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Validating Small-Scale Sugarcane Farmers' Climate Perceptions Through Scientific Climate Data to Enhance Awareness of Climate Change: The Case of Swayimana Area in KZN Midlands, South Africa

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ABSTRACT

Climate change is a serious challenge that poses an additional problem to the many existing difficulties in the agricultural sector. It will likely exacerbate an already dire situation by making current production methods less sustainable. Previous studies concluded that most people in developing countries perceive climate change as a spatially and temporally distant threat. However, recent studies have raised a new narrative, suggesting that rural communities are becoming more aware of climate change and variability. The study, therefore, aimed to compare the perceptions of climate change among small-scale sugarcane farmers with scientifically observed climate trends in the study area. The study mainly analysed rainfall and air temperature trends over twenty years and compared these with climate change, as farmers in the study area perceived. Additionally, it assessed whether the participants had implemented adaptation plans to minimise the adverse effects of the observed climate variations, both scientifically and perceptually. The study findings indicate that small-scale sugarcane farmers perceive climate change fairly accurately. Less than half of the small-scale sugarcane farmers (nearly 40%) observed increased temperatures, rainfall, drought frequency, and frost occurrence. Their perceptions aligned with the findings from the scientific data, which indicated that maximum temperature has been increasing at 0.049 °C per annum^{-1} from 1997 to 2017 while the rainfall showed an increase of 15.475 mm per annum^{-1} over the same period. These findings confirm that these farmers are becoming more aware of climate change occurring in their communities. However, the study results also show that despite the accurate

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perception of climate change, farmers struggle to adapt to this accurately perceived climate change. This highlights their vulnerability to climate change due to a lack of adaptive capacity. The study recommends government intervention to facilitate improved collaboration between academics and farmers for information sharing to identify possible adaptation strategies for small-scale farmers.

Keywords: Climate Change Perception, Climate Change Awareness, Adaptive Capacity, Small-Scale Farming

1. INTRODUCTION

Climate change remains a significant challenge restricting sustainable development progress in many African countries. Climate change will likely aggravate the difficult situation by making the current livelihoods unsustainable, leading to deeper poverty. Climate change studies show that most parts of Africa are already experiencing significant climatic changes, which are expected to intensify in the future (Abiodun *et al.*, 2019; Karypidou *et al.*, 2021). High surface temperatures, dry conditions and intense rainfall patterns have become prevalent in southern Africa and are anticipated to intensify (Ujeneza & Abioudun, 2015; Abiodun *et al.*, 2019). Developing countries with most of their population depend on agriculture for food and income (Mabhaudhi et al., 2018) and, therefore, must improve their resilience. Specifically, rural small-scale farmers whose livelihoods depend on natural resources will probably bear the brunt of adverse effects. Recurring droughts and other extreme weather events threaten the sustainability of small-scale agriculture, particularly in rural areas where farmers already face other challenges (Mabhaudi *et al.*, 2018). As a result, small-scale farmers are considered one of the most vulnerable groups to climate change and climate variability (Harvey *et al.*, 2018). This necessitates a better understanding of climate change and variability to design relevant adaptation strategies that deal with how climate change impacts small-scale agriculture. This understanding is predominantly needed by smallholder farmers who often suffer the consequences of local and global environmental changes (Mkonda *et al.*, 2018). The literature highlights smallholder farmers' lack of climate change knowledge, resulting in a low adaptive capacity (Ncoyini *et al.*, 2022; Popoola *et al.*, 2020; Lazo, 2015). As such, a lack of knowledge among small-scale farmers exacerbates their vulnerability to the adverse effects of climate change and extremes.

There is a consensus that without scientific information, farmers can use their climate observations and experiences to make necessary agricultural production changes. Farmers who perceive climate change are more likely to pay attention to adaptative actions. Madison (2007) suggests that climate change adaptation requires farmers to first notice that the climate has changed. It is argued that people who are already proactive in climate change adaptation started by perceiving and understanding that the local climate was changing (Hasan & Kumar, 2019; Tesfuhuney & Mbeletshie, 2019). People's perception of climate change is a collective awareness of how climatic parameters have changed over the past years. It is defined as an awareness of the trend in climatic factors such as rainfall, temperature, extreme weather events, and the onset and end of the wet season (Tesfuhuney & Mbeletshie, 2019). Numerous studies have been conducted to understand climate change perception amongst the public (Acquah & Onumah, 2011; Maponya & Mphandeli, 2013; Kibue *et al.*, 2015; Elum *et al.*, 2016; Mkonda *et al.*, 2018; Tesfuhuney & Mbeletshie, 2019; Diniso *et al.*, 2022). Some studies revealed that the public perceives and understands climate change (Kibue *et al.*, 2015; Elum *et al.*, 2016; Tesfuhuney & Mbeletshie, 2019), while others reported a lack of climate change awareness, particularly among small-scale farmers (Maponya & Mphandeli, 2013; Diniso *et al.*, 2022). However, although some studies claim that the public perceives that the climate is changing, the assertion often associates a high level of climate change awareness with simply hearing about it (Kibue *et al.*, 2015). It is important to differentiate between hearing about the climate change concept and perceiving climate change. People often dismiss any subject if its influence is not evident on their livelihood (Diniso *et al.*, 2022). Previous studies have shown a poor understanding and perception of climate change among Africans. For example, Tederera (2010) indicated that South Africans often refer to climate change as "changing weather". Also, Diniso *et al.* (2022) reported that most of the study participants could not comprehend the influence of global warming on climate change. This misunderstanding is of great concern, given that it may adversely influence the extent of adaptation.

In addition, the fact that sub-populations within a specific region may experience climate changes differently needs to be considered. Everyone must first notice that the climate is changing so that everyone can respond to it. Thus, local knowledge is essential for determining how individuals respond to climate change. Kruger & Nxumalo (2017) have indicated that meteorological stations within proximity can show different trends. Thus, they cannot be completely associated with climate change; they can also be associated with other influential

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local factors. The observed difference in climatic trends may indicate diverse climate conditions experienced by communities within the same region. Kruger (2006) highlighted the low density of weather stations in KwaZulu-Natal (KZN), and MacKellar *et al.* (2014) argued that stations within the same hydroclimatic area may fail to represent the heterogeneity of the area. Kruger & Nxumalo (2017) emphasise that rainfall amounts across districts lack homogeneity, particularly in areas with complex topography. This highlights that those farmers within the same district can experience and observe different climate variations.

Previously, climate change studies focused more on climate change and its impacts based on climate change scenarios, using solely measured climatic data and models (James & Washington, 2012; Engelbrecht *et al.*, 2015; Dosio, 2017). Similar studies in the study area analysed climate change based only on measured climate data (Strydom & Savage, 2018; Ndlovu *et al.*, 2021). The differences observed in different weather stations indicate that a successful understanding of climate change is not only limited to the values of climate parameters but also includes climate variability and associated extreme weather events, as well as the understanding of these by local people experiencing these changes. Therefore, an in-depth study was needed to determine small-scale farmers' climate change experience against measured climate data. Hence, this study compares small-scale sugarcane farmers' climate change perceptions with scientifically observed climate trends. The study also assessed whether the participants had adaptation plans to minimise the adverse effects of the climate variation observed scientifically and perceptually.

2. MATERIALS AND METHODS

2.1. Study Site

The Wartburg area is situated in KwaZulu-Natal, southeast South Africa. It is located at 29.4332 ^{o} S and 30.5812 ^{o} E at 1000 m above sea level. The study site is characterised by a subtropical climate with warm, wet summers and cool, dry winters with a long-term annual average rainfall of 881 mm and an average air temperature of 18^{o}C. The study area is amongst the regions with high-quality farming in the province and specialises in sugarcane production under dryland conditions. The survey data was collected from a rural farming community called Swayimana. This community is situated to the East of Pietermaritzburg. Farming serves as a primary source of livelihood in the area. The area is characterised by good rainfall and arable soils; hence, it is predominantly used for agricultural production.

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2.2. Survey Data Collection Method

The study used a random sampling technique to select the prospective participants. Face-to-face interviews were conducted following a questionnaire guide for data collection. The questionnaire consisted of both open- and closed-ended questions. The inclusion of open-ended questions was intended to allow respondents to provide insight into their personal experiences. Despite having access to meteorological data for analysis and guidance in compiling options for them to select from, it was felt that the results would likely be biased and fail to reflect their true observations and experiences. The interviews were conducted over two months (from 13 December 2018 to 05 February 2019). These were carried out individually and in a native language (isiZulu) to ensure the prospective respondents understood the questions well. A total of 66 questionnaires were completed through the interviews. This represents 30% of the sugarcane farmers in the study area.

2.3. Meteorological Data and Methodology

The meteorological data used in this study were accessed from the South African Sugarcane Research Institute (SASRI) through the SASRI website. The study analysed data from Bruny's Hill weather station located 29^{o} 25' 0" South and 30^{o} 41' 0" East and at an altitude of 990 m. The study analysed annual and monthly data over 20 years (1998 – 2018). The weather station was selected based on its vicinity to the Swayimana community in Wartburg, where the survey was conducted. The datasets included daily, monthly and yearly data on maximum and minimum air temperature and rainfall. The study analysed average annual air temperature and rainfall trends. The daily data were used for the calculation of drought indices. The data was collected from an automatic weather station and was of good quality with no missing values.

2.4. Drought Indices Used in the Study

The Standardised Precipitation Evapotranspiration Index (SPEI) was used to analyse historical drought trends at the study site. The SPEI has been extensively used for defining and monitoring drought in many parts of the world (Khan *et al.*, 2017; Lee *et al.*, 2017; Jang, 2018), including southern Africa (Edossa *et al.*, 2014; Botai *et al.*, 2016; Botai *et al.*, 2019). The SPEI is preferred for drought characterisation over the Standardised Precipitation Index (SPI) because its calculations consider the effects of air temperature on drought occurrences. It is computed as the difference between precipitation (P) and potential evapotranspiration (PET). This study employed the SPEI script embedded in R software (R Core Team, 2013) to calculate the drought

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index. The potential evapotranspiration used for drought index calculations was computed using the Hargreaves air temperature-based method (Hargreaves & Samani, 1985). This is calculated based on the daily maximum and minimum air temperature range and the latitude of the study site. The Hargreaves air temperature-based method is believed to produce sensible results because it is linked to solar radiation through the daily air temperature range and the mean extraterrestrial radiation (Yates & Strzepe, 1994). A detailed description of the SPEI calculation can be found in Beguería *et al.* (2014).

3. RESULTS AND DISCUSSION

3.1. Demographic Information of the Participants

According to Table 1, sugarcane small-scale farmers are evenly distributed in gender, with the percentage of male farmers (51%) slightly higher than female farmers (49%). The participants' age distribution ranged from the late 20s to over 60. The results of this study reflect the reality of farmers' ages in the agricultural sector. In South Africa, the average age of farmers is 62 years (Sihlobo, 2015), partly due to a continuous decrease in youth participation in agriculture since early 2000, particularly in rural areas (Cheteni, 2016). The literacy level of the participants reflects their age. Most elderly people in South Africa are uneducated (Khuluvhe, 2021), and this study confirms that the majority of the participants only had primary education. Over 77% of the participants produced sugarcane in a piece of land less than 2 ha in size. Twenty percent of the participants have been farming for five consecutive years or less after taking a long break from production due to substantial losses occurring in the past.

TABLE 1: Demographic Results of the Respondents (n = 66)

Variables	Description	Responses (%)
Gender	Male	51
	Female	49
Age (years)	<40	24
	41-50	20
	51-60	25
	>60	31
	Primary	52

Literacy level		
	Secondary	46
	Bachelor degree	2
Farm size (ha)	<1	30
	1-2	47
	>2	23
Farming experience	<1	3
	1-5	17
	5-10	40
	>10	40

3.2. Scientifically Measured Climate Data Trends Versus Trends in People's Perceptions of Climate

The controversy in climate change perception studies has been clear enough to stimulate interest in local studies to better understand climate change perception amongst the public in rural farming communities. Initially, it was concluded that most people in developing countries perceive climate change as a spatially and temporally distant threat (Maiella *et al.*, 2020). However, recent studies (Elum *et al.*, 2016; Tesfuhuney & Mbeletshie, 2019) raised a new narrative, indicating that rural communities have started observing and experiencing climate variations in their respective communities. This implies that rural communities are becoming more aware of climate change and variability (Elum *et al.*, 2016; Tesfuhuney & Mbeletshie, 2019). This study utilised meteorological data from a nearby weather station to study local climate trends, particularly rainfall and air temperature, over twenty years. The study results are presented in Figures 1 and 2 and Table 2. The results of the study suggest a significant ($p < 0.05$) decrease in minimum air temperature (Tmn) and a negligible reduction in maximum air temperature (Tmx) over the 20 years under study. The rainfall trends also suggest a significant ($p < 0.05$) increase for the study site.

Minimum temperatures have been reported to increase faster than Tmax in various parts of the world (He *et al.*, 2020); however, the study results suggest a decreasing trend of Tmn throughout 1998-2018, indicating that the study area is becoming cooler. The Tmn significantly

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decreased at 0.05 ºC per annum^{-1} for 1998-2018. This decrease has also been observed at a nearby station in Cedara (Kruger *et al.*, 2019). Given global warming, it is difficult to explain the possible reason behind the decreasing minimum air temperature at the study site. However, it is fair to highlight that the 2014 frost event might have contributed to the decreasing Tmn trend (Ramburan *et al.*, 2015). The decreasing Tmn trend might also confirm the influence of other factors rather than climate change (Kruger & Nxumalo, 2017). For instance, factors that affect microclimate also tend to significantly influence atmospheric variations at a local level. These factors encompass elements such as land use, topographical aspects, land cover, and proximity to the ocean. Drought also influences the decrease in Tmn due to the absence of clouds and insufficient water vapour to enhance downward longwave radiation. Because clouds act as insulators for nighttime temperatures, their absence causes efficient heat loss from the surface (Lopez-Diaz *et al.*, 2013). Therefore, this suggests that dry conditions increase maximum temperatures but decrease minimum temperatures, increasing the diurnal temperature range.

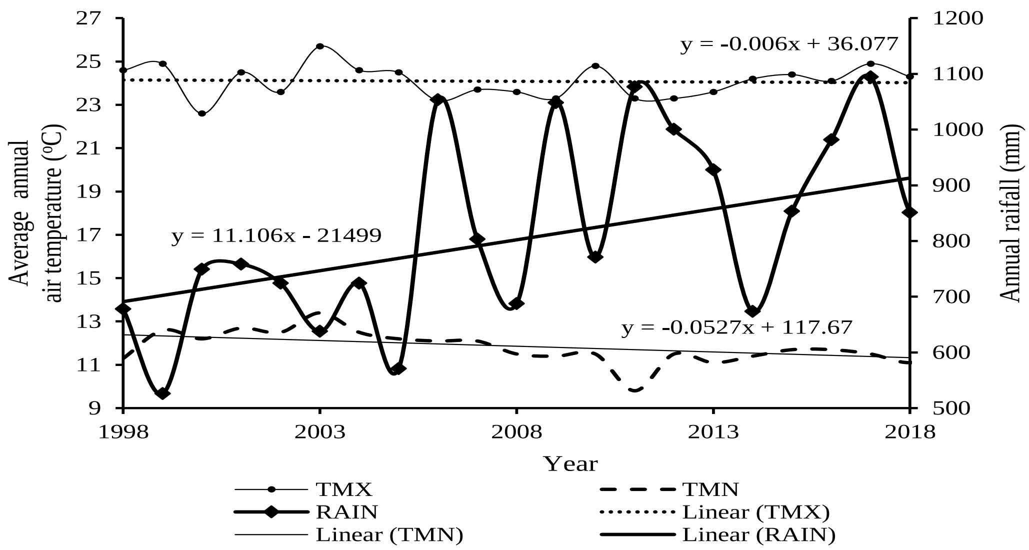

FIGURE 1: Average Annual Air Temperature and Total Rainfall Variation for Bruny's Hill Station From 1998 to 2018

The negligible decrease in Tmx is not aligned with the widely acknowledged Tmx increase worldwide (Halimatou *et al.*, 2017; Aguilar *et al.*, 2005; Larbi *et al.*, 2018). However, these results partly concur with Kruger & Nxumalo (2017) and Kruger *et al.* (2019), who found no change in maximum air temperature trends in a nearby weather station from 1931-2015 and 1951- 2005, respectively. The study results suggest that local factors might influence local climate trends more than a global phenomenon. Figure 2 shows the trend over a decade (2007 to 2017), and Figure 3 indicates small-scale farmers' perception of climate variability in the study site over the same period (2007 to 2017). Over a decade, there has been an insignificant increasing Tmx and rainfall and an insignificant decrease in Tmn.

Based on their experience and observations, small-scale farmers indicated that they noticed some climate change from 2007 to 2017. Figure 3 shows that over 35% of the participants observed increased rainfall and air temperatures. Their observations are aligned with the measured climatic data from Bruny's weather station. According to the results, over the 2007 to 2017 period, the study site experienced a maximum air temperature increase of 0.049 ^{o}C annum $^{-1}$ and a rainfall increase of 15.475 mm per annum^{-1}. Although an increase in annual rainfall has been observed, it does not automatically translate to good rains for agricultural production. Ncoyini-Manciya (2021) reported an increase in the yearly maximum one-day precipitation (RX1day) and annual total rainfall from daily precipitation greater than the 95th percentile (R95p) indices, which indicates that high amounts of rainfall are received over a relatively short period.

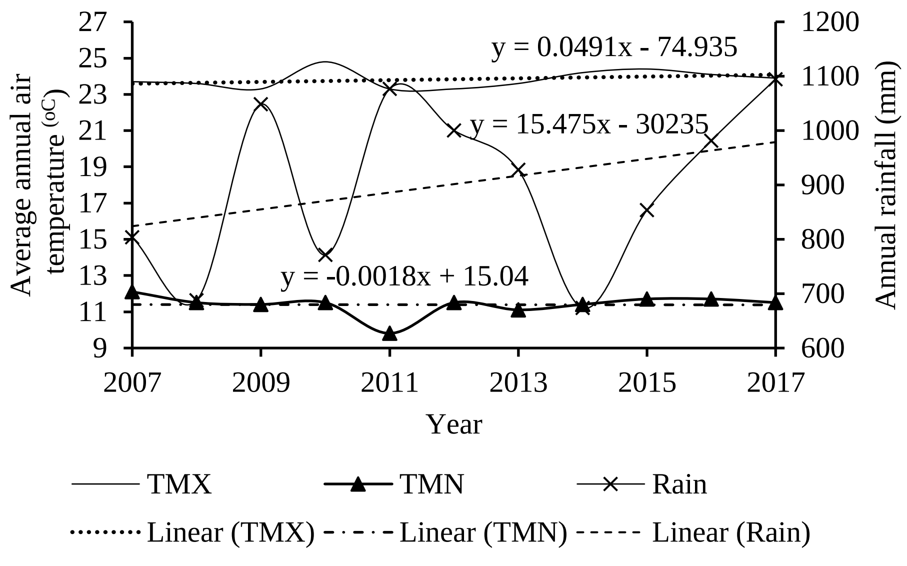

FIGURE 2: Average Annual Air Temperature and Total Rainfall Variation for Bruny's Hill Station From 2007 to 2017.

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Secondly, some small-scale farmers have also observed frequent extreme weather events and drought occurrences at the study site. The rainfall trends found in the study site are consistent with Trenberth's (2011) statement, which states that as air temperature continues to increase due to high greenhouse gas concentration in the atmosphere, the water-holding capacity of air will also increase, leading to the greater moisture content in the atmosphere. Consequently, precipitation will increase due to high atmospheric content and warmer air temperatures (Fowler & Hennessy, 1995).

TABLE 2: Regression Results for Annual Rainfall and Average Annual Air Temperature From 1998 to 2018

Variable (1998- 2018)	**Slope**	**p-value**
Tmax	-0.006	0.512
Tmin	-0.070	0.006
Rain	16.640	0.003
Variable (2007- 2017)	**Slope**	**p-value**
Tmax	0.049	0.322
Tmin	-0.002	0.311
Rain	15.475	0.975

The perceived frost occurrence aligns with the observed decreasing Tmn in the study site. The perceived prevalence of frost events may be partly attributed to the topography. Areas with high altitudes (>800 m) tend to experience cooler climate conditions. Some farmers observed delays in rainfall season start (7%) or storms and wind (17 %), while others perceived no change (5%). High rainfall, high temperatures, and drought occurrences were among the most perceived climate changes at the study site. The measured data from the weather stations correspond with the farmers' observation, showing increased rainfall and maximum temperatures.

According to Nhamo *et al.* (2019), the Southern African region has been experiencing an increase in the frequency and intensity of drought. Climate change perception results (Figure 3) indicate that some farmers, although only 10%, have observed an increase in the frequency of extreme weather events. Based on the findings, the prevalence of high rainfall, high temperatures, and drought were amongst the area's most common climate/weather extremes. To validate the drought trend perception, the study employed the SPEI to compute drought

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indices for the period under study. Figure 4 shows the drought index results calculated using measured meteorological data.

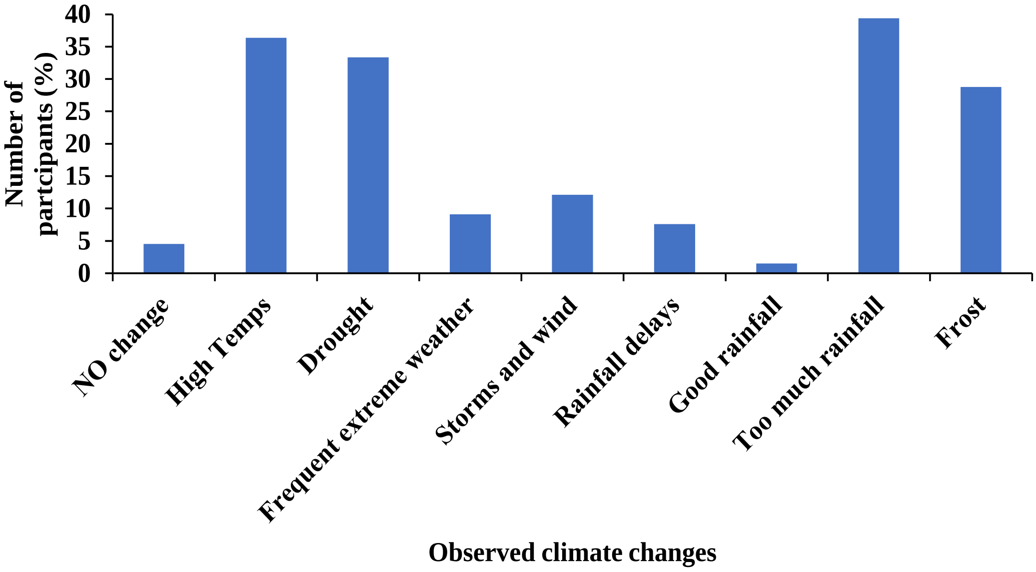

FIGURE 3: Perceived Climate Change in the Wartburg Area From 2007 to 2017. *(participants selected more than one option)*

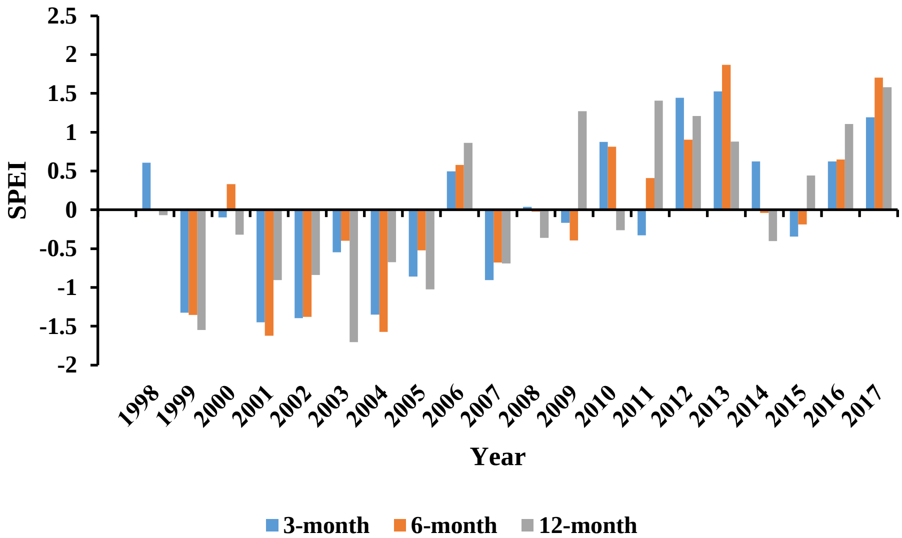

FIGURE 4: Drought Events Characterised by SPEI From 1998 to 2018.

The SPEI results indicate that the study site has experienced both dry and wet conditions over the 2007 to 2017 period. The SPEI results concur with the wet and dry patterns the farmers have been observing, with extreme wetting trends more frequent than extreme drying. The prevalence of wet and dry conditions in the study site confirms the increased frequency of extreme weather events as perceived by the study participants. However, severe drought events occurred before 2007. The study findings concur with Kibue *et al.* (2015), Elum *et al.* (2016), and Tesfuhuney & Mbeletshie (2019) that small-scale farmers perceive and understand climate change occurring in their respective areas.

3.3. Adaptation Strategies Employed by Sugarcane Small-Scale Farmers in KZN Midlands

Figure 5 indicates sugarcane small-scale farmers' adaptation strategies to deal with the perceived climate changes in the study site. Fifty-five percent of the participants indicated that they did not have any strategies in place for minimising the adverse effects of perceived climate change. At the same time, about 40% of them relied solely on mulching. They reasoned that mulching was adopted based on what they observed from the nearby commercial farmers. They did not understand the reason for the application of mulch, but they decided to apply it. That aside, the results confirm that despite the observed increase in drought frequency and projected prevalence of drought events in southern Africa, sugarcane small-scale farmers have no plans to adapt to climate change. The study findings are aligned with the lack of adaptative capacity among small-scale farmers, which has been extensively discussed in the literature (Dasgupta *et al.*, 2014; Ofoegbu *et al.*, 2016; Karienye & Macharia, 2020). Subsequently, a decline in small-scale farmers' production has been noted (Mnisi & Dlamini, 2012), and this decline is partly attributed to extreme weather events (Dubb, 2013). The minimal adaptive capacity that is evident emanates from restricted funds and limited knowledge of the possible adaptation strategies. Furthermore, illiteracy has been reported to cause poor crop husbandry practices among sugarcane small-scale farmers in South Africa (Eweg *et al.*, 2009; Zulu *et al.*, 2011).

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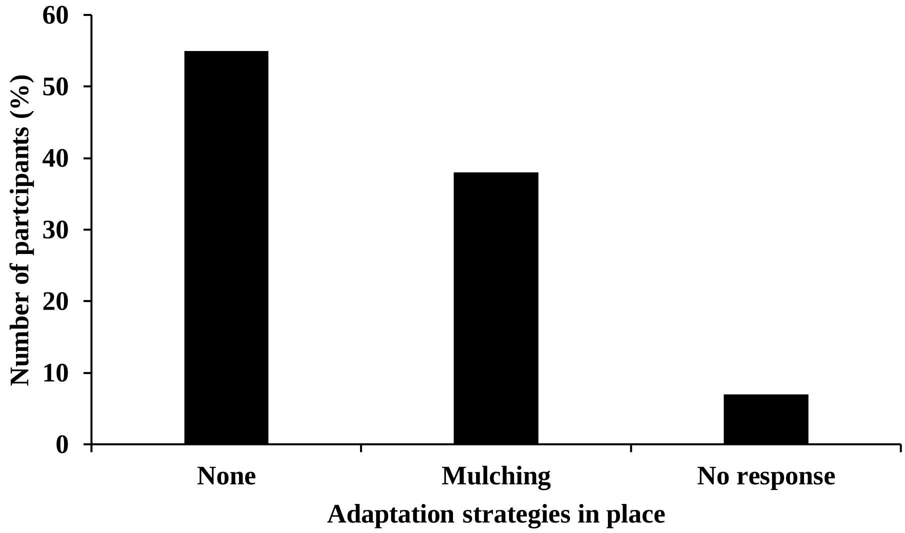

FIGURE 5: Strategies Adopted by Sugarcane Small-Scale Farmers in the Study Site.

4. CONCLUSION

The study intended to compare the meteorological data available with the climate change perceptions of small-scale farmers in the study area from 2007 to 2017. The meteorological data results indicated the exact climate change that farmers perceived. The study findings suggest that farmers are becoming more aware of the climate changes in their respective areas. This implies that farmers no longer perceive climate change as a distant threat but rather as a serious issue that needs to be dealt with. However, farmers struggle to adapt to climate change successfully and sustainably due to a lack of knowledge, funding, and high illiteracy levels. Therefore, the study findings encourage improved collaboration between farmers and academics or researchers for better information sharing that would capacitate them on possible adaptation strategies. Farmers would benefit from further training on climate change. Thus, it is recommended that the government intervene to facilitate the necessary collaboration for this purpose. This study only focused on small-scale sugarcane farmers in a specified study site. Future research could broaden the study area and/or include small-scale farmers in general from regions near a weather station to study their perceptions of climate change versus measured climate data from a weather station.

5. AVAILABILITY OF DATA AND MATERIALS

The datasets used in this study are available from the provided website. The data from the survey is available on request.

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6. CONFLICTS OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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