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# Understanding the local implications of climate change: Unpacking the experiences of smallholder farmers in Thulamela Municipality, Vhembe District, Limpopo Province, South Africa

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## Abstract

Climate change is experienced locally. However, climate change impact assessments are often done at the international, regional and national levels. Local level impacts are less prolific. When international, regional and national level predictions are applied to the local level, they are out of context. Therefore, it is important to understand the local impact of climate change to enhance formulation of suitable adaptation strategies. This study aimed to understand the local impacts of climate change on smallholder farmers in Thulamela Municipality, Vhembe District, Limpopo Province, South Africa. The actual experiences of smallholder farmers were unpacked. Face-to-face interviews with farmers in the region were conducted to solicit data on the climatic changes experienced, the impacts on crop and livestock production and social wellbeing. Data on the intensity of the impacts was also solicited. Results show that the experienced climatic changes emanated from temperature changes and shifts in rainfall patterns. The impacts on crop and livestock production as well as social wellbeing are all negative. Farmers indicated that the impacts were mostly average to high. It is concluded that smallholder farmers are aware that climate change impacts are negatively affecting their livelihoods. Investments towards building the capacity of smallholder farmers are pertinent.

## 1. Introduction

### 1.1 Background

Climate change is a major challenge affecting the social, economic and environmental aspects of all people. Globally, it is causing severe tribulations [1], due to persistent climate change related hazards such as droughts and floods. There is increasing global concern about climate change impacts on climate-dependent livelihoods particularly rain-fed agriculture [2]. This concern is emphasized on a global scale with the introduction of the Sustainable Development

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Goals (SDGs) of 2015 by the United Nations (UN). Specifically, SDG 13 was formulated to combat climate change impacts while building resilience and improving adaptive capacity of communities to respond to the changes as stated in the Sustainable Development Goals Report of 2023.

Regionally, Africa is one of the most affected due to persistent poverty, complex socio-economic challenges and high dependency on climate-sensitive livelihoods. Africa is one of the most vulnerable continents despite contributing less than 5% of the global emissions [3]. Sub-Saharan Africa (SSA) is not spared either. Mixed crop-livestock farming systems in the region experience severe climate changes that compromise food and feed production [4]. South Africa located in SSA is impacted by frequent heat waves, droughts, and floods [5]. Heat waves that last for more than six days are common in the northern parts of Limpopo Province [6] where Thulamela Municipality, Vhembe District is located. Frequent droughts are also common in South Africa with severe consequences in rural provinces such as the Eastern Cape [7, 8], Free State [9], KwaZulu Natal [10] and Limpopo [11, 12]. Excessive rainfall resulting in floods have been recently experienced in KwaZulu Natal with severe psychopathological consequences [13].

These climatic extremes are also a major development challenge for groups that depend on agriculture [14] such as smallholder farmers because it is a climate-sensitive livelihood. Smallholder farmers in developing countries like South Africa are largely not responsible for the climate change crisis. More than 75% of the Greenhouse Gas (GHG) emissions come from the burning of fossil fuels such coal, oil and gas in developed countries like Russia, United States of America and China. Although South Africa emits the highest levels of GHG emissions in the region from the burning of coal to meet the country's electricity supply needs [15], the smallholder farmers are among the groups that contribute the least to the climate change crisis, just like elsewhere in the world. However, their livelihoods are increasingly jeopardized by its effects [16].

## 1.2 Background of South Africa's smallholder farming sector

The term smallholder farmer is widely used by researchers in existing literature and there are various schools of thought in defining the term. Several expressions are also used to refer to smallholder farmers and these include small-scale, family farmers, emerging farmers and subsistence farmers, among others [17]. Hence, there is neither a single nor an agreed definition. There is a tendency of defining smallholder farmers using the size of land owned. However, this was discredited based on the argument that a high value production system can produce high returns even on a small piece of land [18]. As such, earlier work on "Supporting smallholder farmers into the commercial sector" [19], focused on distinguishing smallholder farmers from commercial farmers. This work developed a typology of smallholder farmers in South Africa. Four distinct classes were formulated. These are subsistence oriented, market oriented in loose value chains where farmers sell in local markets [20], market oriented in tight value chains where farmers undergo complex value chains involving multiple groups [20] and small-scale capitalists. These were distinguished in terms of the objective of production (e.g. household consumption, cash income or profit), proportion of marketed output (e.g. none/insignificant, 50% or higher, 100%), source of labour (e.g. family or hired), level of mechanization (e.g. low, medium or high), capital intensity (e.g. low, medium or high), and access to finance (no access, low, medium or high access), among other characteristics.

Upon this background, the South African Department of Agriculture, Forestry and Fisheries (DAFF) defined smallholder farmers as farmers who produce both for household consumption and for sale to earn income while working towards expanding operations to become

commercial farmers [21]. The narrative shows that smallholder farmers are diverse [22] and this diversity makes it difficult to put together a single definition. As such [22] recommended that a typology of smallholder farmers should be best developed based on their diverse and/ or local needs that suit their livelihoods.

## 1.3 Study context

The various views shared by researchers and organizations in defining smallholder farmers are highly appreciated. However, they do not incorporate smallholder farmers' status in terms of climate change impacts, the focus of this research. South Africa is susceptible to climate change and is considered warm with unequal distribution of rainfall and frequent extreme events such as droughts and floods [23]. Smallholder farmers are vulnerable to these climatic changes because they are marginally located in rural areas and mostly depend on rain-fed agriculture [23, 24]. It has also been observed that variable rainfall and prolonged heat waves affect the sustainability of smallholder mixed-farming systems in South Africa [25]. This intensifies the vulnerability of smallholder farmers.

These views establish an important characteristic of South African smallholder farmers' vulnerability status in terms of climate change. This study borrowed some ideas shared by other researchers to define smallholder farmers for the purpose of the research and infuses the climate change vulnerability dimension. In this research, smallholder farmers refer to subsistence and market-oriented farmers in lose value chains, who produce for household consumption and sell surplus for additional income, uses family and occasionally hired labour, use low levels of mechanization, with low capital investments, have little or no access to finance and are marginally located while highly vulnerable to climate change. It is important to understand the local impact of climate change on smallholder farmers as it enhances the identification of adaptation strategies suitable for suppressing the negative impact of climate change [26]. However, the overall impact of climate change on agricultural production in SSA remains uncertain [27]. Continuous evaluations that aim to understand the local implications of climate change on smallholder farmers are crucial to enhance locally informed policy decisions for effective adaptation planning.

## 1.4 The gaps in research

Several studies seeking to understand the impact of climate change on smallholder farmers exist. However, most are modeling studies that make projections of climate change impacts for future scenarios. For example, [28] modeled the impact of climate change on smallholder farmers in SSA under six climate scenarios for maize, millet and sorghum. Results indicate diminishing food availability and increasing climate related stress on smallholder farmers with time. Similarly, [29] modeled the impact of climate change on intensified sustainable cropping systems for maize in selected SSA countries using 25 maize models. Results show that maize that is intensively managed with nitrogen fertilizers will be more sensitive to climate change in the long run. The importance of such modeling studies cannot be undermined as they present a platform for developing relevant policy interventions based on the simulations. However, modeling studies are mere simulations for the future. They do not show what is happening on the ground. The main challenge is that simulations may represent something else different to what will happen. Also evident in these studies is that they mainly focus on climate change impact on plant growth and crop yield leaving out other important dimensions such as the impact on social wellbeing that is important for smallholder farmers.

Another challenge is that the bulk of the modeling studies are done at the international, regional and national levels. Local level impacts are often eliminated and scaling down to local

level is difficult. Consequently, when results are applied at local level, they are usually out of context. Past research shows that there remains some uncertainty about the local implications of climate change due to limited spatial resolution of global climate models [30]. Natural disasters are a local phenomenon as climatic changes vary per location [31]. The Intergovernmental Panel on Climate Change (IPCC) posited that climate change impact assessments that lack consideration of the local impact reduces the effectiveness of adaptation and sometimes result in maladaptation [32]. All these issues are compounded by the prohibitive nature of understanding long-term observational data, especially in regions with poor monitoring records [33].

This study was designed to address this gap by introducing the locality dimension while investigating the actual experiences of smallholder farmers so that results can be "aggregated out" to the country, regional and international levels (bottom-up approach). The term "local implications of climate change" is used to refer to the experienced impacts of climate change as reported by smallholder farmers. Therefore, the study's aim was to understand the local impacts of climate change by unpacking the experiences of smallholder farmers in Thulamela Municipality located in Vhembe District, Limpopo Province of South Africa. Three important questions underpinned the study. These questions are: a) What climate changes did smallholder farmers experience? b) What were the impacts of the experienced climatic changes on (i) crop production, (ii) livestock production and (iii) social well-being? c) How do farmers rate the impact of climate change on (i) crop production, (ii) livestock production and (iii) social well-being? It is hoped that the answers to these questions would bring adaptation solutions tailored to the local conditions and or needs of the farmers in Thulamela.

## 2. Materials and methods

### 2.1 Study area and rationale for selection

This study was conducted in seven villages in Thulamela Municipality, Vhembe District, Limpopo Province, South Africa. These are Tshiombo, Maraxwe, Murara, Mbilwi, Thsivhulani, Dzingahe and Mianzwi. Fig 1 shows the location of the villages in Thulamela Municipality. Thulamela Municipality is mostly rural with high levels of poverty [34]. Subsistence farming plays a vital role in food supply to local households. The municipality has the most agricultural households as compared to the other three municipalities in the district [35].

It is generally hot with long-term average temperatures of 34˚C, characterized by decreases in summer rainfall and increased occurrence of extreme weather events such as floods and droughts [36]). Thulamela Municipality has high environmental, economic and physical vulnerability indices [37].

Vhembe District Municipality (VDM) where Thulamela is located is at high risk of climate change impacts and it has been acknowledged that climate change poses a threat to the environment, the residents and future development [38]. The Council for Scientific and Industrial Research (CSIR) conducted a vulnerability assessment and projected that the district will experience highly increasing temperatures, increasing rainfall variability and increasing storms and flooding events for the 2021–2050 period [39]. According to the Local Government Climate Change Support Program, Limpopo Province in which Vhembe District is located, is the "breadbasket" and "agricultural engine" of South Africa contributing about 60% of the agricultural produce from the commercial agriculture sector and houses a large rural population dependent on subsistence agriculture. The province receives rainfall mostly in summer with the northern region in which Vhembe District is situated experiencing hot and humid summers. Such a setting subject to climatic changes and weather extremes, with high numbers of

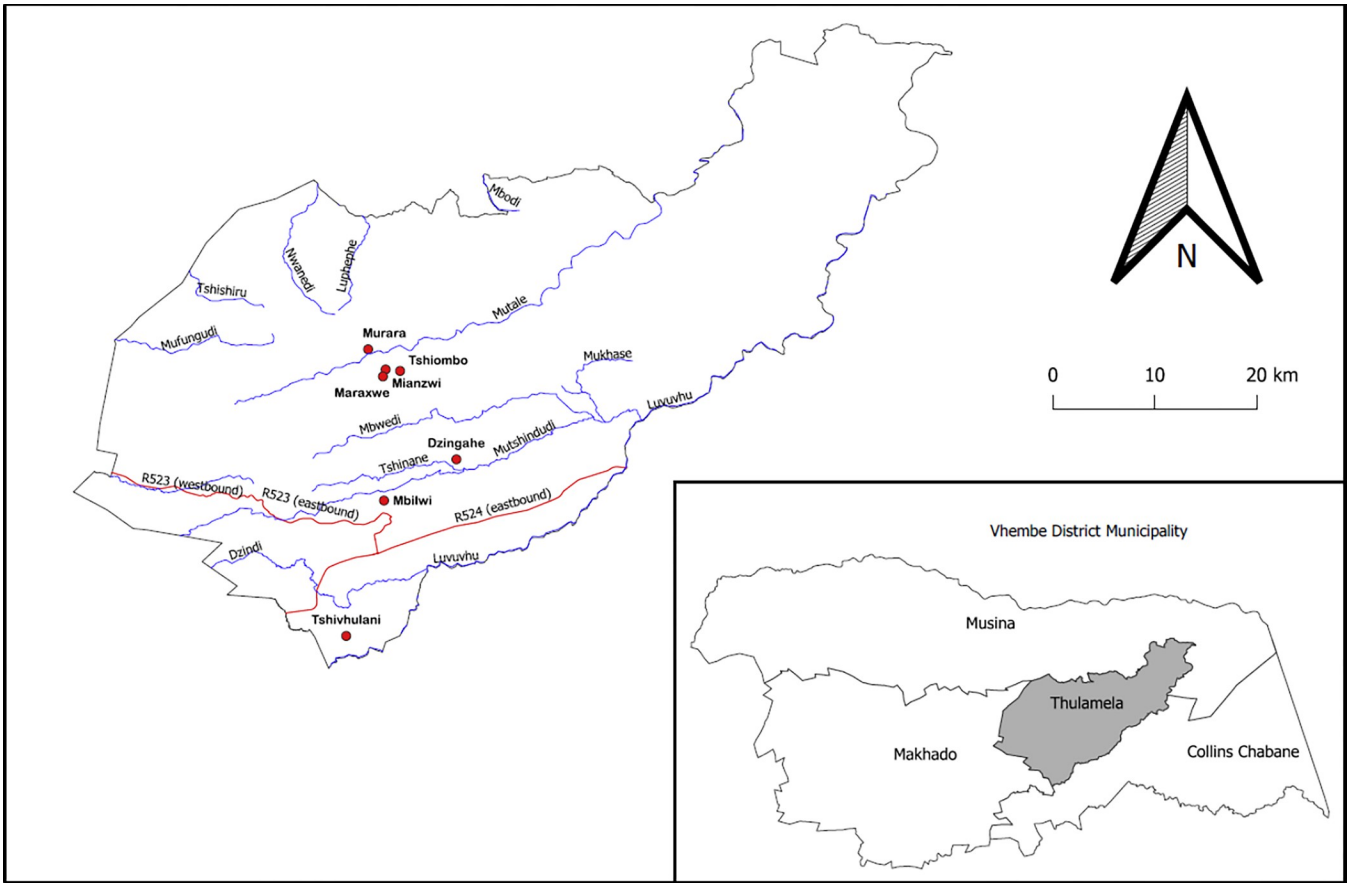


**Fig 1. Location map of the villages in which the study was conducted.**

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rural populations dependent on agriculture that is sensitive to changes in weather conditions presented candidates suitable for the study.

## 2.2 Research design

A quantitative cross-sectional household survey [40] was adopted. The study investigated a social phenomenon, the climate change impact experiences of smallholder farmers. Elements of the quantitative and cross-sectional survey designs were combined to capture the experiences. The quantitative research design allowed the collection and analysis of numerical data [40] on climate change impacts experienced by smallholder farmers. The design enabled the researcher to use a systematic and structured approach to collect data, analyze it and visualize patterns and relationships [41] of the climate change impacts experienced. The cross-sectional design allowed data collection at a single point in time [42]. Data was collected from a sample of the population and the findings were generalized to the entire population. Hence, it is described as a snapshot [43] of the climate change impact experiences of smallholder farmers in Thulamela.

## 2.3 Population and sampling

The population of the study was all smallholder farmers in Thulamela. This comprised of 71 812 households according to the Community Survey of 2016. To come up with a manageable sample, the villages in which the study was to be conducted were selected first. This was done

with the assistance of extension officers from Thulamela Municipality who work directly with the farmers. The extension officers provided insights into the villages that were suitable. It was agreed that the villages should represent the distinct types of smallholder farmers in Thulamela. It was found that there were three types of farmers using three different modes of production. Farmers practice either cropping or livestock farming or mixed farming. Farmers either use irrigation or practice wetland farming or rain-fed farming. Therefore, heterogeneous or maximum variation purposive sampling technique [44] was used to ensure that the sample represented all types of farmers under different modes of production. This led to the selection of seven representative villages. Dzingahe and Murara represented crop farming, Maraxwe represented livestock farming and Mbilwi represented mixed farming. The different modes of production were represented by Tshiombo, Mianzwi and Tshivhulani representing irrigation, rain-fed farming, and wetland farming, respectively.

Selection of farmers to participate in the study followed. Sample size was determined using the Slovin's formula,

$$\mathrm{n} = \frac{N}{(1 + Ne^2)}$$

Where n = sample size,

N = Population size and

e = acceptable margin of error.

As stated, population size is 71 812. The margin of error is usually between 4 and 8%. The study used 7.5%. Hence, the appropriate sample size was 177.

A decision was made to select farmers who experienced climate change impacts, were still producing enough to cater for subsistence needs during the time of the study and always have extra to sell. This was informed by the need to establish evidence from "information rich" participants to tap into their experiences and develop tangible evidence that would better inform other farmers in similar situations. Simple random sampling technique was used to select the farmers to participate in the study.

Although the appropriate sample size was 177, a total of 181 smallholder farmers were interviewed. The extra four farmers from Tshiombo where interviews were conducted at the fields were included because they insisted on participating. Therefore, a decision was made to include them as they met the selection criteria. The number of farmers to participate in the interviews from each village was determined proportionally. A relatively larger number of farmers were selected from Tshiombo since it has the highest number of farmers among all the other villages while the least number of farmers were selected from Maraxwe, which had the least number of farmers. Fig 2 summarizes the sampling procedure.

## 2.4 Data collection and analysis

The main data collection tool was a structured questionnaire. The questionnaire was developed following steps outlined by [45]. A literature review was conducted on climate change impacts among smallholder farmers at the global, regional and national levels which helped in developing a conceptual basis of the questionnaire. Effort was put into developing clearly worded and well-formulated close-ended questions. Attention was given to the order of the questions to ensure an easy flow from one question to the next. A feasibility assessment of the questionnaire was conducted to test its ability to solicit the required data. The questionnaire was externally tested [45] by the extension officers and pre-tested [46] on five farmers to ensure that the content was well understood by the farmers. Face-to-face interviews were conducted between 1 and 30 September 2023 by trained research assistants who administered the

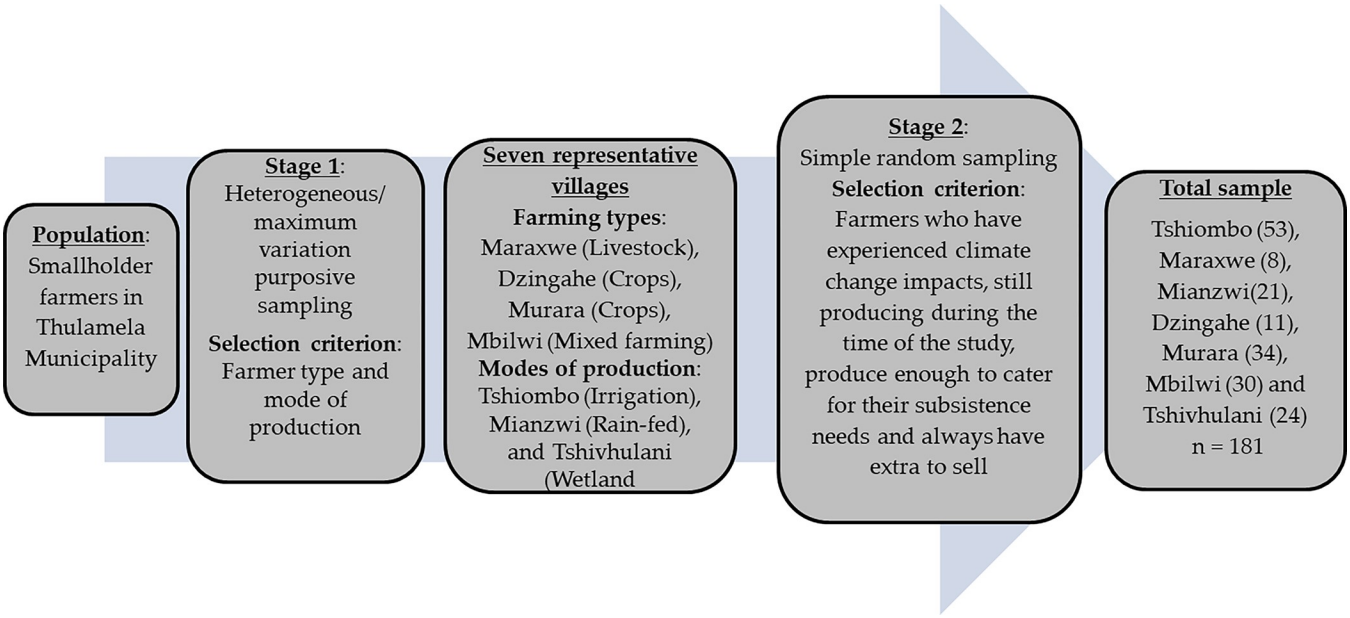


**Fig 2. Sampling procedure.**

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questionnaire in Tshivenda, the local vernacular language, so that farmers could understand better.

The collected data went through a data cleaning process to ensure accuracy and consistency with the research objectives. The identified structural errors were fixed to ensure the data made sense and it was decided that missing data was to be treated as 000 during data capturing. Data was then captured into the Statistical Package for Social Sciences (SPSS) Version 25. A data template was created which captured all the questions on the structured questionnaire. For each question, a variable was formulated with its corresponding value labels. Each row captured information for a specific smallholder farmer who participated while each column represented a specific variable. Data was analyzed using descriptive statistics. Measures of central tendency such as frequencies and measures of central tendency were used to summarize and describe the data.

### 2.5 Ethical considerations

Approval to conduct the study was sought from the University's Ethics Committee. An Ethical Clearance Certificate was issued. Permission to conduct the study in Thulamela was sought from and granted by the Department of Agriculture and Rural Development. A clear and concise explanation of the purpose of the research, what the interviews will involve and how the information was going to be used and stored was given to the respondents before commencement of the interviews. Respondents were required to sign a consent form to show their willingness to participate.

## 3. Results and discussion

This section presents and discusses results of the study. Characteristics of smallholder farmers experiencing climate change impacts in Thulamela are presented first followed by the type of agriculture-based activities practiced. The presentation and discussion turn to the nature of the climatic changes and the associated impacts that farmers are experiencing. Finally, the ratings of the extremity of these changes according to the farmers are outlined.

### 3.1 Characteristics of smallholder farmers in Thulamela

Only 63 women out of 181 farmers participated. This illustrates the pre-existing structural inequalities in land ownership between men and women in South Africa like in other developing countries. Access to land in rural South Africa remains elusive for most women [47]. This is due to the negative effect of customary law [48]. However, with the increasing climate change impacts in South Africa, it is vital that these structural inequalities are rectified because women have a significant role in building resilience to climate change. Women have the skills, knowledge and traditional experience ranging from food handling, preparation and preservation as well as knowledge of traditional medicinal plants that is valuable during extreme weather conditions like cyclones and floods, when food markets and hospitals are inaccessible [49].

Farmers' age shows a skewed outcome with a larger proportion of farmers (71%) in the older age groups above 41 years. The results highlight findings from past research that found a significant relationship between farmers' age and climate change awareness. Age is highly co-related with knowledge and experience in most analyses. In the context of climate change impacts, as farmers get older, they acquire more knowledge and experience. This raises their awareness of climate change impacts from lessons learnt from the past and enables them to react accordingly [50, 51].

Seventy two percent of farmers attained secondary education and only eight percent did not have formal education. Education is desirable in enhancing future adaptive capacities. It is hypothesized and confirmed that investing in primary and secondary education is the most effective strategy for enhancing coping mechanisms against climate change risk around the world [52]. This is because education creates opportunities for livelihood diversity which enhances resilience. It was highlighted that some form of education enhances access to relevant information such as early warnings for extreme weather conditions, enhances cognitive skills and willingness to change risky behavior that may be maladaptive. Although education may be a vital tool to promote environmental action, [53] posited that nurturing climate change knowledge can be difficult for minority groups such as women with low self-perceived knowledge of climate change literacy. The same authors recommended that such minority groups need interventions that can improve their climate change intelligence perception.

Marital status influences the level of vulnerability to climate change impacts among different farmers. Results show that a large proportion of farmers (67%) are married followed by widows, the divorced then the single. The results illustrate that climate change affects all individuals regardless of their marital status. However, another study has revealed that the widows and the divorced are highly vulnerable to climate change impacts compared to the married [54]. The study posited that this could be because they are culturally disadvantaged and, in most cases, they are the sole bread winners whose responsibility is to provide for large families.

The sources of income are varied and 85% of the farmers in Thulamela have more than one source that are non/off-farm. Non/off-farm income sources include remittances, social grant wages and salaries and. Remittances are money sent to the farmers by relatives and many households rely heavily on it as a source of income. Some farmers in Thulamela receive financial support from the government in the form of social grants. Some farmers indicated that they were working elsewhere where they are paid in the form of wages and salaries. Results concur with [55] who measured vulnerability of smallholder farmers to climate change at household level in Ethiopia. Households with non-farm income sources had a lower probability of vulnerability. Diversifying income sources widens the safety net for smallholder farmers and helps them to recover quickly from climate change impacts. Table 1 summarizes the characteristics of smallholder farmers experiencing climate change impacts in Thulamela.

**Table 1. Characteristics of smallholder farmers in Thulamela.**

| Characteristic | Attribute | Overall sample (n = 181) | | Village | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Tshiombo (n = 53) | | Mianzwi (n = 21) | | Murara (n = 34) | | Mbilwi (n = 30) | | Tshivhulani (n = 24) | | Maraxwe (n = 8) | | Dzingahe (n = 11) | |
| | | Actual | % | Actual | % | Actual | % | Actual | % | Actual | % | Actual | % | Actual | % | Actual | % |
| Gender | Male | 118 | 65 | 24 | 45 | 12 | 57 | 32 | 94 | 19 | 63 | 18 | 75 | 6 | 75 | 7 | 64 |
| | Female | 63 | 35 | 29 | 55 | 9 | 43 | 2 | 6 | 11 | 37 | 6 | 25 | 2 | 25 | 4 | 36 |
| Age | 21–30 | 6 | 3 | 3 | 6 | 0 | 0 | 2 | 6 | 1 | 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 31–40 | 46 | 25 | 3 | 6 | 7 | 33 | 13 | 38 | 9 | 30 | 7 | 29 | 3 | 38 | 4 | 36 |
| | 41–50 | 42 | 23 | 13 | 25 | 3 | 14 | 8 | 24 | 7 | 23 | 7 | 29 | 3 | 38 | 1 | 9 |
| | 51–60 | 43 | 24 | 18 | 34 | 6 | 29 | 8 | 24 | 3 | 10 | 5 | 21 | 2 | 25 | 1 | 9 |
| | 61+ | 44 | 24 | 16 | 30 | 5 | 24 | 3 | 9 | 10 | 33 | 5 | 21 | 0 | 0 | 5 | 45 |
| Marital status | Single | 10 | 6 | 4 | 8 | 0 | 0 | 5 | 15 | 1 | 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Married | 121 | 67 | 34 | 64 | 17 | 81 | 25 | 74 | 19 | 63 | 15 | 63 | 6 | 75 | 5 | 45 |
| | Widowed | 33 | 18 | 13 | 25 | 2 | 10 | 3 | 9 | 7 | 23 | 3 | 13 | 1 | 13 | 4 | 36 |
| | Divorced | 17 | 9 | 2 | 4 | 2 | 10 | 1 | 3 | 3 | 10 | 6 | 25 | 1 | 13 | 2 | 18 |
| Educational level | No formal education | 14 | 8 | 5 | 9 | 3 | 14 | 1 | 3 | 3 | 10 | 1 | 4 | 0 | 0 | 1 | 9 |
| | Primary | 36 | 20 | 13 | 25 | 6 | 29 | 2 | 6 | 6 | 20 | 4 | 17 | 2 | 25 | 3 | 27 |
| | Secondary | 80 | 44 | 28 | 53 | 9 | 43 | 17 | 50 | 10 | 33 | 11 | 46 | 2 | 25 | 3 | 27 |
| | Tertiary | 51 | 28 | 7 | 13 | 3 | 14 | 14 | 41 | 11 | 37 | 8 | 33 | 4 | 50 | 4 | 36 |
| Source of income | Farming only | 27 | 15 | 4 | 8 | 2 | 10 | 4 | 12 | 5 | 17 | 8 | 33 | 3 | 38 | 1 | 9 |
| | Farming and remittances | 4 | 2 | 1 | 2 | 1 | 5 | 1 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 9 |
| | Farming and social grant | 53 | 29 | 26 | 49 | 5 | 24 | 3 | 9 | 10 | 33 | 4 | 17 | 1 | 13 | 4 | 36 |
| | Farming and salary | 88 | 49 | 16 | | 12 | 57 | 26 | 76 | 14 | 47 | 12 | 50 | 4 | 50 | 4 | 36 |
| | Farming, remittance, social grant | 9 | 5 | 6 | | 1 | 5 | 0 | 0 | 1 | 3 | 0 | 0 | 0 | 0 | 1 | 9 |

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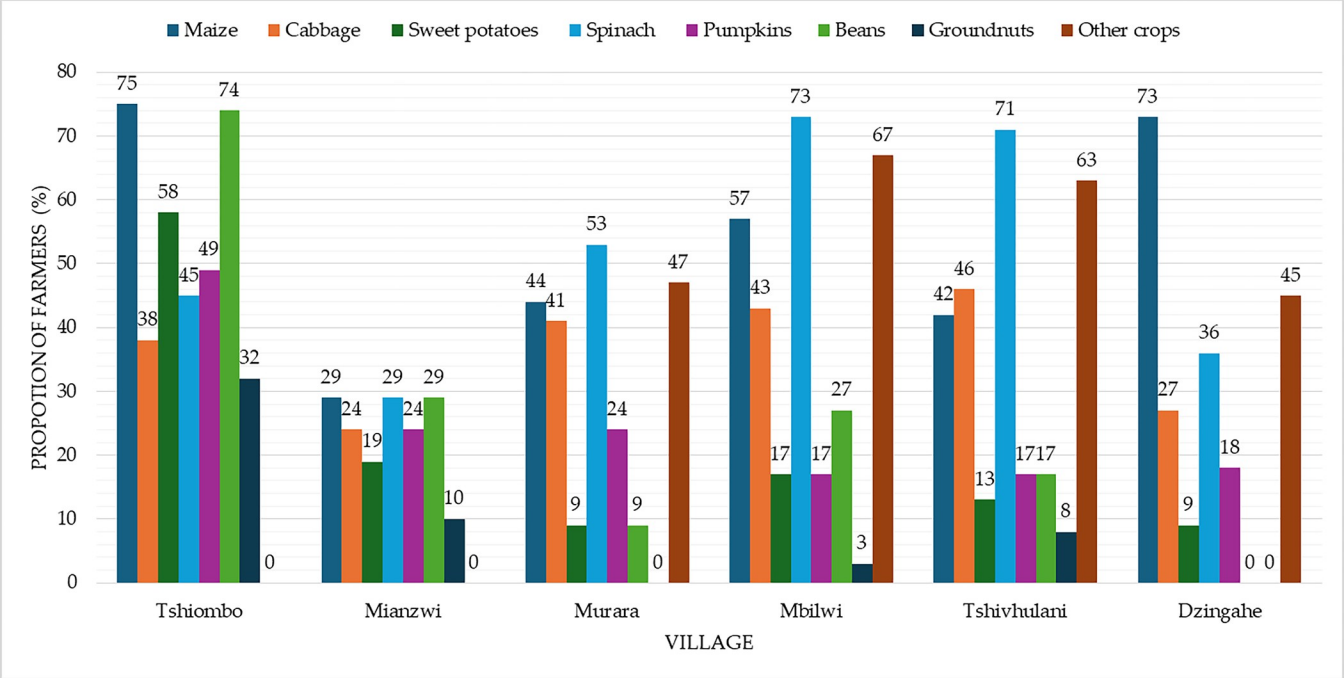


**Fig 3. Crop-based activities practiced in Thulamela.**

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## 3.2 Agriculture-based activities practiced in Thulamela

Farmers in Thulamela practice both crop- and livestock-based agricultural activities. Fig 3 illustrates the specific crop-based activities and these include maize, cabbage, sweet potatoes, spinach, pumpkins, beans and groundnuts. Other crops included tomatoes, peppers, chilies, onions, carrots, watermelons and beetroot. Maize farming, although highly susceptible to climate extremes like drought [56], is most practiced. Spinach is the second most popular while groundnuts production is the least practiced. Maize is widely produced because it is the main crop in the South African food system and plays a significant role in the diet of the people in the country [57]. It is the staple food in South Africa like in other parts of SSA [58], where it is ground into mealie meal and served as the main starch in most meals. The Agricultural Research Council (ARC) of South Africa noted that the cereal plays an important role in food and nutrition security in the country (ARC 2013). Furthermore, maize is relatively easy to produce compared to other cereals like millet and sorghum [59]. Maize is considered a "flex crop" because of its "multiple-ness and flexible-ness" since it has several uses and can be easily used in place of other ingredients [60]. As a major field crop in Limpopo, maize is easily rotated with other vegeS1s such as spinach, cabbage and beans to maximize food availability in the households [61, 62].

Livestock-based activities practiced in Thulamela include both large and small stock as shown in Fig 4. Common livestock kept are cattle, goats, sheep, pigs, chickens and rabbits. Poultry is the most common followed by cattle and sheep is the least. Poultry farmers keep various breeds. Most of the farmers keep village chickens and a few rear broilers and layers. Village chickens also referred to as indigenous, local, scavenging, backyard, family or traditional chickens [63], are highly adaptable to harsh environments [64] and can withstand climatic changes compared to exotic breeds. The naked neck breed is one of the common breeds kept which is kept for its resistance to heat stress. Village chickens are economically, socially and

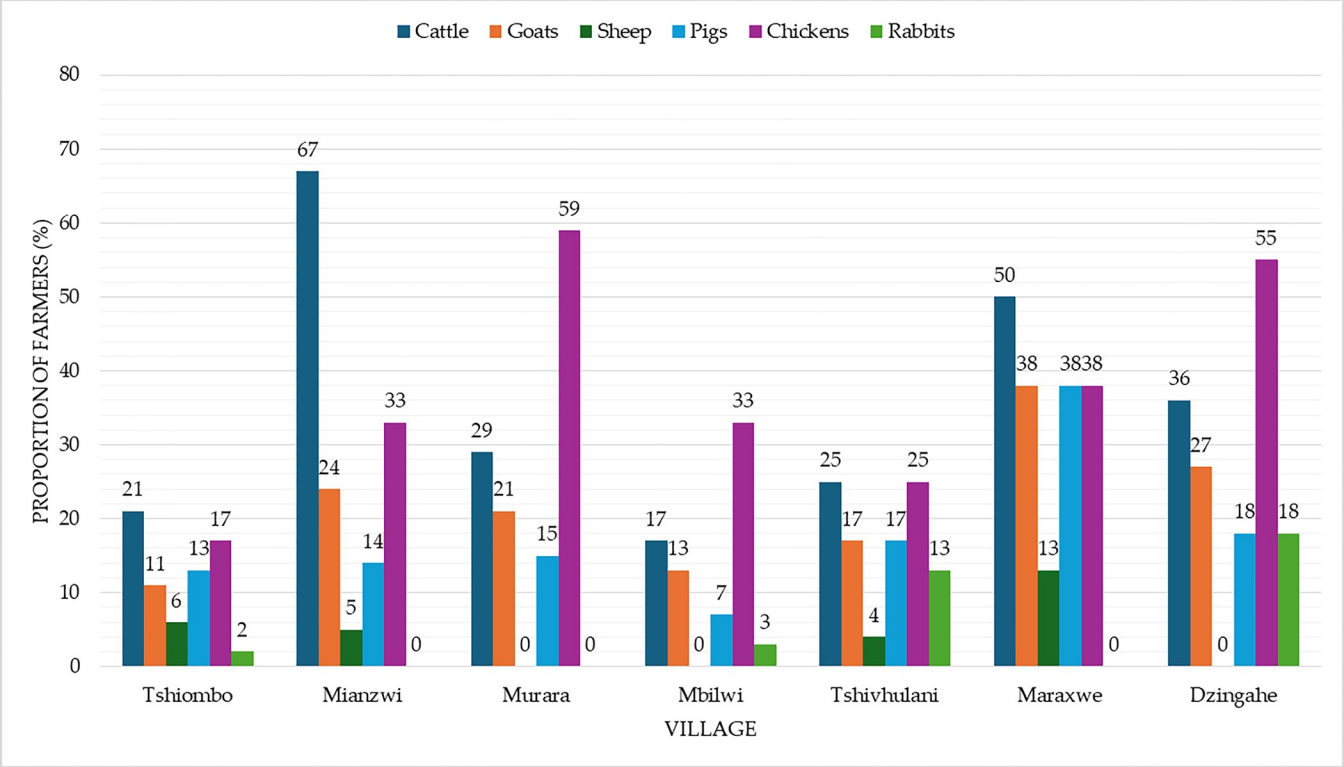


**Fig 4. Livestock-based activities practiced in Thulamela.**

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culturally important to Africans [65]. They provide a cheap source of protein, generate income as farmers sell meat and eggs and are important for traditional purposes. Despite the importance of village chickens and ability to withstand various climatic changes, scientific research is limited and has received little attention in terms of improving production [65].

Cattle are essential in smallholder farming systems used for meat and milk production, as a source of income, draft power, used to settle bride price, provide manure for vegetable gardens and play a significant role in food and nutrition security [66].

However, they are less tolerant to climatic extremes such as high temperatures [67] compared to small stock such as sheep and goats. Sheep and goats were ranked by farmers in Limpopo and Mpumalanga as very important [68] and farmers were willing to invest in adaptation and mitigation strategies for these livestock types. Sheep and goat rearing is increasing in rural Limpopo because of their ability to withstand the frequent droughts [69].

## 3.3 Experienced climatic changes and associated impacts in Thulamela

Several climatic changes were experienced as shown in Table 2. The climatic changes emanated from changes in temperatures and shifts in rainfall patterns. Changes in temperature were experienced in the form of high temperatures, heat waves and droughts, while shifts in rainfall patterns were experienced as reduced amount of total rainfall, precipitation variation which manifested as little rains or medium rains or excessive and persistent rains, floods, and late onset of rains. Results correspond to other scientific studies conducted in Thulamela Municipality, Vhembe District and other districts in the province. For example, [70] observed increased frequency in drought, change in frequency and distribution of rainfall and increased temperatures in Maheni community also situated in Thulamela. Findings of the study also

**Table 2. Experienced climatic changes in Thulamela.**

| Climatic changes | Total sample (181) | | Tshiombo (53) | | Mianzwi (21) | | Murara (34) | | Mbilwi (30) | | Tshivhulani (24) | | Maraxwe (8) | | Dzingahe (11) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Actual | % | Actual | % | Actual | % | Actual | % | Actual | % | Actual | % | Actual | % | Actual | % |
| High temperatures | 181 | 100 | 53 | 100 | 21 | 100 | 34 | 100 | 30 | 100 | 24 | 100 | 8 | 100 | 11 | 100 |
| Heat waves | 180 | 99 | 53 | 100 | 21 | 100 | 34 | 100 | 30 | 100 | 24 | 100 | 8 | 100 | 11 | 100 |
| Drought | 158 | 87 | 41 | 77 | 20 | 95 | 34 | 100 | 27 | 90 | 20 | 83 | 6 | 75 | 10 | 91 |
| Mid-season dry spells | 140 | 77 | 41 | 77 | 19 | 90 | 27 | 79 | 27 | 90 | 18 | 75 | 0 | 0 | 8 | 73 |
| Precipitation variation | 140 | 77 | 37 | 70 | 20 | 95 | 28 | 82 | 28 | 93 | 19 | 79 | 0 | 0 | 8 | 73 |
| Extended winters | 130 | 72 | 31 | 58 | 9 | 43 | 29 | 85 | 27 | 90 | 20 | 83 | 3 | 38 | 11 | 100 |
| Reduced rainfall totals | 122 | 67 | 46 | 87 | 18 | 86 | 19 | 56 | 19 | 63 | 10 | 42 | 1 | 13 | 9 | 82 |
| Flood | 120 | 66 | 3 | 6 | 20 | 95 | 34 | 100 | 30 | 100 | 21 | 88 | 4 | 50 | 8 | 73 |
| Late onset of rains | 108 | 60 | 38 | 72 | 6 | 29 | 16 | 47 | 23 | 77 | 17 | 71 | 0 | 0 | 8 | 73 |
| Reduced season length | 57 | 31 | 22 | 42 | 5 | 24 | 9 | 26 | 7 | 23 | 6 | 25 | 0 | 0 | 8 | 73 |

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correspond to a scientific study conducted in Vhembe and Mopani Districts [71]. The study assessed rainfall and temperature trends from 1960 to 2018 and how it affected crop production. A significant decline in total annual rainfall and an increase in annual minimum and maximum temperatures were observed. The two districts recorded an aridity index of -0.70 categorized as dry and water scarce. These climatic changes create a hostile environment for agricultural activities resulting in significant negative impacts.

Several impacts were experienced by smallholder farmers as shown in Table 3. For crop-based activities, climate changes mainly affected the development and growth of crops resulting in considerable yield losses. Reduced rainfall patterns, precipitation variations and high

**Table 3. Associated impacts of the experienced climatic changes in Thulamela.**

| Impact | Total sample (181) | | Tshiombo (53) | | Mianzwi (21) | | Murara (34) | | Mbilwi (30) | | Tshivhulani (24) | | Maraxwe (8) | | Dzingahe (11) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Impact on crops | | | | | | | | | | | | | | | |
| | Actual | % | Actual | % | Actual | % | Actual | % | Actual | % | Actual | % | Actual | % | Actual | % |
| Reduced plant growth | 114 | 63 | 40 | 75 | 6 | 29 | 19 | 56 | 22 | 73 | 18 | 75 | - | - | 9 | 82 |
| Moisture stress, wilting | 116 | 64 | 40 | 75 | 6 | 29 | 19 | 56 | 24 | 80 | 18 | 75 | - | - | 9 | 82 |
| Pre-mature death of crops | 96 | 53 | 36 | 68 | 4 | 19 | 13 | 38 | 17 | 57 | 17 | 71 | - | - | 9 | 82 |
| Poor germination | 102 | 56 | 34 | 64 | 6 | 29 | 14 | 41 | 21 | 70 | 18 | 75 | - | - | 9 | 82 |
| Increased pests and diseases | 116 | 64 | 40 | 75 | 6 | 29 | 19 | 56 | 24 | 80 | 18 | 75 | - | - | 9 | 82 |
| Yield loss | 116 | 64 | 40 | 75 | 6 | 29 | 19 | 56 | 24 | 80 | 18 | 75 | - | | 9 | 82 |
| **Impact on livestock** | | | | | | | | | | | | | | | | |
| Reduced forage | 65 | 36 | 9 | 17 | 13 | 62 | 11 | 32 | 10 | 33 | 11 | 46 | 6 | 75 | 5 | 45 |
| Reduced feed intake | 6 | 3 | 0 | 0 | 1 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 38 | 2 | 18 |
| Decreased production | 102 | 56 | 16 | 30 | 15 | 71 | 26 | 76 | 12 | 40 | 15 | 63 | 8 | 100 | 10 | 91 |
| Poor health | 101 | 56 | 15 | 28 | 15 | 71 | 26 | 76 | 12 | 40 | 15 | 63 | 8 | 100 | 10 | 91 |
| High mortality rates | 102 | 56 | 16 | 30 | 15 | 71 | 26 | 76 | 12 | 40 | 15 | 63 | 8 | 100 | 10 | 91 |
| Animal heat stress | 70 | 39 | 7 | 13 | 4 | 19 | 21 | 62 | 11 | 37 | 10 | 42 | 8 | 100 | 9 | 82 |
| Increased spread of diseases | 102 | 56 | 16 | 30 | 15 | 71 | 26 | 76 | 12 | 40 | 15 | 63 | 8 | 100 | 10 | 91 |
| **Impact on social wellbeing** | | | | | | | | | | | | | | | | |
| Food shortages | 117 | 65 | 41 | 77 | 18 | 86 | 12 | 35 | 20 | 67 | 14 | 58 | 5 | 63 | 7 | 64 |
| Loss of surplus to sell | 176 | 97 | 51 | 96 | 21 | 100 | 34 | 100 | 29 | 97 | 23 | 96 | 8 | 100 | 10 | 91 |
| Financial constraints | 176 | 97 | 51 | 96 | 21 | 100 | 34 | 100 | 30 | 100 | 24 | 100 | 8 | 100 | 10 | 91 |

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temperatures resulted in poor germination and crop. In a study by [72] it was illustrated that different climatic changes affect the germination stages for maize in Limpopo Province. Dry conditions delay germination by 14 days. Water stress stops expansion of seed growth cells. Germination does not occur under high temperatures above 300C. Prolonged dry spells slow seedling growth. Floods cause waterlogging which slows down seedling growth. These factors also affected germination and crop stand of crop production among smallholder farmers in Thulamela.

The variations in climate also created favorable breeding ground for pests and diseases hence, it was mentioned by the highest number of farmers at the exact matching level with yield loss as the most devastating impacts for crop production. Results correspond to [61] who assessed the factors influencing pest prevalence in Vhembe and found that dry spells and high temperatures were perceived to be the main cause. The same authors listed aphids, fall armyworm, stalk borer among others as the common pests in Thulamela. The devastating effects of pests and diseases on crop production in Thulamela is a cause of concern because the extension officers have been found to have limited knowledge on other pest management strategies such as biological control, cultural methods and integrated pest management [73].

Climatic changes impacted livestock production in different ways. Increased spread and transmission of diseases, poor animal health and reproduction, reduced meat and milk production and high mortality rates were experienced the most. Prevalence of livestock diseases has been a critical challenge in South Africa due to the increasing climatic variations and changes. Past research in Limpopo Province established the prevalence of several livestock diseases such as foot and mouth, tick borne attributed to the changes in climate [74, 75]. The prevalence of diseases, coupled with heat stress, caused by high temperatures in Thulamela resulted in poor reproduction and health of livestock. This led to reduced meat and milk production.

Reduced quantity and quality of feed although mentioned by a relatively a small number of farmers (36%) is a very critical downstream consequence of climatic extremes like drought. Findings tally with Lamega, Komainda [76] who found that the availability of quality feed in the right amounts is the major constraint in livestock production in Limpopo. The same authors found that providing sufficient and quality forage for livestock especially under changing climatic conditions is causing feed deficits and gaps particularly between June and September, the winter months in the region. The findings illustrate that climate change has the potential to affect forage production in Limpopo as such there is an urgent need to map a way forward towards developing appropriate ways to mitigate the impact otherwise, livestock production systems will be compromised and fail to achieve the desired livelihood outcomes. Climate changes also affected other livestock types. Increases in temperature are a cause of concern for poultry farmers in Thulamela especially farmers practicing broiler production. Although referring to indigenous chickens [77], share the same sentiments pointing out that heat stress which is more harmful to broiler chickens affect chicken growth and development and increases mortality rates.

The impacts of climate change on both crop- and livestock-based activities affected the social wellbeing of smallholder farmers in various ways. These impacts are indirect and complex as they affect social dimensions. Most of the smallholder farmers indicated that they experienced loss of surplus to sell and financial constraints. Results also show that food shortages were common with the demand for food exceeding the supply at household level. The amount of food produced by smallholder farmers could not sustain the daily food requirements. These impacts stemmed from the yield losses that were experienced because of the recurring climate changes and associated impacts that have disrupted the food system exacerbating food shortages especially among the vulnerable groups of smallholder farmers.

### 3.4 Intensity of climatic change impact

The study also assessed the intensity of climatic change impact on crop- and livestock-based activities as well as social wellbeing. For each of the impacts, farmers were asked to state whether the intensity was low, average or high at a score of 1, 2 and 3, respectively. Fig 5 shows a stacked bar graph of the intensity of climate change impact on crop production. Moisture stress, wilting and drying out, increased incidences of pests and diseases as well as yield loss were rated average to high. It can be deduced that the intensity of climate change impact on crop production in Thulamela is severe. This is mostly because most of the farmers in Thulamela rely on rain-fed crop production which is highly sensitive to climatic changes. Those under irrigation at Tshiombo face a lot of challenges as the infrastructure is often dilapidated and there are several issues that affect water access [78]. Those under wetland farming lack the suitable technologies and labour to draw water from the ponds to irrigate and may be limited by the conservation and management legislations as well. Findings tally with past research carried out in the region. Reduction in crop yields is the most popular impact perceived by farmers in SSA. For example, an exploration of the level of impact of climate change on crop production in SSA showed that more than 90% of the respondents claimed that it had a serious impact [79]. Similarly, reduced crop yield was ranked first in the top ten impacts of climate change by farmers in Agro-Ecological Zone 2 of Zimbabwe, despite being an intensive farming region [80].

Fig 6 shows how farmers rated the impact of climate changes on livestock production. Reduced forage, increased incidences of diseases, poor reproduction and high mortality rates were rated average to high impact. The reduction in grazing pastures and forage is closely related to reduction in crop yields as climate change affects the vegetative growth of pastures. Reduced forage due to climate changes is one of the significant impacts of climate change in the region. Findings of this study are in line with discoveries made by [81] who observed a reduction in number of animals owned per farmer from 37 to 21 was observed in Greater Letaba during the 2014–2016 drought seasons. About 32% of the participants had to walk long

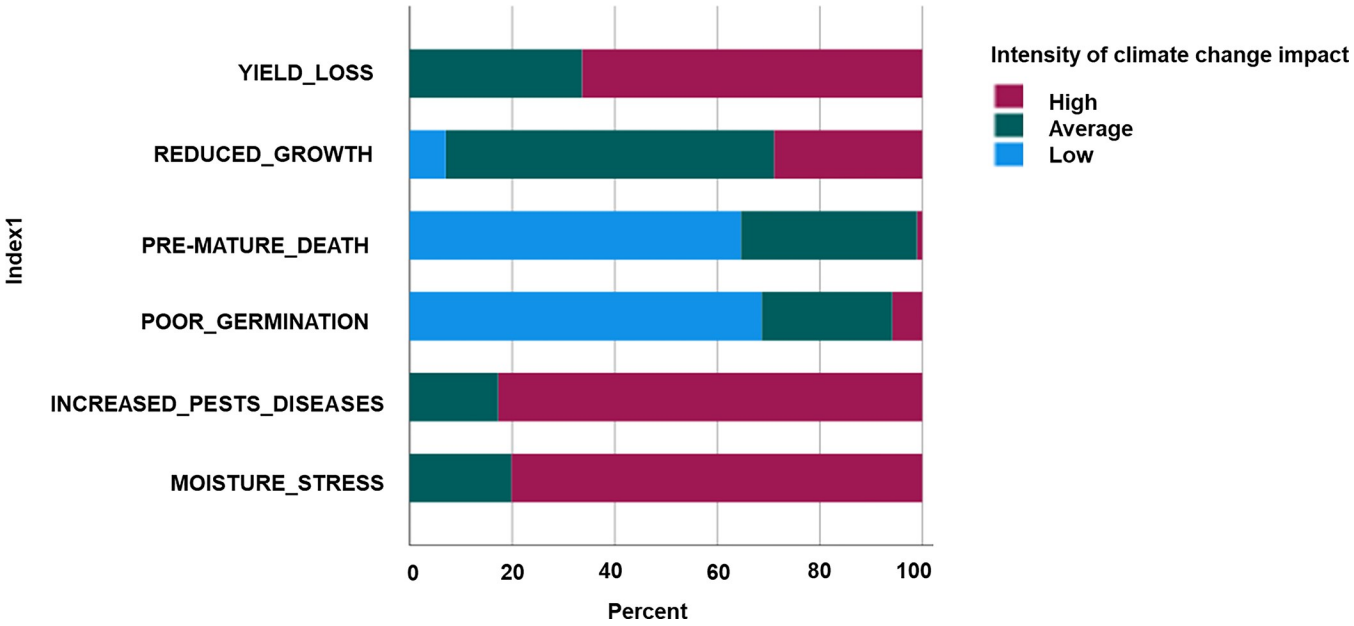


**Fig 5. Livestock-based activities practiced in Thulamela.**

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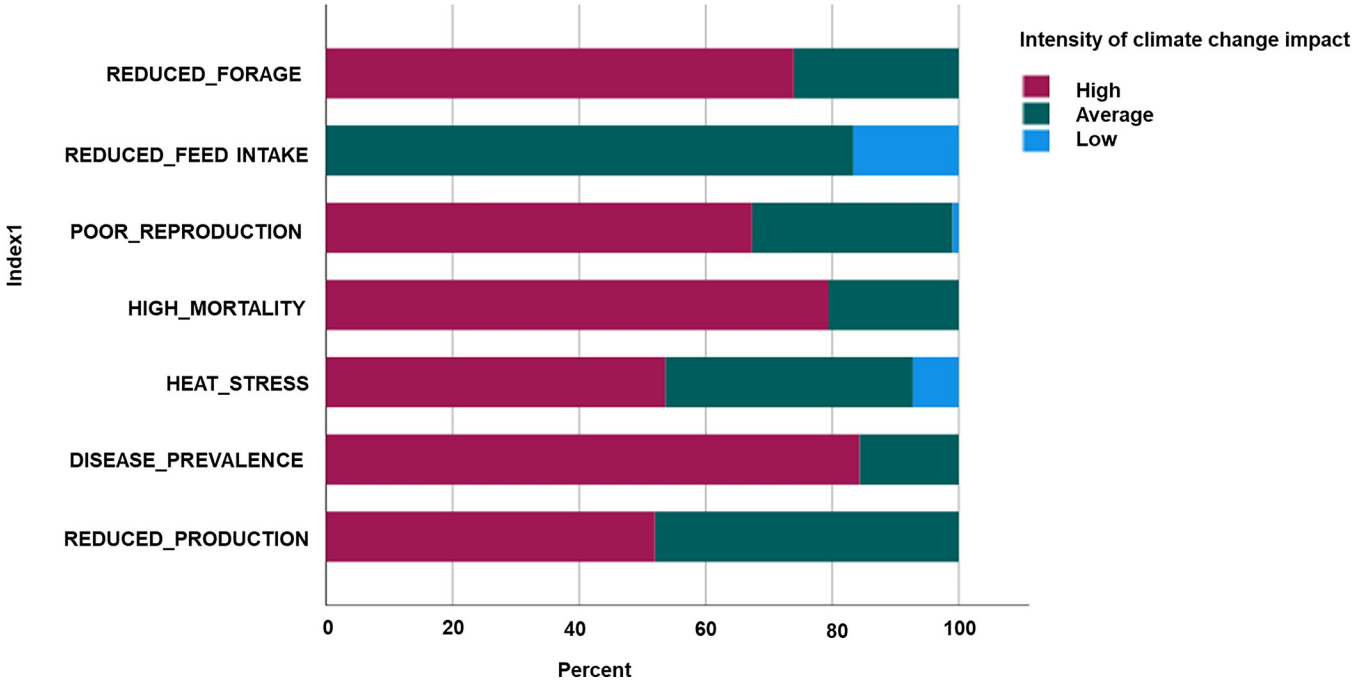


**Fig 6. Intensity of climate change impact on livestock production.**

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distances in search of water sources for their livestock [81]. This shows the severity of climate change impacts on forage availability in Limpopo Province.

Results of this study provide evidence of claims made by the IPCC that impacts on livestock production are considered large especially for cattle in the tropics and sub-tropics [32]. Findings also agree with [82] that heat stress is the largest factor affecting livestock production in Africa. The impact of climate change on livestock production is deemed compounding as there are interconnected linkages from diminished forage availability and quality, diminished availability of water, direct heat stress and increased incidences of livestock diseases [83, 84].

Climate change affects other dimensions apart from crop and livestock production. In this study social dimensions such as the food availability, amount of surplus to sell and level of income from agriculture were considered. Reduced crop and livestock production cause a ripple effect of events that affect the social wellbeing of farmers. Food shortages were rated low to average implying that it was moderate. This suggests that food shortages were seasonal and were not experienced all year round. Seasonal food shortages are common among smallholder farmers especially from June (although it varies with different situations) when the previous harvest is used up and the next harvest has not yet started [85]. The same authors indicate that the larger the household size (6 to 7 members) and higher the level of poverty the higher the level of food insufficiency, availability and access. Type of crops grown also influences the level of insufficiency in food availability and access with households that grow staple crops less likely to experience insufficiency while households that grow other crops are likely to experience insufficiency.

Smallholder farmers are considered entrepreneurs by nature whose aim is to produce more than they can consume and sell excess produce [86]. However, due to climatic changes and variations, this has been a difficult task as evidenced in Thulamela where losses in surplus for sale were rated mostly average to high. Surplus for sale refers to the portion of farm produce which goes to the market for sale. As a result of the losses in production experienced due to

climate change, surplus for sale is limited in Thulamela. Farmers must ensure that their household food requirements are met first before they spare produce for sale. With smallholder farmers in Thulamela struggling to meet their food requirements, having surplus that would be meant for selling is a tall order as there are food deficits already.

Financial constraints were rated average to high due to loss of income from reduced surplus meant for sale. Findings tally with [27] who found out that loss of income is one of the main social consequences of climate change impacts. Furthermore, [87] illustrates that climate change impacts due to drought result in a decline in livestock prices. The same authors noted a decline in livestock prices of 25% for cattle, 19% for sheep, and 19% for goats resulting in less income and profits for farmers. The financial constraints faced by farmers in Thulamela could also be due to some technical problems elsewhere. For example, persistent rains and floods worsens the poor road systems in rural areas where smallholder farmers are located making it difficult to access the market. As such, market participation among smallholder farmers is limited [88] and they are often forced to sell their produce at farm gate prices that are lower than the prices fetched at market centres [89]. The impacts of climate change on social wellbeing are likely to breed psychological problems among farmers that affect the achievement of the Sustainable Development Goals (SDGs) [90]. Hence, adaptation initiatives are critical to reduce the impact of climate change so that they do not develop into complex challenges. Fig 7 shows how farmers rated the impact of climate changes on social wellbeing.

Overall, the findings of this study tally with the Sixth Assessment Report (AR6) of the IPCC [32]. The report has it on high confidence that the extent and magnitude of climate change impacts on people and ecosystems are more than expected. This is true for smallholder farmers and agricultural ecosystems. The same report illustrates that the impacts of climate change are widespread, pervasive, and in some cases interconnected and irreversible. Climate change impacts have also resulted in acute food shortages and water insecurity, especially in less developed regions like Africa.

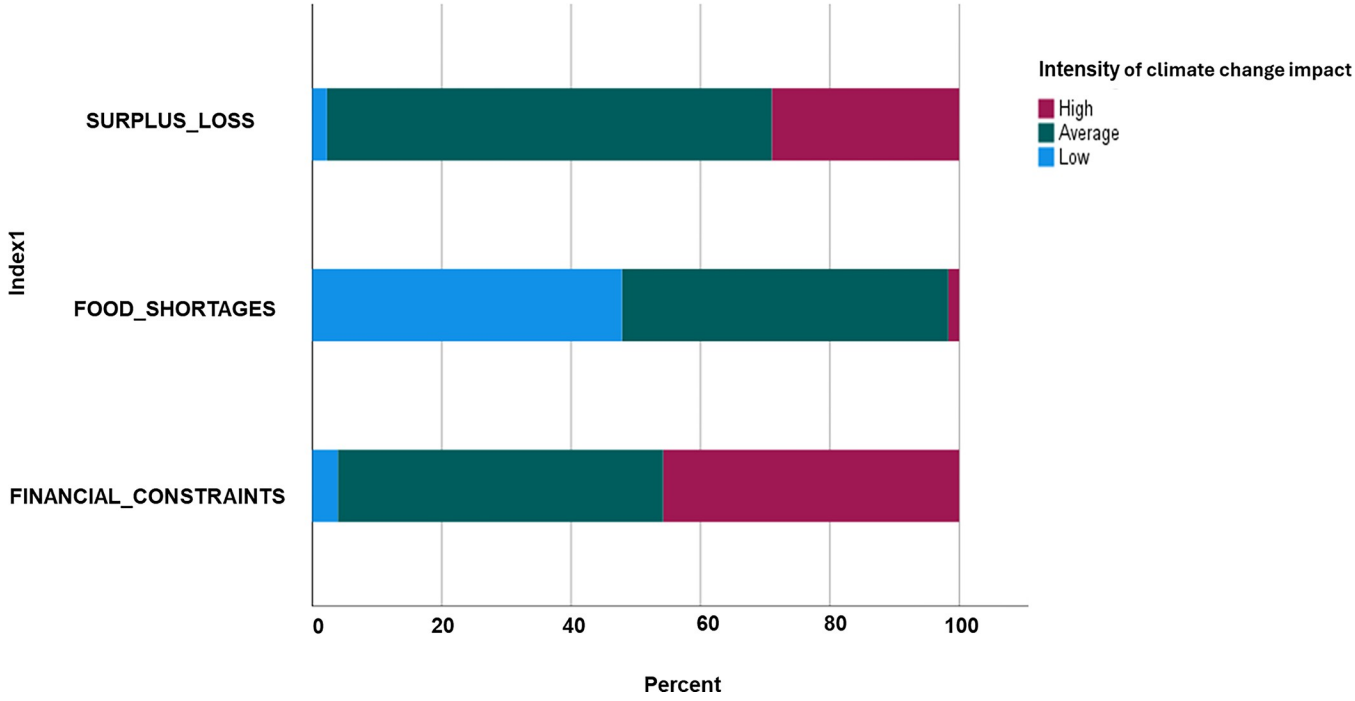


**Fig 7. Intensity of climate change impact on social wellbeing.**

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## 4 Conclusions and recommendations

Climate change impact assessments that lack consideration of the local impacts reduces the effectiveness of adaptation. Understanding the local impacts of climate change for smallholder farmers is essential in the development of locally appropriate interventions. However, there is uncertainty about the local implications of climate change due to limited spatial resolution of climate models and lack of data due to the absence of monitoring records at a local scale. This study sought to understand the local impacts of climate change of smallholder farmers in Thulamela. The intention was to introduce the locale dimension and build evidence based on the local experiences. It is envisaged that this will enhance the development and implementation of context-specific responses to reduce the effects. Findings show that farmers in Thulamela experience several climatic changes and impacts emanating from temperature changes and shifts in rainfall patterns. The climatic changes yielded negative impacts on crop and livestock production as well as social wellbeing of farmers. According to smallholder farmers, climate change impacts in Thulamela were mostly average to high. Locally appropriate actions that are pertinent for resilience building and investments towards building capacity of smallholder farmers should be made. There is urgent need towards developing appropriate ways to mitigate climate change, otherwise agricultural production will be compromised. For crop production, investments can be made in enhancing knowledge of farmers in integrated pest and disease management strategies and biological and cultural methods. Production of underutilized indigenous crops such as bambara groundnuts and cowpeas suitable for arid and semi-arid areas are also recommended to improve smallholder farmers' resilience to climatic stresses while meeting food and nutrition security. In livestock production, investments in research and development of small stock should be prioritized to promote rearing of small stock that can withstand climatic changes. Investments should be made towards building women's social, ecological and economic capacity seeing that they are underrepresented in terms of land ownership, yet they have the skills, knowledge and traditional experience valuable for use under extreme weather changes.

Based on the study findings, enabling policies should be formulated to enhance understanding of the local implications of climate change for smallholder farmers. Policy initiatives should consider creating enabling environments that facilitate research initiatives at the local level. This can be done through channeling funds towards local climate change research. Overall, national governments should develop supportive policies to ensure that research institutions do not shun away from conducting climate change research at the local level so that findings will be aggregated out to the national, regional and international levels. This bottom-up approach is crucial for development. A limitation of this study is the narrow focus on the socio-economic factors of smallholder farmers as the only determinants of the extent of climate change impacts. Therefore, as a recommendation for future research, a deeper analysis that incorporate institutional factors such as support policies, funding, infrastructure, organizational membership, extension services and training influence that influence the magnitude of climate change impact is required.

## Supporting information

**S1 Data.**
(XLSX)

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## Author Contributions

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**Supervision:** Walter Musakwa, Clare Kelso.

**Validation:** Walter Musakwa, Clare Kelso.

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