Peer review history for:

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HOW TO CITE:
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Reviewer 1: Round 1

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Reviewer 2: Round 1
Date completed: 24 September 2024
Recommendation: Accept / Revisions required / **Resubmit for review** / Resubmit elsewhere / Decline / See comments
Conflicts of interest: None

Does the manuscript fall within the scope of SAJS?
Yes/**No**
Is the manuscript written in a style suitable for a non-specialist and is it of wider interest than to specialists alone?
Yes/No
Does the manuscript contain sufficient novel and significant information to justify publication?
Yes/**No**
Do the Title and Abstract clearly and accurately reflect the content of the manuscript?
Yes/No
Is the research problem significant and concisely stated?
Yes/No
Are the methods described comprehensively?
Yes/No
Is the statistical treatment appropriate?
Yes/**No**/Not applicable/Not qualified to judge
Are the interpretations and conclusions justified by the research results?
Yes/Partly/No
Please rate the manuscript on overall contribution to the field
Excellent/Good/**Average**/Below average/Poor
Please rate the manuscript on language, grammar and tone
Excellent/**Good**/Average/Below average/Poor
Is the manuscript succinct and free of repetition and redundancies?
Yes/No
Are the results and discussion confined to relevance to the objective(s)?
Yes/No
The number of tables in the manuscript is
Too few/**Adequate**/Too many/Not applicable
The number of figures in the manuscript is

Too few/**Adequate**/Too many/Not applicable

Is the supplementary material relevant and separated appropriately from the main document?

Yes/No/**Not applicable**

Please rate the manuscript on overall quality

Excellent/Good/**Average**/Below average/Poor

Is appropriate and adequate reference made to other work in the field?

Yes/No

Is it stated that ethical approval was granted by an institutional ethics committee for studies involving human subjects and non-human vertebrates?

Yes/**No**/Not applicable

If accepted, would you recommend that the article receives priority publication?

Yes/**No**

Are you willing to review a revision of this manuscript?

Yes/No

With regard to our policy on 'Publishing peer review reports', do you give us permission to publish your anonymised peer review report alongside the authors' response, as a supplementary file to the published article? Publication is voluntary and only with permission from both yourself and the author.

Yes/No

Comments to the Author:

Title and general comments:

The title suggests that the study aims to explore the relationship between seasonal climate forecasts (SCFs) and food security. However, the abstract and methodology do not explicitly describe how food security was measured or analysed in relation to SCF use.

The author should clearly define how SCF could be linked to food security. The reviewer would rather suggest to determine whether knowledge of SCF's has an effect on economic or financial situation.

Abstract

Lacks link to theme - food security?

Methodology

- Is your methodology only qualitative or also quantitative?
- A quantitative analysis to examine the relationship between SCF use and food security outcomes are necessary to prove relationship/correlation.
- Insufficient definition of small holder... Clearly explain who this group is.
- How many people per focus group? This may determine the effectiveness of discussions.
- Clearly explain the sample size - number of participant in each group and how you have recruited respondents.
- What is the reason for comparison between the exact two groups? Are the Western Cape farmers representative of "commercial crop farmers" and same with Eastern Cape farmers, same with enterprises farmed with. -- If this could be justified, the title needs to change due to its large populations mentioned in the title.
- Clearly provide reasoning and quantification for selection of samples and representation of populations.
- The results do show acceptable feedback from farmers but should still link to the title of the study.

[See Appendix 1 for Reviewer 2's comments made directly on the manuscript]

Author response to Reviewer 2: Round 1

1. Title and general comments:

The title suggests that the study aims to explore the relationship between seasonal climate forecasts (SCFs) and food security. However, the abstract and methodology do not explicitly describe how food security was

measured or analysed in relation to SCF use.

AUTHOR: We have modified the title and bolstered the abstract, introduction, and conclusions to show a better link with food security. Please note that the study did not directly measure or analyse food security. Instead, food security is implied. Food security is especially important for the smallholder farmers. If their crop fails or has lower than expected yields, their food security is directly impacted. But suboptimal commercial farming can also lead to food security issues. For commercial farmers, if their crop yields are lower than expected then there is less food to go around. This impacts food prices and food access, especially for the poor. For the smallholder farmers it is largely about being able to feed themselves and to make a small profit that will enable them to purchase other food staples that they can't grow themselves and other necessities like clothing. For the commercial farmers, if their farming operations are continuously non-financially viable they will consider stopping farming, thus placing overall food security at risk. It ultimately comes down to food security. We have made an adjustment to the title to reflect that the study is not relational, but exploratory.

2. The author should clearly define how SCF could be linked to food security. The reviewer would rather suggest to determine whether knowledge of SCF's has an effect on economic or financial situation.

AUTHOR: As mentioned in the first comment by the reviewer, we have tried to bolster the connection with food security throughout the paper. While the economics and the financial situation of farmers is obviously important, this wasn't the focus of this manuscript other than as one of numerous considerations for the farmers. Instead, we are interested in whether the farmers understand the limits of SCFs and how to weigh SCF information into the farming decision making.

3. Abstract
Lacks link to theme - food security?

AUTHOR: Agreed. We have made a better link to food security in the abstract.

4. Methodology
Is your methodology only qualitative or also quantitative?

AUTHOR: Yes, this manuscript only reports on one of the qualitative components of the research. We have used the word "qualitative" in the manuscript to make this clear.

5. A quantitative analysis to examine the relationship between SCF use and food security outcomes are necessary to prove relationship/correlation.

AUTHOR: Showing a quantitative relationship between SCF use and food security was not one of our research aims. The larger research project is looking at the co-production of SCF information so that it can potentially be used by farmers to improve their decision making (and by implication, to improve their food security). We are therefore reporting on the first step in this process. In particular, is there anything useful in an SCF that a farmer can use and if there is, how can it be used to make decisions about their farming. If the answers to both these questions are that SCFs are useless and it doesn't support their decision making, then the co-production of SCFs for farming is questionable.

6. Insufficient definition of small holder... Clearly explain who this group is.

AUTHOR: We have added material to the introduction to help with defining a smallholder farmer.

7. How many people per focus group? This may determine the effectiveness of discussions.

AUTHOR: We have added information on the size of the focus groups. Where there were too many workshop participants, they were assigned to smaller groups of 12 or fewer for the focus group discussions and then each focus group reported back to the larger workshop group for further discussions. The details are given in a new Table 1.

8. Clearly explain the sample size - number of participant in each group and how you have recruited respondents.

AUTHOR: As with our answer to comment 7, we have added more information about the size of the focus groups. With regards to recruitment, Reviewer 1 had a similar comment and we have explained the purposive sampling component of our sampling strategy.

9. What is the reason for comparison between the exact two groups? Are the Western Cape farmers representative of "commercial crop farmers" and same with Eastern Cape farmers, same with enterprises farmed with. -- If this could be justified, the title needs to change due to its large populations mentioned in the title.

AUTHOR: We think that there might be a misinterpretation here. It was not our intention to say that all farmers in the WC are commercial crop farmers and that all farmers in the EC are smallholder crop farmers. There are commercial farmers in the EC and smallholder farmers in the WC. We also know that our sample of WC farmers is not representative of all commercial crop farmers, even in the WC (it doesn't include fruit farmers or wine farmers, for example). Similarly, our EC farmers are not necessarily representative of all smallholder farmers, even in the EC (depending on the geographical area, aspects like temperature, soil quality, and growing seasons will vary). There are also farming differences between the commercial crop farmers (who are mainly farming winter crops because that is when there is rain) and the smallholder farmers (who farm different crops depending on the season). But our research is not about the different crops. It is about whether SCFs can be of value for each condition and what types of decisions they might be able to make to improve their farming prospects. The two groups are best distinguished by the resources they have available to make decisions. Finally, we have raised the inequality between the two groups as a potentially confounding factor for generalisability in the limitations, although this would be common to all qualitative work.

10. Clearly provide reasoning and quantification for selection of samples and representation of populations.

AUTHOR: In qualitative research the important aspect of representivity is whether the sample captures the diverse perspectives of the population. Therefore diversity is favoured over generalisability. This is achieved through purposive sampling, the saturation of responses, and reflexivity in data collection. These are explained in the revised text and generalisability is noted as a limitation.

11. The results do show acceptable feedback from farmers but should still link to the title of the study.

AUTHOR: Agreed. As per our response to the first comment we have made further links to food security in the conclusion.

Appendix 1: Reviewer 2's comments on original manuscript

Commercial and small holder crop farmers' seasonal climate forecast needs for food security

Abstract

Seasonal climate forecasts (SCFs) are explored as an additional tool for farmers to use to act against seasonal climate fluctuations and to ensure greater food security for themselves and their customers. In this study we compared the SCF needs and possible farming actions of commercial farmers (Western Cape) and smallholder farmers (Eastern Cape) while exploring the possibility of developing SCF tools to aid farmers. The results show that both farmer groups saw value in SCFs to improve their farming actions and provided detailed information on their specific SCF needs to support their decision-making such as how to improve trust, what type of information they would like, how to make SCFs more understandable, and relevant for their farming actions. The needs for the two groups differed marginally, but the major barrier for smallholder farmers was SCF access due to a lack of smartphones and network coverage.

Significance

The findings help us understand what farmers need to know to take more informed farming actions that will increase their resilience to climate change and improve their food security. This will enable us to build seasonal climate forecasting information tools that can be easily accessed and understood by commercial and smallholder farmers alike.

Keywords: food security; information needs; seasonal climate forecasting; climate variability; technology access

Commented [A1]: The title suggests that the study aims to explore the relationship between seasonal climate forecasts (SCFs) and food security. However, the abstract and methodology do not explicitly describe how food security was measured or analysed in relation to SCF use

Introduction

While proportionally low in comparison to other African countries, malnourishment and perceptions of food insecurity are both on the rise in South Africa equating to 4.7 million South Africans who are malnourished and 5.3 million who report severe food insecurity[1]. While South Africa is often viewed as food secure, large scale commercial farmers are often financially incentivised to favour exports, leaving millions with reduced access to affordable food. The largest proportion of farmers in South Africa are small holders with limited access to technology, finances or information, and rely largely on rain-fed agriculture. Crop yields have already been negatively impacted by climate change in Southern Africa[2] and these are predicted to worsen by 2050 under current climate change predictions[3]. This may have negative consequences for food security but will also impact the economy through the loss of income, job loss, and the reduction of exports[4-5], further exacerbating food insecurity. Despite these early warning signs, South African farmers have yet to fully develop their resilience to climate change.

Significant research efforts have explored adaptation strategies to mitigate the long-term effects of the changing climate through modelling and remote sensing assimilation[6], but climate variability remains of near-immediate (i.e., this season) importance. In South Africa, climate variability affects the agricultural sector and results in fluctuating crop yields and the loss of crops on a seasonal time scale[7]. To address growing food insecurity, farmers can adopt precision agriculture methods to boost their yields and output. Seasonal Climate Forecast (SCFs) provide an opportunity for farmers to gain insights into medium term meteorological conditions and thus adapt their meteorological-related inputs. SCFs offer crucial insights into potential climate anomalies expected in the upcoming season[8]. Weather forecasts predict the timing and intensity of events, whereas SCFs provide estimates of average seasonal conditions over a specified period, typically one to three months[9]. While they cannot predict specific meteorological events, SCFs indicate whether the upcoming season is likely to be wetter, drier, hotter, or cooler compared to typical regional averages. SCFs are therefore particularly useful in the agricultural sector since they may influence farmers' decisions regarding when and what to plant, what supplementary inputs to use, what yields to expect, and expected harvesting timing[10-11]. Effective SCFs are therefore valuable for the agricultural sector to make these routine farming decisions as well as to manage risks (e.g., drier seasons, late seasonal onsets, or likelihood of frost), and to implement risk-reduction strategies (e.g., the crop mix, seed choices, insurance, or land management). These decisions are important even for smallholder farmers with limited

resources[12]. Hansen et al.[13] reported that farmers in Sub-Saharan Africa who responded proactively to SCFs produced proportionately higher crop yields than those who did not.

Although the benefits of SCFs are clear, historically they have not been frequently adopted in the agricultural sector[14-15] apart from in the United States[16]. Farmers encounter challenges in accessing, interpreting, and applying the forecasts[17]. Generally, Bruno Soares and Dessai[18] found that organisations in Europe failed to use SCFs because they were unaware of them, the skill and reliability were perceived as too low, there was a high level of perceived uncertainty in SCFs, and they often lacked the perceived relevance for their organisation. In a study on the value of SCFs for agriculture in Australia, Ash et al.[19] noted that they were limited by poor skill, short lead times, were difficult to access and understand, and farmers struggled with understanding their relevance to agricultural decision-making. In the United States, Briley et al.[20] reported that farmers experienced difficulties in understanding the information provided by SCF experts, were unrealistic in their expectations of what SCFs could produce, and were unsure when it was appropriate to make decisions based on SCFs.

Several literature reviews have summarised the problems experienced by farmers across Africa with SCF adoption. Hansen et al.[13] identified three broad categories faced by Sub-Saharan African farmers: content limitations; accessibility problems; and a lack of resources to address any seasonal variability. Content limitations included spatial scales that were too broad, imprecise timing of meteorological events, unclear forecast periods, and poor forecast accuracy. Accessibility problems included not knowing where to access SCFs, inequitable access to SCFs from differential technology availability, and the SCF not being available in the local language. Resource limitations prevent necessary adjustments for the coming season. A lack of resources included financial resources to purchase preferred cultivars, insufficient access to lines of credit, unsuitable soils for the meteorological conditions, and insufficient credit to purchase soil enrichment resources. Chisadza et al.'s[21] review found similar issues being faced by African smallholder farmers. In Muita et al.'s[22] review of SCF problems experienced by Kenyan farmers identified accessibility problems, limited access to farm inputs (e.g., appropriate seeds or fertiliser), language barriers, a lack of trust in SCFs, and spatial and temporal limitations of the forecasts. In interviews in South Africa, Thatcher et al.[23] found that a variety of SCF end-users struggled with understanding various elements of SCFs.

Ebhuoma[24] provided the most comprehensive review of the problems experienced by South African farmers when considering SCFs. Some of the issues were similar to those identified

elsewhere in Africa[12, 21-22] such as the lack of access to SCFs (especially in a local language), poor forecast accuracy, difficulties in understanding probabilistic forecasts, and the same spatial and temporal problems. However, there were also issues that were not present in these other reviews. Specifically, the South African farmers expressed greater trust in indigenous knowledge systems and didn't trust the producers of SCFs or the intermediary disseminators of SCFs (usually extension officers). Low literacy was a perceived barrier to SCF adoption, and younger farmers were more likely to consider adopting SCFs than older farmers.

In summary, farmers expressed problems with getting access to SCFs, understanding the information on the SCFs if they could access them, and struggled to see the relevance of SCFs for their farming decisions.

SCF tool co-production for South African farmers

Current SCF information available in South Africa is either produced in-country, either by the South African Weather Service for official dissemination or in an academic context (e.g., Forecast Worx), or are produced globally by, for example, the European Centre for Medium-Range Weather Forecasts or the International Research Institute for Climate and Society. Such products are largely developed as top-down data dissemination tools, while for effective forecasting the World Meteorological Organisation[25] calls for co-design with the clients. For the WMO, this means strengthening collaborations between the forecast scientists and social scientists to determine what to communicate and how to reveal actionable information for end-users. Muita et al.[22] made a similar recommendation based on their review of SCF use with farmers in Kenya. Other studies have shown the value of SCF co-design for end-users, such as Sanchez-Garcia et al.[26] who co-developed SCFs tools for moderate and advanced users in Europe or Steinke et al.[27] who co-developed an SCF tool for a seed supply company in Zimbabwe. For this study we adopted an ergonomics/human factors (E/HF) approach[28] to co-designing an SCF tool to assist farmers to access, explore, understand, and facilitate the extraction of actionable information for decision-making.

This study focuses on the co-production of an SCF exploration platform for crop farmers, which intends to address needs of both smallholder (typically in Eastern Cape) and commercial (typically in Western Cape) farmers of South Africa. These are often the two groups into which farmers are placed in South Africa[29]. Commercial farmers have access to land and their produce is predominantly sold for a profit. Smallholder farmers are more

difficult to define and represent a range of different farmers. Smallholder farmers usually have limited access to land, and produce food for their household, with surpluses sold for commercial gain[29]. In South Africa, both farmer groups are highly dependent on rainfed agriculture which is susceptible to climate variability. The first step in the E/HF approach[28] when designing a new tool is to gather information about users' needs and to understand the kinds of decisions that can be made.

The aims of this study are therefore two-fold in comparing the smallholder and commercial crop farmers: (1) to compare the SCF needs; and (2) to compare the possible farming actions that enable sustainable food production. There are currently no studies comparing the SCF needs of smallholder and commercial farmers in South Africa or that have looked at how these two farmer groups might use SCFs to enhance their farming decision-making.

Methods

Procedure

Commented [A2]: Qualitative only or also quantitative?

The study followed ethical procedures for human participants approved by the respective ethics committees at the [institutions and reference numbers anonymised]. The data were collected in two stages. The first stage involved semi-structured, in-depth interviews. Assistance was provided by Overberg Agri (Western Cape) and Grain SA (Eastern Cape) to identify potential interviewees. Interviews took place in farmers' homes, offices, or community halls, in September and October 2021. Interviews were conducted in English or Afrikaans (Western Cape) and English or IsiXhosa (Eastern Cape) and lasted approximately one hour. The interviews were audio-recorded and professionally translated/transcribed into English for analysis. The second stage involved focus group discussions to corroborate the interview data and to identify new issues. Focus groups were held in Caledon (Overberg district, Western Cape) and Moorreesburg (Swartland district, Western Cape) in July 2022 and in Nqanqarhu, Mount Fletcher (Gqabi district, Eastern Cape) and Bizana, eMaxesibeni (Alfred Nzo district, Eastern Cape) in November 2022. The focus groups took place in the Overberg Agri offices (Western Cape) and community halls (Eastern Cape). Each focus group lasted approximately 120 minutes. In the Western Cape the focus group facilitator spoke Afrikaans whereas in the Eastern Cape the facilitator was assisted by an IsiXhosa speaking extension officer using the IsiXhosa version of the focus group questions. The geographical areas from where participants were drawn are shown in Figure 1.

Instruments

The interview schedule started with biographical questions about the farmer, their farming activities, and their use of climate services, to establish rapport. Next, farmers were asked about their SCF needs with regards to their farming activities. Last, farmers were asked about the types of actions they could take based on SCFs.

The focus group discussions started with an explanation of SCFs and the issues of probability and forecasting skill. Next, the farmers' perceptions regarding the usefulness, understandability, and trustworthiness of SCFs were probed. Finally, farmers were asked about the actions that they could adopt based on SCFs.

The interview and focus group schedules were developed in English and translated into Afrikaans and IsiXhosa.

Participants

Commercial farmers

In the Western Cape 13 interviews were held with commercial grain farmers growing various Winter rainfall grains, mostly wheat and barley, and 2 interviews were held with extension officers from Overberg Agri. All interviewees were white males who spoke Afrikaans as their home language. This was followed by 2 focus group discussions with 52 commercial grain farmers and 2 extension officers as participants. Participants were all white, Afrikaans speakers, with 4 females and 50 males.

Commented [A3]: How many people per focus group,

Commented [A4R3]: Clearly explain the sample size - number of participant in each group and how you have recruited respondents

Smallholder farmers

In the Eastern Cape 16 interviews were held with smallholder crop farmers growing a wide range of summer rainfall crops including maize, cabbages, beans, and potatoes. All interviewees were black and spoke IsiXhosa as their home language, with 4 females and 12 males. This was followed by 4 focus group discussions with 93 smallholder crop farmers and 3 extension officers as participants. Participants were all black IsiXhosa speakers, with 51 females and 45 males.

Figure 1: Geographical areas of participants.

Analysis

After transcribing the interview and focus group recordings, a random sample of the transcriptions were checked against the recordings by an independent reviewer for accuracy. The interview and focus group data were imported into Nvivo and analysed using Thematic Analysis (TA). The six-phase approach to TA was followed[30]: (1) familiarisation with the data; (2) generating initial codes; (3) searching for themes; (4) reviewing potential themes; (5) defining and naming themes; and (6) writing the report.

Commented [A5]: What is the reason for comparison? Are the Western Cape farmers representative of "commercial farmers" and same with Eastern Cape farmers, same with enterprises farmed with. Clearly provide reasoning and quantification for selection of samples and representation of populations.

Commented [A6R5]: If this could be justified, the title needs to change due to its large populations mentioned in the title

Results

Most interviewees had not used SCFs (smallholder farmers: 77% and commercial farmers: 77%) and many had not even heard of SCFs (smallholder farmers: 69% and commercial farmers: 15%) with some smallholder and commercial farmer interviewees sceptical that seasonal forecasting was even possible. For this reason, the focus groups started with a presentation on SCFs and what they were potentially capable of achieving. Attention was paid to the need to present SCF capacity as fairly as possible, including clarification of inherent uncertainties and skill variations.

SCF Needs

Six themes regarding needs from SCFs were identified from the interviews and focus groups (see Table 1), although differences were noted between the commercial and smallholder farmers.

Accuracy

Both the commercial and smallholder farmers specified that SCFs needed to demonstrate sufficient accuracy in their forecasting ability to be considered usable. The commercial farmers specified what they considered to be acceptable accuracy levels (levels of either 60% or 70% accuracy) whereas the smallholder farmers indicated that accuracy should be better than random chance (i.e., 50% or better).

Easier access

While accessibility of SCFs was a theme for both the commercial and smallholder farmers, their needs were different. Commercial farmers wanted access either through an application on their mobile phone or from a website. The smallholder farmers had poorer access to smartphones/computers and limited Internet/network connectivity, and therefore expressed a preference for access through their mobile phones either as text messages or WhatsApp messages or through radio broadcasts like weather forecasts. Smallholder farmers also expressed an interest in having SCFs explained to them by extension officers or other authority figures (e.g., by an experienced local farmer or by the SCF developers themselves). Both farmer groups wanted the information accessible in their home language.

A complete picture

To provide the necessary support for their farming operations both groups of farmers felt that SCFs should provide a “complete” picture of meteorological information. However, the two groups differed in what was considered “complete”. Both groups indicated that rainfall, temperature, the likelihood of extreme events (e.g., heavy rainfall, floods, and drought), and the spread of rainfall across the season (e.g., how many days of rain and when the rain was expected during the forecast period) were important. Both groups felt that wind information was important, but for different reasons. The commercial farmers needed this information in conjunction with rainfall and temperature to determine soil moisture. The smallholder farmers needed temperature and wind information to determine the likelihood of wildfires that might threaten their crops. Smallholder farmers were interested in the likelihood of hail, frost, and snow that might damage their crops. All the farmers were interested in the onset date of the rainfall season (particularly in anticipation of the planting) as well as the distribution of rain

across the season (i.e., whether it will fall regularly or whether there is a likelihood of extreme rainfall events).

Relevance

Both farmer groups struggled to identify their own farms/locations on a larger map and wanted an ability to zoom into the maps to more accurately identify their specific location (and therefore also their specific probabilistic estimates). The smallholder farmer group was also concerned that forecasts were being made based on data collection points that were far away and not relevant for their specific locality (e.g., the meteorological station was in a town 70km away). Both groups of farmers expressed a need to consider the historical accuracy (i.e., against their own records or own recollections). This would allow the farmers to make a connection with the forecasts. Both farmer groups also want to know whether the SCFs aligned with their own indigenous knowledge experiences (e.g. March lilies flowering in March).

Trust

Generally, both farmer groups felt that more could be done to improve user trust in SCFs. The smallholder farmers felt that trust could be established by the SCF producers speaking to them in-person. They valued the personal connection and the ability to be able to ask questions and engage in a dialogue. The commercial farmers wanted information on the sources of the SCFs to be able to identify whether the information came from trustworthy sources. They thought that understanding the science underlying SCFs and that could demonstrate historically accurate predictions would increase trust.

Understandability

The smallholder farmers were aware that they would be unable to interpret the SCFs without some form of training or support (e.g., from extension officers, educated farmers, or younger farmers who would be familiar with technology). Commercial farmers also felt that they would benefit from training in how to interpret SCFs, but also suggested other ways to improve their understanding. Some of these issues related to the current SCF representations which often are presented as terciles (e.g., “above normal”, “normal”, or “below normal” rainfall) using colours or colour gradients. The terms “above” and “below” normal were considered unhelpful unless the average or normal rainfall for the specific region and time of year were known. Instead, the commercial farmers wanted a short, simple explanation. The use of technical terms (e.g., ROC curves, skill, probability), which the farmers considered to be jargon, was also identified as problematic.

295

296 **Table 1**: Themes identified of farmers' SCF needs.

Commercial farmers (Western Cape)	Smallholder farmers (Eastern Cape)
Accuracy - Must be better than chance (60%; 70%+)	**Accuracy** - Must be better than chance
Easier access - Through apps on mobile phones or website - Information in Afrikaans	**Easier access** - Through extension officers - Through mobile phones (WhatsApp and text messages) - Through radio broadcasts - Information in IsiXhosa
A complete picture - Rainfall and temperature - Wind (soil moisture) - Intensity of extreme events - Frequency/spread of rainfall - Date of seasonal onset (e.g., date of first rains)	**A complete picture** - Rainfall and temperature - Wind (wildfires) - Hail - Frost/snow - Intensity of extreme events - Frequency/spread of rainfall
Relevance - Exact location of farm on map - Historical comparison - Alignment with indigenous knowledge	**Relevance** - Weather stations are too far away to provide meaningful information in their area - Exact location of farm on map - Historical comparison - Alignment with indigenous knowledge
Trust - Understanding of underlying science behind SCFs - Reliability of source of SCFs - Demonstrate historical accuracy	**Trust** - Producers of SCFs must come and speak to them
Understandability - Training in how to interpret SCFs - "Above" and "Below" average is unclear (unless you know the average) - Actual values, not averages - Less jargon (e.g. skill, probability) - Short and simple explanation - Colours are difficult to interpret	**Understandability** - Training in how to interpret SCFs - Avoid or simplify academic "jargon" (e.g. uncertainty, probability)

297

298 *Actions available from SCFs*

299 Farmers need to know that SCFs will add value to their farming practices. It was therefore
300 important to understand what actions that the different farmer groups felt they could take
301 based on information obtained from SCFs. It is unsurprising that the actions available to
302 smallholder farmers were fewer than commercial farmers, although there were still many
303 actions available to smallholder farmers.

304

Input costs

All the farmers indicated that they could use SCF information to regulate their input costs. The number and variety of these input costs was far greater for the commercial farmers. Both farmer groups could regulate the choice of cultivars (e.g., drought-resistant cultivars in a dry season, early or late maturing), the mix of crops (e.g., changing the proportion of different crops planted or the types of crops planted) to suit the expected conditions, and whether to buy fertiliser (i.e., if good rainfall was expected). The commercial farmers indicated that they could also switch to other types of farming (e.g., shifting to livestock farming). This might also have been possible for some smallholder farmers, although it was not mentioned. Related to this, commercial farmers could also decide how much seed to plant to optimise yields. Commercial farmers indicated that they could also make decisions about how much fertiliser, pesticide and fungicide (especially if rainfall was expected to be high) to purchase. Smallholder farmers were further limited to deciding whether to purchase insurance to secure against poor yields or crop failures. Presumably this would also be available to commercial farmers although it was not mentioned by them.

Timing

Both farmer groups could use SCF information to adjust the time of planting, the time of harvesting, and the time when fertiliser would be applied. While the flexibility to adjust some of these timings was limited, the information could also help farmers in preparing for these activities (e.g., ensuring equipment was ready, personnel were in place, or the land was prepared). The smallholder farmers also indicated that they could use SCF information to adjust when they would start preparing their land and when they would need to weed the land (if rains have been good). For smallholder farmers these activities are usually manually and labour intensive because they generally do not have regular access to motorised technology. They would therefore benefit from advanced warnings to enable preparation. Smallholder farmers also indicated that they could decide to stagger their planting rather than planting all their seeds at the same time. For example, if a dry season was expected they could plant less seed at the start of the season and if the rains arrive, they could plant more seed.

General planning

The commercial farmers also indicated that there were other general planning activities that would benefit from SCFs. If irrigation possibilities existed (e.g., they had a water use licence for extracting from a water source or for storing water) they could start planning the irrigation distribution (e.g., laying pipes or digging irrigation channels). Most commercial farmers also

have contractual agreements with grain buyers. The SCF information could help these farmers to determine profitable and realistic delivery contracts. Additionally, the commercial farmers indicated that they could use the SCF information to make general farming decisions such as whether to suspend farming operations (e.g., if the predicted conditions were highly unfavourable). None of the smallholder farmers mentioned any general farm planning activities.

Fatalistic attitude

Both farmer groups also expressed responses that suggested that there was little direct, physical action that could be taken. Both farmer groups indicated that SCF information only promoted an emotional response. Farmers suggested that their emotional responses could range from hope (e.g., hope that the SCF was wrong or that it was correct) to despair (e.g., it is going to be a bad year). Both farmer groups felt that there was nothing that they could do about the future weather. The smallholder farmers suggested that they could ask their extension officer what they could do. Commercial farmers were more likely to feel that the SCFs were interesting, but not necessarily informative. Nevertheless, the commercial farmers did feel that SCFs would be a further resource to their existing decision-making processes. Despite the limitations, both groups of farmers welcomed additional information, which could confirm (or disconfirm) the actions that they were already thinking of making and which would either increase their confidence or result in uncertainty.

Table 2: Themes identified for actions that farmers could take to address seasonal fluctuations.

Commercial farmers (Western Cape)	Smallholder farmers (Eastern Cape)
Input costs - Choice of cultivars - Choice of crop mix - Shift/diversification to other types of farming (e.g. livestock) - How much seed to plant - Buying fertiliser - Buying fungicide - Buying pesticides	**Input costs** - Choice of cultivars - Choice of crop mix - Buying fertiliser - Purchase insurance
Timing - Adjust time of planting - Adjust time of harvesting - Fertilising - Fungicide application - Insecticide application	**Timing** - Adjust time to prepare the land - Adjust time of planting - Stagger planting - Adjust time of harvesting - Fertilising - Weeding time
General planning - Planning irrigation opportunities - Planning delivery contracts	

Commented [A7]: Be consistent - either use buying or purchasing

- Financial planning (when to cut losses)	
Fatalistic attitude - Interesting rather than informing decision-making - Emotions (hope/despair) - "Nothing can be done, it's all down to rainfall"	**Fatalistic attitude** - Ask extension officers what to do - Emotions (hope/despair) - "Nothing can be done, it's all down to rainfall"

Discussion

The identified needs were broadly similar to previous literature reviews[13, 21-24] identifying the lack of access, the lack of SCF skill and accuracy, the problematic spatial and temporal scales, and wanting SCFs in their local language. The accuracy of SCFs is difficult to guarantee, but conveying the limitations of SCFs in an open and honest manner is still important. Both farmer groups could see the potential of SCFs and suggested several content parameters that would improve their decision making including the distribution of rainfall events (commercial farmers), and the likelihood of frost, snow, or hail (smallholder farmers). Both farmer groups expressed an interest in being trained how to interpret and use the SCFs, especially in learning to understand concepts such as probability and uncertainty, and what they mean for farmers. Hansen et al.[13] and Hansen et al.[17] have been successful in developing training techniques enabling farmers to understand probabilistic forecasts which could be applied for this purpose.

Both farmer groups expressed the need for greater trust in SCFs. Alexander and Block[14] also highlighted the importance of user trust in the adoption of SCFs. For the commercial farmers, trust needed to be built up through experience in seeing how the SCFs performed against real conditions. The smallholder farmers needed to develop trust through direct interactions with the SCF producers. Given the access issue, it is also possible that a trusted intermediary (e.g., an extension officer) might need to perform this role. This would mean improved training of extension officers to be able to translate the SCFs while applying local relevance. Much of the wariness appears to stem from the smallholders' distrust of authorities. For the older farmers this is related to their past experiences of authority figures under Apartheid and the continuation of misinformation under post-Apartheid governance regimes. These farmers tended to trust indigenous knowledge systems more than scientific knowledge systems. The smallholder farmers also expressed problems that the meteorological data stations were not co-located with their farms. They therefore doubted whether the SCFs would give them accurate information. Hansen et al.[13] also noted that the

historical data coverage that informs SCF modelling tends to be sparser in remote rural areas which would correspond to the lived experiences of these smallholder farmers.

While both farmer groups wanted to access the SCFs in their home language, how the two groups envisaged accessing SCFs differed. The commercial farmers were more technologically inclined, preferring to access the SCFs through mobile phones or a website. Access for the smallholder farmers was more complicated. If smallholder farmers had mobile phones, they wanted to receive the SCF information as text (either text messages or Whatsapp messages). This is probably related to the sporadic network coverage in many of the more geographically remote farming areas. Smallholder farmers also considered accessing SCFs from radio (and television) broadcasts which is the usual way of accessing weather forecasts. Independently of the medium, it is highly likely that smallholder farmers would need some type of intermediary mechanism (or person) to access or pre-interpret the SCFs.

Similarly to Hansen et al.[13], this study found that smallholder farmers were more limited than commercial farmers in their capacity to respond to SCF information. Commercial farmers already have more resources at their disposal and therefore have more alternatives. For smallholder farmers there were definite benefits from SCFs for early planning from the pre-planting to the post-harvesting stages. Given their heavy reliance on manual labour, this gives them time to put the relevant resources in place. The smallholder farmers were, however, more likely to feel that there was nothing that they could do and would rely on external inputs (e.g., from extension officers) to aid their decision making. Commercial farmers could make a wide array of decisions based on SCFs including more general planning for farming decisions such as financial planning.

Future developments and limitations

While we do not envisage addressing all the needs, we believe that SCFs offer some level of value that is still largely unexploited. Without attempting to improve the inherent skill of SCFs, this study emphasises numerous avenues for improvement. These arise from better tailoring of SCFs to farmers' needs, offering local relevance, and expressing more honestly the SCFs success and failure potential. The next steps would involve developing and testing prototypes that address the SCF needs of each farmer group. It is important to consider what is possible with regards to the types of information that these farmers would consider useful. Some aspects such as the exact date of the seasonal onset, the distribution of rainfall events, and the intensity of extreme events are extremely difficult to represent with any

degree of skill or accuracy. Improving the skill of SCFs in Southern Africa would assist in increasing trust, but skill is highly dependent on the geographical location and the identification of appropriate and strong forecasting signals. Other aspects such as different language versions pose their own challenges with the translation of highly specific scientific terms but are arguably easier to implement. Given the high rate of technology adoption (especially mobile phones) in the commercial farming communities, access to SCFs for this group would be straightforward through a mobile phone application or web-based platform. There are considerable challenges around accessibility for smallholder farmers, especially in the more remote areas of the Eastern Cape which face the dual challenge of low smartphone ownership coupled with poor network coverage. Clearly, alternative methods of disseminating seasonal forecasting information to these farmers through some intermediary person or organisation would be preferred.

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