of my new plantation; that had to be replanted this year." (F9_WI)*
	Financial losses	Experienced climate-related financial losses and decrease in profitability	*"Well we're not profitable anymore. I think that's the biggest problem. That's because production is related to irrigation." (F9_WI)*
	Damage to seeds and shoots	Experienced climate-related damages on seeds and shoots of crops	*"Sometimes we start early to plant and the seeds won't come up because they … they will come up but they only get like 4,5 mm of water and come up and then die. So the next rain is taking too long to come." (F14_WH)*
	Erosion and runoff	Experienced climate-related erosion and runoff	*"Because it's very hilly you get a lot of erosion, because you're breaking up the soil, it's a lot of loose soil. And if it (the rain) comes so quickly in 24 or 48 h there isn't really time for the soil to absorb the moisture, it's a lot of running water." (F15_WH)*
	Shorter growing season	Experienced climate-related shortening of agricultural season	*"Some of the seasons are like last year shorter and then it's a big problem for us because you don't get the tonnage that you must have." (F3_WH)*
	Increasing pests	Experienced climate-related increase of pests on crops	*"Yeah more ants. And the ants are the carrier of the mealybug. So yeah we, I think we had a good fight with the mealybug with the biological ways we use. So the ants weren't a problem for us but you can see there is more ants." (F12_WI)*
	Lower crop quality	Experienced climate-related decrease of crop quality	*"So with the temperatures rising there was a real problem with the quality of wheat." (F15_WH)*
	High risk perception		

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Minor category	Code	Description of code	Representative quote
Climate change risk perception		Strong concern for climate change and high perceived probability of being exposed to its impacts. Encompasses statements of anxiousness and resignation towards climate change and its impacts.	*"So it's getting really really hot, so that scares me. Really. So I have spoken to my one son, the oldest one and we are very concerned about this. About the climate change. I don't know what we can do, because I think, I think what going to be late, too late for the people in the world to do something." (F13_WI)*
	Moderate risk perception	Moderate concern for climate change and moderate perceived probability of being exposed to its impacts. Encompasses statements of composure and relativization of the severity and urgency of climate change and its impacts.	*"So this is actually a very good spot for farming wheat. So we are lucky in that regard. So when the full rough of climate change is going to come to us I think we will be the last influenced by it … hopefully." (F15_WH) "Last year was a difficult year and this year it was normal again. So you don't know … you can maybe (…) try to prevent stuff and then it's not necessary (…) So we basically just take it as it comes." (F7_WI)*
	Low risk perception	Low concern for climate change and low perceived probability of being exposed to its impacts. Encompasses statements of optimism, hope, wishful thinking and avoidance of climate change and its impacts.	*"But I'm not afraid of global warming. There is something that tells me, it's there. But I'm not afraid of it. I think we will overcome the problem." (F10_WH) "I think with climate change I rather just put my head in the … put a blanket on my head and don't worry about it." (F9_WI)* *"We believe in the God. And we believe that we will [be] here for the next, how many years. Maybe. I don't know … That's why I say, isn't it a phase that we go in, warmer climate and is there after this warmer climate is there another colder time for us? Maybe?"* (F10_WH)

Coding system: 2. Factors influencing adaptive behaviour.

2.1. Perceived adaptive capacity

Major category encompassing farmers different perceptions of their own adaptive capacity and attitude towards adaptation and change

Minor category	Code	Description of code	Representative quote
Low perceived adaptive capacity	Perceived exhaustion of adaptation possibilities	Statements expressing a low perceived ability to undertake adaptation actions due to a perceived exhaustion of adaptation possibilities	*"All that I can think of that we did already. We're out of … options." (F6_WH)*
	Superiority of nature and climate	Statements expressing a low perceived ability to undertake adaptation actions due to a perceived superiority of nature and climate	*"But I don't know how to adapt … at the moment we don't know what will happen if the climate turns against us." (F5_WH)*
High perceived adaptive capacity	Positive or proactive attitude towards adaptation and change	Statements expressing a high perceived ability to undertake adaptation actions. Encompasses statements that reveal a positive or proactive attitude towards adaptation and change	*"But to be a good farmer you must change. So if the world changes, so you must change. If you don't change you lose your farm." (F2_WH) "It isn't a challenge to change, you just have to make a mindset and be adaptable. My dad wasn't very, but they are the older generation. So for us it's easier, we can adapt like that [snaps fingers]." (F16_WH)*
	Combative attitude towards adaptation and change	Statements expressing a high perceived ability to undertake adaptation actions. Encompasses statements that reveal a combative attitude towards adaptation and change	*"I think we will … outperform maybe climate change, that is my aim. I intend … of 20 years' time I want to sit back and say 'but climate change haven't affected me'." (F11_WH)*

2.2. Barriers or support to adaptation

Major category encompassing barriers or support to climate change adaptation, which address the availability or lack of resources such as knowledge, money, and institutional support

Minor category	Code	Description of code	Representative quote
Institutional and political constraints	Lack of governmental support for farmers	Lack of or insufficient governmental support for farmers and agriculture (e.g. lack of subsidies) is perceived to be an institutional barrier to adaptation	*"Our government is not looking after our farmers. We don't subsidize, we don't get subsidies, nothing. You must do all the stuff on our own." (F8_WI)*
	Inadequate water management of municipalities	Adverse or inadequate water management by government and municipalities	*"Because the government, (…) they already said they all going to take the farmers' water. Like we have the water that's registered on our farm, on our farm we don't have enough space in the dam to get that. So they … everything you don't use they gonna take from you." (F7_WI)*
	Insecurity of land rights	Statements expressing fear, concern or perceived insecurity on land rights due to on-going debates on land reforms and restitution programs	*"The future is not so clear for us in South Africa, so that is the one thing but that is not what you want the answer for so … it's a bit demotivating to build your soil and one day in a month you maybe go and say to yourself: Is this really worth it? Because are you going to have your farm? If I am building up my soil and they are taking the land, what if I've been working for my whole life." (F11_WH)*
	Restrictions on building dams	Institutional restrictions to build dams that complicate access to and availability of water sources are perceived to be an institutional barrier to adaptation	*"And you can't build dams because the … you're not allowed to do it. (…) that's a big problem. "(F10_WH)*
	Lack of capacity of government institutions	General incapacity of government institutions (e.g. lacking financial resources) is perceived as an institutional barrier to adaptation	*"The problem is, there is a very very great incompetency in every state control department of them. They appoint people that does not have the ability or the qualities to do the job for their appointment. And that's a pity. And a lot of money is going into*

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Minor category	Code	Description of code	Representative quote
			that, so there is money for their salaries, but not for research, there is nothing left anymore." (F6_WH)
Biophysical constraints	Dependency on nature and climate	Dependency on nature and climate is perceived as a biophysical constraint to adapt to climate change	*"You can't fight against nature. So you can only do what you can do. If there is no water you can do nothing "(F1_WH)*
	Farm topography	Unfavourable topography of farm as a biophysical constraint to adapt to climate change	*"So in a perfect world I would love to keep the stubble and prepare my soil better to when the big and quick rains come that the impact of the rain isn't that big and that it absorbs the water better and running away of water is stopped. And I have a very hilly farm, so it's a problem. If I had a flat farm, it's much easier." (F15_WH)*
	Local soil compositions	Diverse soil compositions of the Western Cape as a biophysical constraint to identify common adaptation strategies	*"I think with the diverse different soils that we have in the Swartland area, you know it's challenging. You know there is not one formula fits all type of thing. You know the cover crop which works for me doesn't work for my neighbour on the other side of Malmesbury or on the other side in Koringberg." (F9_WI)*
Economic constraints	Maintaining profitability	Maintaining profitability is perceived to be an economic barrier to adapt to climate change	*"I think we … the challenges is … these dry season challenges very much economically wise. We learn to save more in these years." (F8_WI)*
	Lack of financial means	Lack of financial means is perceived to be an economic barrier to adapt to climate change e.g. by not being able to invest in new technologies	*"I think probably capital is going to be our biggest challenges because … it's most of these changes will involve new implements and new strategies how to do stuff and (…) everything is just getting so much more expensive. So if you don't have capital behind you that's probably going to be your biggest challenge." (F16_WH)*
	Increasing input costs	Increasing input costs (e.g. fertilizers, fuel) are perceived as an economic barrier to adaptation	*"The chemical companies can make the prices they want and when you sell, it's the other way around you have to take the price they give you. (…)There is no bargaining, you just have to take the price. But our inputs versus outputs from the farm, they don't have anything, any power or bargaining that we can do with that. We just have to accept that." (F6_WH)*
Behavioural constraints	Perceived exhaustion of adaptation possibilities	Statements expressing a perceived or experienced exhaustion of adaptation possibilities	*"But if the rain gets less, there is not much we can do if the rain gets less and less … I don't know, how we're going to adapt any further, I don't … " (F5_WH)*
	Lack of motivation to plan for the future	Statements expressing a lack of motivation to plan for the future and to implement future adaptation strategies	*"The future is not so clear for us in South Africa, so that is the one thing (…) it's a bit demotivating to build your soil and one day in a month you maybe go and say to yourself: Is this really worth it?" (F11_WH)*
	Lack of open-mindedness toward change	Lack of open-mindedness or ignorance towards climate change as a perceived behavioural constraint to adaptation	*The first thing is you have to be open-minded for (climate change), that you mustn't ignore the fact that it will or may affect us." (F4_WH)*
Information constraints	Lack of reliable information and weather forecasts	Lack of information on climate change and/or reliable weather forecasts	*"Like in the beginning with this year, three meteo that we use weather predictions, they predicted no rain for the whole year. (…) And we had quite a lot of rain this year. So it's good to have predictions but you can't … I can't say threemeteo says there is no rain this year so I won't be planting this year. Because it's not dependable enough. Any weather prediction that's in the long term … you can really predict a week or 10 days maybe, but long term … All that we saw about the long term predictions is that it's not, you can't work with that, it's not dependable enough." (F5_WH)*
Technological constraints		Practical or technological challenges in farm practices as a perceived barrier to adaptation	*"I would love to farm in soils that is rich in earth worms and you can just see the microbial activities there. We've tried it for few years on the one field but as the organic stuff increases the flow becomes a problem in the planter. So you win on the one hand but the practical stuff gets more difficult on the other hand. So we have very stony soils, so it's difficult to move away from the tine implements." (F15_WH)*
Information on climate change from technology	Media	Information on climate change or adaptation strategies that is derived from media such as newspapers, TV and radio	*"You hear it on TV, global warming and all that stuff." (F8_WI)*
	Internet	Information on climate change and/or adaptation strategies that are derived from the internet	*"These days you know that everything is on internet and google and something." (F3_WH)*
	Weather forecasts	Information on climate change and/or adaptation strategies that are derived from weather forecasts such as weather stations, programs or mobile apps	*"We've got weather stations in Moorreesburg and Langebaan so we've got all that information." (F3_WH)*
Information on climate change from people	Farmers' unions (Afrikaans: Landbouverenigeng)	Information on climate change and/or adaptation strategies that are derived from local, monthly self-organized farmers unions	*"We are on (…) an agricultural organization in town. We call it the Landbouverenigeng in Afrikaans. (…) So if there is any climate changing that will be happening and then like there will be … it's harvesting time and there will be lot of big rain they will tell the guys, you know." (F8_WI)*
	Other farmers and people	Information on climate change and/or adaptation strategies that is derived from other farmers or other people	*"It's on everybody's tongue. Everybody is worried about it and everybody talk about it." (F10_WH)*
	Agricultural consultants	Information on climate change and/or adaptation strategies that is derived from or offered by agricultural consultants	*"I just have this wonderful friend of mine (…) she is practicing on old vines and she, she really looking about the whole industry, about wines, about climate and everything." (F13_WI)*
	Department of agriculture		

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Minor category	Code	Description of code	Representative quote
Information from institutions and companies		Information on climate change and/or adaptation strategies that is derived from or offered by the Department of agriculture	*"I get emails sometime from (…) the department of agriculture, they now and then have an article about climate change and predictions and stuff." (F11_WH)*
	Research farms and science institutions	Information on climate change and/or adaptation strategies that is derived from research farms (e.g. Langgewens) and science institutions (e.g. Agricultural research council)	*"There is a farm Langgeweens and that's a farm, I think it's owned by the (…) Agricultural research council they call it. The other farm … people come and (…) plant new cultivars there. (…) At the end of the year when everything is harvested we get the results. So you can see okay this cultivar did good." (F5_WH)*
	Non-profit agricultural companies	Information on climate change and/or adaptation strategies that is derived from non-profit agricultural companies such as GrainSA, Vinpro, Infrutec	*"No except for the research they are doing on the different varieties of wheat and barley and even canola. So they are trying to get varieties that are growing with less water and especially the growing season, they try to shorten it. Like if the drought is coming at the end, that the growing season is not like 130 days but 110 days so (…) they are working on that and we are getting the information all the time from Sensako and Grain South Africa." (F3_WH)*
	Agrochemical companies	Information on climate change and/or adaptation strategies that is derived from agrochemical companies such as fertilizer companies	*"Some of the fertilizer companies, the chemical companies they do a lot of research. (…) And they give us information. (…) Yeah because they develop stuff that they can sell. So if they can develop something that they can sell, then we get the info." (F5_WH)*
	Academia	Information on climate change and/or adaptation strategies that is derived from academic institutions	*"The university of Cape Town they've got a department of studying of climate change. There is one often, not regularly, I hear it on the radio or if I can read something I will read it." (F4_WH)*
Information on climate change from own experiences and observation		Information on climate change and/or adaptation strategies that is based on own observations of nature and local surroundings	*"And you live it, you can see it around you. It's happening."(F12_WI) "I took more time to notice the changes. If you are aware of something then you're much more susceptible to look at it and to see if there is something changing or what." (F6_WH) "I have to look self at nature, I have to be in the field the whole day to felt it, to see it." (F14_WH)*
Information on climate change from magazines		Information on climate change and/or adaptation strategies that is derived from agricultural magazines (e.g. Landbouweekblad)	*"Only thing is the Landbouweekblad. You can read it, you can maybe get an article or something like that." (F14_WH)*
Information on climate change from seminars and vocational trainings		Information on climate change and/or adaptation strategies that is derived from agricultural seminars and vocational trainings	*"There is a seminar that I visited last year. It's bewaringslandbou (Afrikaans) (…) Conservation farming basically. It's not very well attended but very informative. They would advise you to … keep … to increase carbon in the soil." (F1_WH)*
Information on climate change from overseas farming systems		Information on climate change and/or adaptation strategies that is derived from farming systems or agricultural practices in other countries	*"So we constantly looking at whatever Canada or Australia are doing with canola, because they are the leaders. So just in terms of that and I think they're also far ahead of us in terms of using it effectively in conjunction of climate change." (F16_WH)*

Coding system: 3. Adaptation strategies.

3.1. Implemented adaptation strategies

Major category encompassing different farm-level adaptation strategies that farmers have applied as a response to climate change and the experienced climatic stresses in their (1) crop management (2) soil management (3) water management (4) livestock management (5) introduction of new technologies and (6) expansion of farm units

Minor category	Code	Description of code	Representative quote
Crop management	Change of harvest and planting time	Implemented changes in harvest and planting time of crops as a response to climate change	*"So just by maybe planting a bit later we always start first of March, maybe we start 10th March or 20th March." (F14_WH)*
	Introduction of legume cover crops	Introduction of legumes (medics, clover etc.) as cover crops in farming system as a response to climate change	*"(Medics) is a natural way to put nitrogen into your soil. And if you get drought natural nitrogen is much better for the plant than chemical nitrogen." (F2_WH)*
	Crop rotation	Use of multi-year crop rotations (such as wheat-medics systems) as a response to climate change	*"We must help the soil with the material to absorb more moisture and that kind of stuff. And that is our aim with our crop rotation and the part of on the wheat side." (F4_WH)*
	Diversification of crops	Diversification and extension of cultivated crops on the farm	*"We're just feeling that we love to have another branch to divide the risk. (…) So if we do have a drought, a dry year like last year and the wheat is not doing good then maybe the cattle is doing better or the wool is very good and then maybe the tea can help. It's just to not to have all your eggs in one basket." (F3_WH)"*
	Removal of unproductive crops	Removal of unproductive crops to reduce water stress	*"And to remove some older orchards that are not productive, to remove them. And there we had a lot of problem with water." (F10_WH)*
	Reduction of fertilizer input	Reduction of fertilizer application on crops	*"And we lowered it (the fertilizer input) with the medic-clover system to 60, 50 kg of nitrogen. We're half … did the half. And now we're on 9 kg of N with this." (F11_WH)*
	Increase of fertilizer input	Increase of fertilizer application on crops as response to climatic stresses	*"We are under pressure with the size (of fruits) (…) So we've … more water, more fertilizer especially phosphate, more phosphate, the nitrogen for the fruit size to get better but you can do anything but if the temperatures is not right then you can do nothing." (F10_WH)*
	Introduction of cultivars with shorter growing season	Introduction of crops and cultivars with shorter growth time/growing season	*"We plant the wheat cultivars that grow shorter." (F5_WH)*
	Crop protection with netting	Application of nets to protect crops from climatic stresses such as sun, storms and winds	*"We have put some nets on, nets. And the nets … we're using 50% less water than we had using in the past." (F13_WI)*

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Minor category	Code	Description of code	Representative quote
	Introduction of drought-tolerant cultivars	Introduction of drought-tolerant or resistant cultivars to reduce water stress	*"Barley (…) can grow with less water than wheat. (…) So we bring that in for rotation with wheat and the canola and the medics. So there is definitely one thing we're looking to extend our barley branch, especially for the dry years." (F3_WH)*
Soil management	Minimum tillage	Usage of minimum tillage or no-till practices to reduce mechanical disturbance of the soil	*"I think the best precaution we did here for the drought is the no-till. Because if you take where the ground is heavy worked (…) there your moisture in the ground gets less, so you get … your tons per hectare on your wheat on the no-till and your tons per hectare on conventional it's much better." (F5_WH)*
	Increased soil cover	Increase of soil cover by leaving stubble or other organic material on the ground to reduce evaporation and improve soil	*"So we try and leave as much stubble or material on the soils to keep it cooler." (F15_WH)*
	Building top soil	Soil management practices that facilitate the buildup of top soil/organic carbon content of the soil	*"Because the way we are farming now with the less disturbance of the soil and we try to build up the organic material in the top that will absorb more moisture." (F4_WH)*
	Composting	Application of compost	*"We're using some compost and everything and put better … they can use less water I think." (F13_WI)*
Water management	Water conservation techniques	Water management techniques that conserve water/reduce water usage, such as introduction of drip irrigation	*"We went from sprinklers to drip irrigation (…). And you save a lot of water. And you give the water only where it's needed on the roots and … so that's one of them." (F12_WI)*
	Technological advancements/moisture meters	Technological innovations that support a general reduction of water usage	*"We had working with moisture meters, we … not giving … not only water. We moisture it by computers, we all … it's all computerized." (F13_WI)*
	Increase of water usage	Higher water consumption or usage	*"So we've (used) more water, more fertilizer especially phosphate, more phosphate, the nitrogen for the fruit size to get better but you can do anything but if the temperatures is not right then you can do nothing." (F10_WH)*
Livestock management	Abandonment of livestock	Temporary or long-term abandonment of livestock as a response to climatic stresses (such as drought)	*"Firstly we had sheep on the farm but the droughts impact on the sheep farming and the cattle farming is so overwhelming … to feed them and to prepare feed for them you need land that you can cultivate wheat on to feed the animals. You see and in the end your profit is diminishing." (F6_WH)*
	Change of grazing patterns	Change of grazing patterns to improve soil health and increase SOC (soil organic carbon)	*"To increase carbon in the soil by not let your sheep overgraze the land, to keep the carbon content of your soil high so you can keep your moisture (…) would be better." (F1_WH)*
	Change of fodder	Change or adjustment of fodder to increase resilience of livestock towards climatic stresses	*"You kill a living animal, you take the stomach, the grass in the animal stomach (…) and you mix it with sugar and yeast and you give it in (…) for the small sheep so the stomach can start working. (…) So the animal can get quicker in to the state to generate its energy from the food that's available." (F1_WH)*
Introduction of new technologies		Utilization of new technologies (such as GPS, solar pumps etc.) to reduce financial, mechanical, fertilizer inputs	*"But all the things that the new technology of implements, soil mapping, so that helps. So that you don't put something in the ground that costs you money that is not necessary." (F2_WH)*
Expansion of farm units		Expansion of farm and cultivated land to compensate decreasing profitability	*"We rent now more land than we actually have, that we own. If we didn't do that, we wouldn't be here anymore. You need to go bigger as (…) your profit, your profit is diminishing very very fast." (F6_WH)*

3.2. Future adaptation strategies

Major category encompassing different farm-level adaptation strategies that farmers intend or consider to apply as a response to future climatic stresses in their (1) crop management (2) water management (3) livestock management, (4) extensive farming practices, (5) soil management (6) expansion of farm units and (7) introduction of new technologies

Minor category	Code	Description of code	Representative quote
Crop management	Introduction of cultivars with shorter growing season	Considered or planned introduction of crops and cultivars with shorter growing season as a response to shorter vegetation periods and seasons	*"And then we need cultivars that ripen earlier in the season and that have shorter ripening period. You know to get your harvest in earlier. You know that you don't have the long term effect of the dryness." (F9_WI)*
	Introduction of drought-tolerant cultivars	Considered or planned introduction of drought-tolerant cultivars as a response to future changes in precipitation, heat stresses and droughts	*"We will have to minimize the risk of drought, then we have to plant cultivars that is more dry resistant" (F4_WH)*
	Extension of crop rotation	Considered or planned extension of crop rotation	*"But the one thing I do know is I can make my rotation longer to survive easier. That I can do." (F11_WH)*
	Introduction of new cover crops	Considered or planned introduction of new and adjusted cover crops	*"Now we have drier winters, you know we're not having those wet soils, so the oats doesn't work anymore. So we've got to find something that grows in the shorter period of time, that will still give me the same amount of mass, of green mass, that I can still mow, that will give me a good cover to protect my soil." (F9_WI)*
	Crop diversification	Considered or planned diversification of cultivated crops to respond to shorter growing seasons, to minimize financial risks or to reduce future water stress	*"The other option is to grow crops that is more … (…) say you produce for three or four months, the grain season of the wheat is six months, so if I go into either vegetables or other stuff that takes a shorter period, that has less water use, we can go in that, on that route." (F15_WH)*
	Crop protection with netting	Considered or planned introduction of nets as physical crop protection from climatic stresses like sun, heat stresses and storms	*"I think the only thing that we can change (…) something that we will look at is netting for the vegetables." (F7_WI)*
	Change of harvest time	Considered or planned adjustments of harvest time to respond to future shift of seasons	*"It's the weather and the rain and we will just have to adapt and move everything two weeks a month. That's … I think that's the only thing that we can do." (F7_WI)*

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Minor category	Code	Description of code	Representative quote
Water management	Water conservation techniques	Considered or planned introduction of water conservation techniques to respond to future water stresses	*"it's like bucket you put around your vines like this bucket plastic thing and you just put it around the vines and it collects the dew, the morning dew. So it collects the dew and the dew just goes down into the soil." (F12_WI)*
	Additional installation of water sources	Considered or planned installation of additional water sources such as drilling boreholes or building dams	*"The one thing is I'm going to the borehole for the water and I have a good feeling about that spot in the renosterveld between the rocks. I think maybe there is some water down there." (F12_WI)*
	Improvement of irrigation	Considered or planned improvements of irrigation	*"If our water resources are not enough then we have to make a plan with the irrigation." (F10_WH)*
Livestock management	Shift to livestock husbandry	Considered or planned shift to or expansion of livestock husbandry as a risk equalization to other farm branches	*"And in my view if the wheat is not profitable we will easily lean more over to the livestock sector." (F4_WH)*
	Change of grazing patterns	Considered or planned adjustment of grazing patterns	*"Like in my business go more natural (…) Different grazing patterns which you see for your cattle or something like that." (F14_WH)*
Extensive farming practices	Reduction of machinery	Considered or planned reduction of machinery usage	*"Like in my business go more natural (…) (with) less machinery." (F14_WH)*
	Lower fertilizer input	Considered or planned reduction of fertilizer application	*"You have to bring in crops that put nitrogen into the ground to less input of your fertilizers and then that is what you have to do." (F4_WH)*
	Extensive livestock husbandry	Considered or planned shift to extensive livestock husbandry	*"You have to farm more extensive with livestock" (F4_WH)*
Soil management	Increased soil cover	Considered or planned increase of soil cover by leaving stubble or organic material on the ground	*"The big thing is to keep more stubble on your fields." (F15_WH)*
	Introduction of legume crops	Considered introduction of legume crops to improve soil structure and water holding capacity	*"Next year I want to plant something like (…) beetroot (…) with roots under the ground. Just for the worms. (…) To make the ground more productive and more absorbing to any water or … to stabilize the ground more." (F14_WH)*
Expansion of farm units		Considered expansion of farm units to enable more extensive farm practices	*"I think what is needed in the future is you have to have a bigger farm, so for that either your neighbour farm needs to be bought and then you rest more fields because we don't get any support, subsidies or anything, you have to plant as much as possible to survive. But if you have a bigger farm, if your hectares are bigger, then you can afford to say a third of your farm just lay barren for a year or two for the soils to rest and for the rotting process to take longer and to build up the organic material in the soils." (F15_WH)*
Introduction of new technologies		Considered introduction of new technologies	*"I think it's important to just keep up with technology whatever they offer." (F16_WH)*

A3: Socio-demographic and agricultural data of interviewees f = female, m = male, n. a. = no answer

Farmer	Gender (m/f)	Years farming	Farm size (ha)	Major Crops	Additional Crops	Livestock
F1_WH	M	33	1600	wheat	medicago	sheep
F2_WH	M	40	1200	wheat	oats	
F3_WH	M	35	1800	wheat	canola	cattle
F4_WH	M	26	n.a.	wheat		sheep
F5_WH	M	22	380	wheat	oats	sheep
F6_WH	M	43	550	wheat, barley	canola, lupins	
F7_WI	F	9	520	wine grapes	vegetables	
F8_WI	M	13	560	wine grapes	wheat	cattle
F9_WI	M	20	180	wine grapes	buchu	
F10_WH	M	40	1600	wheat	nectarines	cattle
F11_WH	M	25	450	wheat	medicago	
F12_WI	M	20	180	wine grapes		
F13_WI	M	30	315	table grapes	wine grapes	
F14_WH	M	6	300	wheat		sheep
F15_WH	M	15	1000	wheat	canola	
F16_WH	M	10	720	wheat	barley	

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