Journal of Environmental Planning and Management

ISSN: 0964-0568 (Print) 1360-0559 (Online) Journal homepage: www.tandfonline.com/journals/cjep20

Indigenous knowledge indicators employed by farmers for adaptation to climate change in rural South Africa

Zongho Kom, Nthaduleni S. Nethengwe, Sylvester Mpandeli & Hector Chikoore

To cite this article: Zongho Kom, Nthaduleni S. Nethengwe, Sylvester Mpandeli & Hector Chikoore (2023) Indigenous knowledge indicators employed by farmers for adaptation to climate change in rural South Africa, Journal of Environmental Planning and Management, 66:13, 2778-2793, DOI: 10.1080/09640568.2022.2086854

To link to this article: https://doi.org/10.1080/09640568.2022.2086854

Journal of Environmental Planning and Management, 2023
Vol. 66, No. 13, 2778–2793, https://doi.org/10.1080/09640568.2022.2086854

Indigenous knowledge indicators employed by farmers for adaptation to climate change in rural South Africa

Zongho Kom[a]*, Nthaduleni S. Nethengwe[a], Sylvester Mpandeli[a,b] and Hector Chikoore[c]

[a]*Deparment of Geography and Environmental Sciences, Faculty of Science, Engineering and Agriculture, University of Venda, Thohoyandou, Limpopo Province, South Africa;* [b]*Water Research Commission, Pretoria, South Africa;* [c]*Department of Geography and Environmental Studies, University of Limpopo, Sovenga, Polokwane, Limpopo, South Africa*

(*Received 21 April 2021; revised 25 May 2022; final version received 25 May 2022*)

The majority of indigenous farmers in South Africa depend on rain-fed agricultural production for their livelihoods. Reliable indigenous weather forecasts are, therefore, required to guide rural farmers' decisions in regard to climate change. Much of the literature has shown that western scientific knowledge has failed at rural level. Indigenous knowledge has, for the past century assisted rural farmers' households in tackling the challenges of climate stressors and enhanced decision-making for adaptation. There is, therefore, much room for advancement in assessment processes to ensure adequate credit for indigenous knowledge systems. This study aimed to address two major knowledge gaps (i) to assess the relevance of indigenous knowledge in weather forecasts used by local farmers for climate adaptation, and (ii) examine farmers' perceptions in regard to climate change in Levubu and Nwanedi sites. Indigenous knowledge indicators used by farmers for weather forecasting, within their communities, were collected through questionnaires, interviews and focus group discussions. The results revealed various forms of indigenous indicators used by local farmers for weather forecasting, such as, star and moon movement, appearance of red and black ants and mist-cover on mountains. A better knowledge of indigenous knowledge systems should play an important role in determining suitable adaptation strategies toward climate change. It is recommended, hence, that policy makers should enhance indigenous knowledge among local communities regarding the implications of climatic stressors to increase crop production.

Keywords: indigenous knowledge systems; adaptation strategies; local farmers; Vhembe district; indigenous indicators; climate change

1. Introduction

Global communities are facing climate change along with actual and potential negative impacts on agricultural activities, although the impacts will not be evenly distributed among farmers (Parrotta and Agnoletti 2012). In Sub-Saharan Africa (SSA) the local farming system is an important sector and is set to be hit hardest by climate variability and change (Deressa *et al.* 2009; Intergovernmental Panel on Climate

*Corresponding author. Email: zogokom@yahoo.fr

Change (IPCC) 2013, 2018). Changes in climate are an important phenomenon that needs close attention as they impact food security for the local population (Vilakazi 2017). Kom *et al.* (2022), note that climate change impacts are felt greatly by rural farmers, as extreme weather events result in crop failure and reduce farmers' livelihood opportunities. Finucane (2009) reported that, in past years, formal scientific knowledge has been insufficient and is limited in combatting climatic issues at the local level.

Modern climate data and weather predictions are important factors to guide indigenous farming choices. Adger *et al.* (2011) generally support that scientific climate forecasts have spatio-temporal limitations for use at the local farming level. Scientific meteorological forecasts are usually questioned for not giving precise weather information at the local scale, in addition to being poorly interpreted by indigenous farmers. Scientific climatic information is, sometimes too systematic and technical for the indigenous people (Joshua *et al.* 2011; Jury 2013; Braman *et al.* 2013). Moreover, extreme increases in temperature and decreases in precipitation in South Africa, have increased doubts about weather forecasting, creating huge challenges to scientific climate experts in their work to advance weather prediction and accuracy (Ambrosino, Chandler, and Todd 2011; Kalanda-Joshua *et al.* 2011). Several studies have documented that scientific knowledge alone cannot sufficiently combat climatic risks among indigenous farmers; hence, there is need to apply local indigenous knowledge (Finucane 2009; Jiri *et al.* 2016; Mugambiwa 2018).

Few studies have been conducted concerning the integration of indigenous and scientific knowledge to adapt to climate risks; therefore, this study focuses on indigenous knowledge used by local farmers as an adaptation strategy in response to changes in climate. Several researchers have gradually accepted that in climate forecasts, indigenous knowledge is found to be more suitable, credible and easily used by rural farmers than western scientific weather information (Kalanda-Joshua *et al.* 2011; Maldonado *et al.* 2016; McPherson *et al.* 2016). According to Kimmerer (2002) indigenous knowledge exists in parallel to scientific information. Several studies have indicated that "indigenous knowledge method tends to be qualitative, and they develop a diachronic databank, that is, a result of observations from local environment over an extended time period" (Kimmerer 2002; Gyampoh *et al.* 2009; Berkes 2012). The Indigenous people are the observers, so their decision-making is directly linked to the quality and reliability of their social and environmental observations (Naci 2009; Mugambiwa and Rukema 2019). On the other hand, western science observations created by a small group of scientists tend to be quantitative and frequently represent synchronic information observations from a wide range of sites, with lack of long-time epoch use by the Indigenous people (Kimmerer 2002; Jury 2013). Local knowledge offers "observations and interpretations at a much finer spatial scale with considerable temporal depth by highlighting elements that may not be considered by climate scientists" (IPCC 2018; Jiri *et al.* 2016).

Berkes (2012) defines indigenous knowledge as "a cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of local people with one another and with their environment". With regard to the context of this paper, indigenous knowledge systems are defined as a collection of know-how, local culture, beliefs, experiences, management of the local resource which has passed down from generation to generation. Indigenous knowledge systems are also labeled in several studies as local knowledge, traditional ecological knowledge, Indigenous people's knowledge or farmers' knowledge.

The Intergovernmental Panel on Climate Change explains adaptation as "an adjustment made to a human, ecological or physical system in response to a perceived vulnerability". Adaptation in regard to climate risks is an adjustment in the physical environment or human systems in response to potential or anticipated climatic shocks, and their impacts (IPCC 2018; Jiri *et al.* 2016). In climate science, this local knowledge is expected to contribute significantly by assisting local farmers with coping and effective adaptation strategies in regard to unpredicted weather conditions and climate change at the local scale (Anchorage Declaration 2009; IPCC 2018; Masinde and Bagula 2011; Ncube and Lagardien 2015). In South Africa, several climate risk adaptation methods have been used, including the production of drought-resistant seeds, crop diversification, changing planting dates, early maturing crops, livestock diversification and water-harvesting (Maponya and Mpandeli 2013; South African National Biodiversity Institute (SANBI) 2013; Jiri *et al.* 2016). Studies conducted in west central Ethiopia, revealed that local farmers used indigenous knowledge indicators to predict the beginning and end of planting seasons. These include the presence of murky clouds, which indicate heavy rain to come and also an increase in insects (Demeke, Keil, and Zeller 2011; Mugambiwa 2018). Furthermore, the commonly-known Southern Ground hornbill (bird), as well as a moon with a halo are used as indicators of rain to come (Ziervogel and Opere 2010; Ajani, Mgbenka, and Okeke 2013).

The majority of Indigenous farmers in South Africa have used indigenous climate indicators for weather prediction and for better decision-making on their farms; this is of importance to climate change and coping strategies (Maponya and Mpandeli 2013; Jiri *et al.* 2016; Masinde and Bagula, 2011). Ubisi *et al.* (2017) reported that, in the Limpopo Province, extreme weather conditions have been experienced by farmers. Due to the poor circulation of climate science information in this province, the majority of local farmers use local knowledge as a means of combating climate change (Maponya and Mpandeli 2013; Ziervogel *et al.* 2014).

Climate variability and change present risks to agricultural production and challenges to smallholder farmers in Vhembe district. Adaptation to climate risks include anticipating change, planting new crops and taking action to reduce the adverse impacts on crop yield. However, scientific models are not cost-effective among the Indigenous farmers in counteracting climate risks for the local communities. Hence, a low level of educational background, lack of climate information and financial resources slow the adoption of smart agricultural techniques, principally those that require modern systems of operation and where investment costs are high. Ncube and Lagardien (2015) noted that it is important to pay attention to indigenous knowledge and to analyze its relationship with climate change and weather predictions. Hence, in the study areas, farmers depend solely on IKS as their adaptive strategy and they used it to predict harvesting and planting seasons, by looking at climate indicators. The South Africa Weather Service (SAWS) disseminates climate change information. Despite this, the weather forecast is limited among indigenous farmers and less cost effective for climate adaptation (Ziervogel *et al.* 2014).

In Limpopo Province, the response to climate change continues at an alarming rate as the impacts of climate variability unfold. Hence, in Vhembe district, gradual postponements in response to climate risks for the past decades have threatened crop production and farmers' livelihoods ((Maponya and Mpandeli 2013; Kom *et al.* 2022).

Climate change impacts on farming activities and crop production are becoming a major challenge for smallholder farmers. These impacts are common in semi-arid areas within the district, with approximately two-thirds of the agricultural land receiving an average annual precipitation of less than 450 mm during winter seasons (Maponya and Mpandeli 2012). High temperatures, prolonged drought and rainfall variability are the major drivers anticipated to have substantial impacts on crop production in Vhembe district. According to Afful and Ayisi (2020), climate forecasts have indicated that the occurrence and intensity of high temperatures, heatwaves, drought and rainfall variability will have negative implications for agricultural production.

Empirical studies have shown that smallholder farmers in Levubu and Nwanedi have used local climate indicators during the changing weather conditions, including mist-cover on mountains, movement of the stars and moon, presence of red and black ants and the appearance of certain plants (Ncube and Lagardien 2015; Maponya and Mpandeli 2012). Similar to weather projections based on scientific knowledge, indigenous knowledge also studies meteorological indicators, such as air temperature and wind movement (Ncube and Lagardien 2015). Scholars now agree that indigenous knowledge and scientific knowledge complement one another. As a result of poor adaptation strategies to climate change in Vhembe district, local farmers in Levubu and Nwanedi use indigenous knowledge indicators as a means of combating climate change and risk (Maponya and Mpandeli 2012). Hence, response from farmers in the study areas indicated the use of indigenous knowledge in weather forecasts within their communities.

Indigenous farmers in Vhembe district believe strongly in the socio-cultural knowledge of their ancestors in connection with extreme weather conditions and agricultural production and we should bear in mind that traditional beliefs and a sense of mythological guidance are paramount in rural areas. There is a strong argument for revamping indigenous resilience as a root for indigenous knowledge coping strategies. In doing so, avenues for debate and planning can be created for rural farmers to share and gain access about climate information in Vhembe district. Previous research testing conventional expertise used to tackle adverse weather events has also been performed at national or multi-regional levels in the rural farming systems in South Africa (Jordaan, Sakulski, and Jordaan 2013; Masipa 2017; Dube, Nhamo, and Chikodzi 2021). Not only are the results of such studies widely aggregated, but they are too common and only useful for rural farmers who are highly localized in terms of the risks of climate change. This paper sought to inform locals and national policymakers on how rural farmers employ indigenous knowledge indicators as a coping and adaptation strategy to combat climate change in Vhembe district. In doing so, we believe the analysis will enable policymakers and practitioners to strengthen adaptation activities, as well as implement and interact within indigenous expertise.

2. Methodology

2.1. Profile of the study area

The study area is located in Vhembe district, Limpopo Province. The district is situated in the extreme Northern part of Limpopo Province, with agricultural activities as the main occupation of the rural communities. This district is subdivided into four municipal areas, namely, Makhado, Musina, Thulamela and Mutale (Figure 1) (Municipal Demarcation Board Annual Report, 2005/2006, South Africa; Vhembe

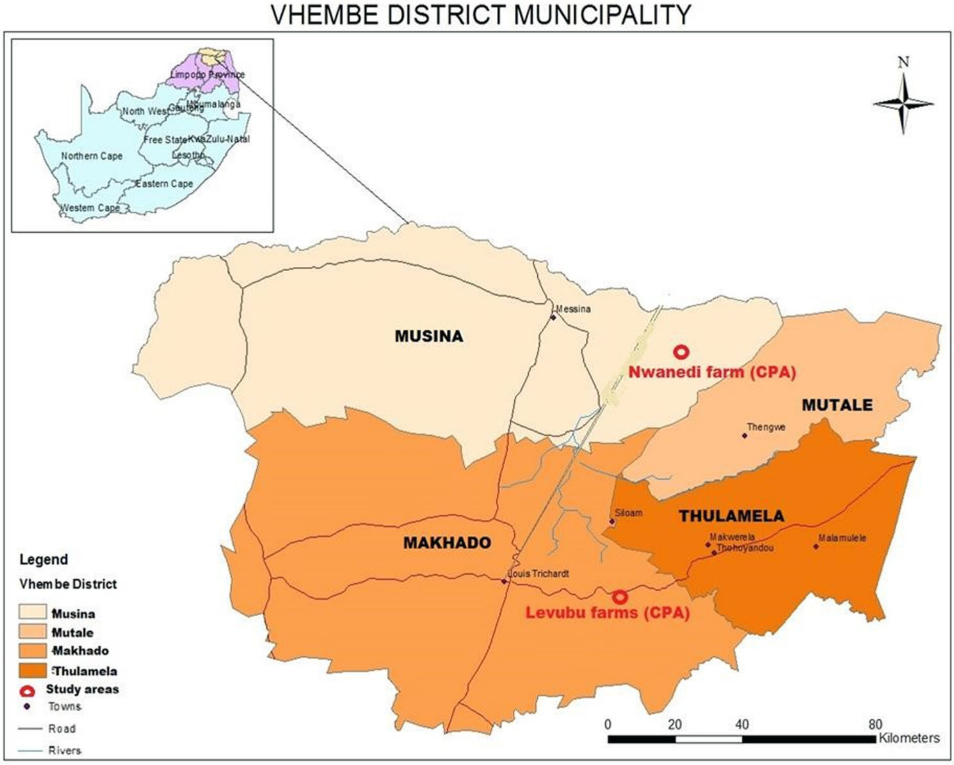

Figure 1. Location of the study area.

District (VD) 2012/2013). The district shares borders in the North East with Botswana, Zimbabwe in the North, and Kruger National Park in the East. This district covers a total surface area of 25,597 square km (9,883 square miles) of land. Its climate ranges from the tropical dry desert conditions to the south of Zimbabwe to the tropical rainy area extending to the coastal plain of Mozambique. Rainfall is unevenly distributed, with an estimate of about 90% occurring during the months of October to April, usually, intense on isolated rainy days and in some areas. Rainfall also varies significantly from year to year, as reported by the Department of Environmental Affairs and Tourism (DEAT) and Department of Environmental Affairs (DEA) (DEAT 2014; Department of Environmental Affairs (DEA) 2015). This spatial and uneven distribution of rainfall, limits agricultural activities, in particular crop production. The major agricultural production sectors in the district face climate change challenges, through prolonged drought and flooding. The area's climatic conditions are generally hot and humid, receiving the bulk of its annual rainfall in November through to January, in line with the Inter Tropical Convergence Zone (I.T.C.Z), as it moves south (Kabanda 2004; Kephe *et al.* 2016).

In Vhembe district, climatic conditions have influenced the yield of crops, such as, sweet potatoes, beans, maize, spinach, ground nuts and tomatoes. The annual minimum temperatures for the area vary, from 10 °C during winter, whereas in summer the maximum varies between 34 °C to 38 °C. Parts of Musina and Makhado rural municipalities, which are predominantly semi-arid, frequently experience prolonged droughts and this is where Levubu and Nwanedi area are located.

2.2. Research design and sampling technique

A multi-stage sampling technique was used to select farming households for the study. The first stage involved the selection of a district within the province, since it was not possible to survey all the farmers practicing smallholder farming. The second stage involved splitting the district into two case study areas, Nwanedi and Levubu; the final stage involved random selection of households practicing smallholder farming. A simple sample approach was used by splitting the district into smaller overlapping areas and then picking a number of these smaller areas randomly (households in the agricultural basins), with the final samples covering the entire district. A sample size of 400 rural farmers was selected from the two study sites, comprising farmers in Levubu and Nwanedi, as the case study sites in the district (Table 1).

The purposeful sample technique was used to identify individual farmers who are knowledgeable and have experience regarding climate change and indigenous knowledge indicators. While the snowball sample technique was used to select information related to aspects of climate change, as existing respondents provided referral to recruiting other farmers. The purposeful and snowball sampling methods were used to select a sample of 400 households. Indigenous knowledge and perceptions on adaptation to climate variability effects vary from one study area to another. The sampling methods used enabled the researcher to obtain a great deal of information from respondents. The investigation was used to collect extensive data on households' traditional knowledge and perceptions to changes in climate. This enabled triangulation of the respondents' response. An exploratory research method was used to collect data among farming households. Exploratory research is a useful technique to gain an in-depth-understanding and discover new philosophies about indigenous knowledge and climate subject matter (Hair *et al.* 2003). In addition, this technique was used as a tool to probe the explanations for changes in climate and traditional strategies used to cope, among rural farmers in Vhembe district.

Table 1. Farmers' indigenous Knowledge indicators for agricultural Weather Forecasting (Sources: Jiri *et al.* 2016; Mafongoya and Ajayi 2017).

Indicators	Meaning according to the rural farmers
Flower and fruit production of rural trees	Many rural trees produce flowers and fruit at the beginning of the season, which is a good sign of a good rainy season
Star and moon movement	Movement of stars from west to east at night under clear skies means rain will fall in a few days time/ good raining days
Wind movement	Winds moving from west to east show the beginning of rainfall
Behavior of certain plants unfurling of new leaves on baobab tree	This tree is common in the Limpopo province; unfurling of new leaves on the baobab tree is an indication of a heavy rainy season
Mist-covered mountains	Showing sign of good rains for a few days to come
Appearance of red ants	Substantial rainfall is coming
Black ants	Appearance of too many black ants is a sign that it was a good rainy season, so farmers can start planting.
Cloud formation	Presence of dark cloud indicates rainfall

2.3. Data collection methods

Data were collected from both primary and secondary sources. Secondary data were collected from journal papers, symposium papers and books, while, primary data were gathered through questionnaires, semi-structured interviews, focus group discussions, transect observations and oral history. During the systematic observation, the researcher shared indigenous knowledge systems about climate change among the rural farmers in the areas. For this paper, the sample size helped to reduce costs and time, and the physical concerns of the dispersed farmers. To determine precision and accuracy, criteria were used to determine the appropriate sample size. A confidence level of 95% and 5% level of correctness were used for the survey to reduce bias, mistakes and increase validity, so that inferences can be made for the whole target unit of analysis

The majority of the respondents were interviewed in order to gather in-depth information. During the interview sessions, the researcher deduced the adaptation strategies employed by the indigenous people to combat changes in climate, and as well as their perceptions on the changes in their natural environment. Selected household heads were used by the study during the interviews to answer the questionnaire. During the focus group discussions and interviews, questions about household demographic attributes were asked; for example, farming experience in years, educational level, gender and household income. The data collected during the group discussions and face-to-face interviews, farmers' perceptions and knowledge from the questionnaires were triangulated.

The focus group discussions were employed to collect in-depth qualitative data about the participants' perceptions, altitudes and experiences on the subject under investigation. In this study, two focus group discussions were used to gather in-depth qualitative information on farming households' climate coping strategies and perceptions of weather conditions. The focus group discussions were made up of tribal heads and elders (both male and female). These focus group talks were undertaken with between 4 – 8 Indigenous people in each group practicing local farming. Each focus group discussion was moderated by the investigator and two research assistants who were able to converse in the local dialects. In group discussions, the investigator employed checklist aspects such as local weather indicators and farmers' perceptions with regard to climate change, negative impacts on crops, farmers' responses and choice of adaptation approach. On the other hand, research assistants were also employed to achieve more effective communication with farmers, because the investigator could not speak the local languages. Further, during group discussions more attention was taken to intentionally interview indigenous farmers who were involved in practicing crop cultivation and had been using traditional practices against climate change for more than 10 years; hence, the smallholder farmers were selected into groups based on their experience, farming system, adaptation methods used and perceptions toward climate change.

Data were further collected through questionnaires. Respondents were asked questions such as *How do you perceive climate variability and change around you? What are some coping and adaptation strategies employed by indigenous farmers to combat climatic stressors?* The study areas (Levubu and Nwanedi) are highly vulnerable to extreme climate events. Despite this, farmers are using IKS coping approach to minimize the negative impact of climate trends on agricultural activities. These two study communities are representative in the sense that they share the same experiences with all other indigenous farmers in Vhembe district

The criteria used for selecting both respondents for interview and focus group discussions included, age of the farmers, and years of experience in farming activities in the areas. These aspects were used to understand farmers' perceptions about climate change and indigenous farming practices in the district. The study focused on respondents who were either aged 45 years and above or have been farming in the area for at least 10 years or more. The purpose for the age limit was to engage respondents who were capable of giving a comparative description of climate change over a long period.

In South Africa, there have been a lot of efforts to adapt and cope with environmental change and climatic stressors as a result of the changing temperatures, heatwaves and low rainfall. Local farmers in the Limpopo Province have cultivated several different crops which are resistant to extreme weather events, and they often supplement these by fishing and gathering wild fruit. The major adaptation practices used by indigenous people in Levubu and Nwanedi included adjustments to planting dates, irrigation practice, shifting to climate-resistant crops, using native plant varieties and ultimately migration to nearby towns for non-farming activities, if all else fails.

However, participation in the study was solely voluntary and an informed consent form was signed before data collection. Data were collected by research assistants and the investigator using a questionnaire administered from October 2019 to June 2020 which is the planting and harvest season. All Covid-19 pandemic protocols were fully observed (facemasks, social distancing and use of hand sanitiser).

2.4. Data analysis

Data were collected using interviews, questionnaire and focus group discussions. Qualitative analysis entailed assessing the perceptions on climate change among respondents through interviews and focus group discussions. While quantitative data were analyzed using the Microsoft Excel 2010 statistical package. This paper used content and ethnographic analytic techniques; both recommended to analyze data from focus group discussions. Thematic content analysis enables a systematic coding of data by organizing the information into categories to discover patterns undetectable by merely listening to the tapes or reading the transcripts. Content analysis operates by breaking down the data collected into various topics and this method was employed to analyze the use, by participants, of indigenous knowledge strategies to adapt to climatic stressors. The ethnographic technique analyses the participants' behaviors and culture. This provided rich and in-depth analytical data, which drew primarily on direct quotes from the group discussions. The data were then coded and classified into different categories, which were used to analyze the adaptation of IKS practices to avert unfavorable climate conditions in the district.

3. Results and discussion

3.2. Indigenous knowledge perceptions and weather indicators

This paper used perception as a way of everyday and long-term interaction with the farmers to process raw data into actual trends. Indigenous understanding depends not only on the identity of the respondents but also on the culture, atmosphere and relationship between these components (Jamshidi *et al.* 2018; Mugambiwa 2018). For studies on indigenous awareness, perceptions of environmental and ecological changes in the Vhembe district of South Africa and the climate were needed to assess the degree of climate change awareness of farmers. One-third, which represented 33.2% of farmers, have a *very high level* of climate change knowledge, 50.8% have *a high level*

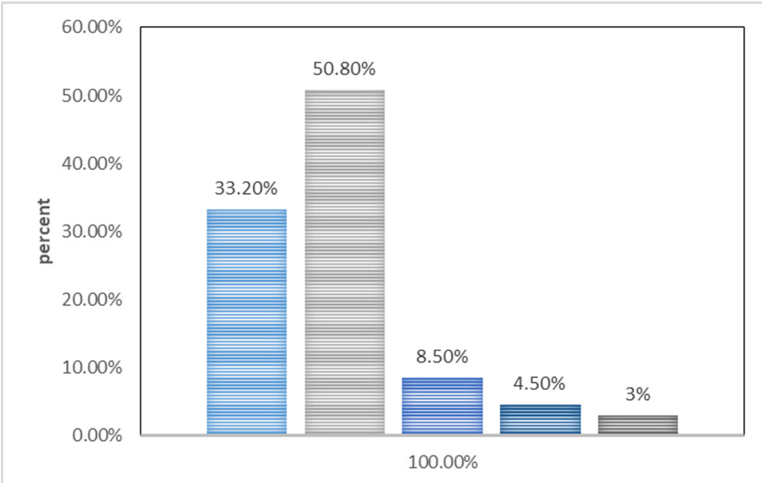

Figure 2. Levels of indigenous knowledge on climate change.

of knowledge, 8.5% have a *very low level*, 4.5% have a *low level*, and only 3% have *no knowledge* (Figure 2).

A significant component of the concept of ethno-meteorology is indigenous knowledge of weather forecasting. It is based on traditional ecological understanding transmitted from generation to generation (Fernández-Llamaz *et al.* 2015; Jiri *et al.* 2016; Mugambiwa and Rukema 2019). During focus group discussions, it was evident that farmers in Nwanedi and Levubu have historically utilized a number of indigenous indicators for weather forecasts based on socio-cultural and environmental beliefs, but with limited documentation. During the field survey, major indicators employed by farmers for forecasting weather and climate change were analyzed. These indicators were used to make farm-level decisions concerning farming systems, such as planting time and the selection of crop types. Such decisions may be based on unreliable information used at the beginning of planting; however, farmers realize that at the beginning of the rainy season the rains give them an idea of how the remainder of the growing season will unfold. Erratic rainfall may trigger misinformation and deceive farmers, as the dry season may be extended. For example, the flowering and leaf sprouting of the Senegali species is characterized as a sign of the summer season. In addition to this plant phenology, at the beginning of September, the presence of stars, the moon, and sun are carefully observed, signaling the beginning of a new season (Nganzi *et al.* 2015; Kimani, Ogendi, and Makenzi 2014; Chambers *et al.* 2019). Also, swarms of dragonflies that migrate east from September to November are another visible sign of the cessation of the rainy season. Farmers in Vhembe district are able to interpret weather signals by the actions of certain plants in the absence of traditional weather forecasting. Also, during group discussions, a respondent in Nwanedi asserted that his great grandfather handed him the interpretation of weather condition signs from the behavior of both plants and animals. Indigenous wisdom shared by forefathers who have learned agricultural expertise, is a long-standing and proven weather forecast know-how from which farmers have benefited. A similar study carried out in South Africa by Mpandeli, Nesamvuni, and Maponya (2015) and *Jiri et al.* (2016), reported that, star movement from west to east at night under clear skies means rain will pour down for a few days to come.

Table 2. Some weather indicators used by farmers for decision-making.

Weather indicators	Percent
Flower and fruit production of rural trees	64%
Wind movement	44%
Behavior of certain plants – unfurling of new leaves on baobab tree	72%
Mist-covered mountains	52%
Appearance of red ants	70%
Black ants	30%

With increasing climate variability and first-rain uncertainty, most of the decisions made by Levubu and Nwanedi Indigenous farmers are based on personal experience. Results gathered from questionnaires indicated that an average of 63.7% percent of respondents in the study site employed IKS to forecast the quality of the planting season so as to make informed farming decisions and manage crops in the changing climatic environment. Results in Table 2 indicate that a total of 64% of farmers used flowers for weather forecasting in deciding to change planting dates (Jiri *et al.* 2016; Masinde 2015; Nganzi *et al.* 2005), while 44% and 72% used wind movement and behavior of new leaves on baobab trees, respectively to indicate the potential for rain in a few days' time. This result concurs with a study conducted by Balehegn *et al.* (2019) and Akullo *et al.* (2007) who used indigenous weather and climate forecasting in eastern Ethiopia. For both mist-covered mountains and the appearance of red ants, 52% narrated that these were used as a potential drought season indicator. Only 30% of the participants used black ants as an indicator of good rain at the beginning of the rainy season to indicate that farmers should get ready for planting. The results of this paper, concur with those of other studies carried out in Limpopo Province, South Africa, by Ncube and Lagardien (2015) and Jiri *et al.* (2016), who reported that black clouds, according to Indigenous farmers, mean that heavy rain is approaching.

3.3. Indigenous knowledge system (IKS) use in managing climate change

The Vhembe district, which is also branded as a drought-prone district in the Limpopo Province, is not unique to high temperature occurrences and declining seasonal rainfall. The manner in which rural farmers understand climate changes are materially different from theoretical and western knowledge (scientific approach). Farmers' preference is for signs as traditional networks of weather information are limited, with only a few functioning weather stations in the district of Vhembe. Traditional awareness of the climate conditions in the study area could have influenced the way in which most rural farmers responded to the various impacts of climate variability and change.

The results reveal the role of traditional knowledge practices in climate change strategies. Rural farmers have limited knowledge about the concept of climate variability and change, although, they have observed and experienced changes, such as decreasing rainfall, early cessation of rainfall, increases in temperature, frequency of drought, and shorter growing seasons. During interviews, the majority of respondents (64%) in the district, employed IKS weather forecasting to grow crops and adopt specific farming operations based on the signs in the environment. This finding is similar to the study conducted by Kom *et al.* (2022), which indicated climate change grounded on empirical evidence, as compared with the perceptions of rural farmers in Vhembe district. Despite these huge challenges from climatic changes, rural farmers still use their indigenous knowledge techniques to cope and adapt. Indigenous farmers, however, are highly vulnerable to the effects of climate change and have low adaptive capacity (Egeru 2011; Jiri *et al.* 2016; Chambers *et al.* 2019). These rural farmers have developed a variety of socio-economic responses that have created the basis for their resilience to climate change; therefore, a strong argument can be made for revamping indigenous-based resilience as a root for coping and adaptation techniques.

The findings revealed that indigenous knowledge plays a major role in weather forecasting and farming decisions in crop planting. This concurs with results of studies carried out in Limpopo and Western Cape Provinces, South Africa (Ziervogel *et al.* 2014; Ncube and Lagardien 2015; Jiri *et al.* 2016). The results also indicated that the presence of morning mist on mountains is a sign of good rains in a few days to come; hence, the farmers prepare the farms for planting. Similar findings were obtained from the studies conducted in Vhembe district (Maponya and Mpandeli 2013). The findings also, indicated that about 72% of farmers both in Nwanedi and Levubu used tree characteristics as indicators within traditional forecasting systems; and 56% indicated that they used other indicators, such as the movement of stars. This movement of stars under clear skies means rain will fall in a few days to come; 90% of respondents in Nwanedi indicated, that the unfurling of new leaves on the baobab tree is a sign of a heavy rainy season. This concurs with studies done in Southern Africa (Kaland-Joshua *et al.* 2011). Older farmers in Nwanedi and Levubu reported that winds moving from west to east show the occurrence of rain within 12 h. During the focus-group discussion, participants also revealed that the behavior of insects sometimes predicts the occurrence of crop disease challenges during the planting season. This study, therefore concludes that in order to cope and adapt, rural farmers had employed a variety of IKS indicators to plan and manage crop production practices (Briggs and Moyo 2012; Enock 2013; Jiri *et al.* 2016).

3.4. Indigenous adaptation strategies

The results of this study indicated that farmers used several adaptation methods to combat climate change and variability within the study areas; these include planting drought resistant crops, shifting from long-season crops to short-season crops, adjustment of planting calendars, using local irrigation strategies and planting native plant varieties.

During the focus group discussions and interview sessions, local farmers in the Levubu river valley suggested water harvesting and constructing local small dams for irrigation during prolonged drought as an active adaptive strategy in response to climate risks. Farmers in both study areas stated numerous adaptive methods that they had engaged in to combat climate risks. One of the methods used was shifting from long sowing seasons to short season crops to cope with the fluctuating seasons. Farmers in Levubu used to plant maize in September, but as a result of climate change, they have changed the sowing period for maize to the beginning of November. This finding is in line with the study conducted by Ambrosino, Chandler, and Todd (2011) and Mugambiwa (2018) that additionally, climate variability in southern Africa has caused uncertainty and adjustments to the planting calendar,

Also, farmers select crops that are resistant to drought within the local areas. The results also indicated that beans, sweet potatoes and maize crops were more tolerant to prolonged drought relative to other crops. Farmers, hence, practice crop diversification and more maize and beans were planted within farms, as local ways to reduce climatic hazard and increase crop production in such unpredictable climate change (Kijazi *et al.* 2013; Jiri *et al.* 2016; Kom *et al.* 2020).

Another adaptation method used by Indigenous animal farmers was to increase livestock size. Local farmers have increased the number of livestock by having a higher diversity of animals, as compared to past years, to reduce the impact of climate risk and improve income diversification. The findings are similar to those of Kalanda-Joshua *et al.* (2011), in Mulanje in Southern Malawi.

During focus group discussions farmers in Nwanedi area indicated that they mainly planted drought-resistant crops, such as sweet potatoes, onions, ginger and Bambara ground nut to combat the effects of the prolonged drought spells. The participants stated that this was, in part, guided by indigenous knowledge systems (Mafongoya *et al.* 2017).

4. Conclusions and policy implications

This study examined the use and existence of IKS in regard to adaptation as a means to minimize the effects of climate change and for weather forecasting among indigenous farmers in Levubu and Nwanedi communities. The farmers employed wind movement, presence of black ants, flowering and fruit production of local trees and the appearance of red ants to predict weather conditions. The study further identified Indigenous people's perceptions of climate change within their specific local area as including signs, such as increases in temperature, heatwaves, prolonged drought spells and reductions in rainfall. The study also demonstrated in what way indigenous knowledge has been beneficial in the formulation of adaptation strategies for diverse climate stressors, such as planting drought-resistant crops, shifting from long-season crops to short-season crops, adjustment of planting calendars, using local irrigation strategies and planting native plant varieties.

The use of indigenous knowledge systems for weather predicting strategies meaningfully enriches adaptive capacity in the locality as the majority of the indigenous farmers do not have access to western methodical weather service information and they have little or no know-how to interpret meteorological data. With the acknowledged importance of IKS as an adaptive strategy, there is a need for support from the national institutions and municipal authorities through climate policy and frameworks.

In South Africa, a comprehensive set of policies that allow climate change adaptation in the natural environment is needed. Current policies include the National Climate Change Response Strategy (NCCRS), the Integrated Rural Development Programme (IRDP); however, these enacted legislation and policy frameworks say little about the significant role played by indigenous knowledge in climate risk adaptation methods (Mokwena 2009; Department of Agriculture and Forestry and Fisheries (DAFF) 2015; Department of Environmental Affairs (DEA) 2015).

This paper has clearly demonstrated how Indigenous farmers still rely on indigenous knowledge systems as a method of climate change adaptation, in managing crop yields under extreme weather events. There is a decreasing recognition of traditional knowledge as farmers are losing confidence in their indigenous knowledge systems; however, lack of interest by the stakeholders about IKS practices has also made the implementation of some of the coping and adaptation strategies challenging.

There is an immediate need to engage in capacity-building projects to enable younger and apprentice farmers to access services that are required to boost their capacity to respond to climate change. The findings revealed that indigenous knowledge has been somehow abandoned and might disappear; this is a real danger as no measures have been employed to research its contribution to the current adaptation strategies to adverse climate change. Therefore, it is recommended, the two systems of knowledge need to be blended. It is not recommended that conventional and indigenous knowledge should replace modern scientific knowledge in order to ensure local farming's sustainable growth in Vhembe district. In addressing environmental problems, all information systems should be used simultaneously in order to achieve sustainable activities for the environment and better livelihoods.

Disclosure statement

No potential conflict of interest was reported by the authors.

ORCID

Zongho Kom http://orcid.org/0000-0002-3294-8651

References

Adger, W. N., J. Barnett, F. S. Chapin, and H. Ellemor. 2011. "This Must Be the Place: Underrepresentation of Identity and Meaning in Climate Change Decision-Making." *Global Environmental Politics* 11 (2): 1–8. doi:10.1162/GLEP_a_00051.

Afful, D. B., and K. Ayisi. 2020. "Farmers' Perceptions of Climate Variability, Their Adaptation Strategies and Agricultural Productivity: A Case of Limpopo Province, South Africa." *South African Journal of Agricultural Extension* 48: 36–49.

Ajani, E. N., R. N. Mgbenka, and M. N. Okeke. 2013. "Use of Indigenous Knowledge as a Strategy for Climate Change Adaptation among Farmers in Sub-Saharan Africa: Implications for Policy." *Asian Journal of Agricultural Extension, Economics & Sociology* 2 (1): 23–40. doi:10.9734/AJAEES/2013/1856.

Akullo, D., K. Kanzikwera, P. Birungi, W. Alum, L. Aliguma, and M. Barwogeza. 2007. "Indigenous Knowledge in Agriculture: A Case Study of the Challenges in Sharing Knowledge of past Generations in a Globalized Context in Uganda." World Library and Information Congress, Durban, South Africa. Accessed January 27 2021. http://www.ifla.org/iv/ifla73/index.htm.

Ambrosino, C., R. Chandler, and M. Todd. 2011. "Southern African Monthly Rainfall Variability: An Analysis Based on Generalized Linear Models." *Journal of Climate* 24 (17): 4600–4617. doi:10.1175/2010JCLI3924.1.

Anchorage Declaration 2009. "Declaration Agreed by Consensus of the Participants in the Indigenous Peoples' Global Summit on Climate Change, Anchorage Alaska, April 24th 2009." Indigenous Peoples' Global Summit on Climate Change, Anchorage, Alaska.

Balehegn, M., S. Balehey, C. Fu, and W. Liang. 2019. "Indigenous Weather and Climate Forecasting Knowledge among Afar Pastoralists of North Eastern Ethiopia: Role in Adaptation to Weather and Climate Variability." *Pastoralism* 9 (1): 8–14. doi:10.1186/s13570-019-0143.

Berkes, F. 2012. *Sacred Ecology*, 3rd ed. New York: Routledge.

Braman, L. M., M. K. Van Aalst, S. J. Mason, P. Suarez, Y. Ait-Chellouche and A. Tall. 2013. "Climate Forecasts in Disaster Management: red Cross Flood Operations in West Africa 2008." *Disasters* 37: 144–64.

Briggs, John, and Boyson Moyo. 2012. "The Resilience of Indigenous Knowledge in Rural African Agriculture: Key Drivers." *Scottish Geographical Journal* 128 (1): 64–80. doi:10.1080/14702541.2012.694703.

Chambers, Lynda, Siosinamele Lui, Roan Plotz, David Hiriasia, Philip Malsale, Rossylynn Pulehetoa-Mitiepo, Melinda Natapei, *et al.* 2019. "Traditional or Contemporary Weather and Climate Forecasts: Reaching Pacific Communities." *Regional Environmental Change* 19 (5): 1521–1528. doi:10.1007/s10113-019-01487-7.

Demeke, A. B., A. Keil, and M. Zeller. 2011. "Using Panel Data to Estimate the Effect of Rainfall Shocks on Smallholders Food Security and Vulnerability in Rural Ethiopia." *Climatic Change* 108 (1-2): 185–206. doi:10.1007/s10584-010-9994-3.

Department of Agriculture, Forestry and Fisheries (DAFF). 2015. Vegetable Crops. Accessed April 29 2021. www.http://www.daff.gov.za/publications.

Department of Environmental Affairs (DEA). 2015. "Long-Term Adaptation Scenarios Flagship Research Programme (LTAS) for South Africa: Phase 2, Report no. 3: Climate Change Adaptation: Disaster Risk Reduction and Management: Provisional Frameworkling of Drought, Flood and Sea Level Rise Impacts and a Description of Adaptation Responses." Accessed February 12 2021. https://www.environment.gov.za/sites/default/files/docs/ltasphase2report3_adaptation_ddrm.pdf

Department of Environmental Affairs and Tourism (DEAT). 2010. *National Climate Change Response Strategy for South Africa*. Pretoria: DEAT.

Deressa, T. T., R.M. Hassan, C. Ringler, T. Alemu, and M. Yesuf. 2009. "Determinants of Farmer's Choice of Adaptation Methods to Climate Change in the Nile Basin of Ethiopia." *Global Environmental Change* 19 (2): 248–255. doi:10.1016/j.gloenvcha.2009.01.002.

Dube, K., G. Nhamo, and D. Chikodzi. 2021. "Flooding Trends and Their Impacts on Coastal Communities of Western Cape Province, South Africa." *GeoJournal*. doi:10.1007/s10708-021-10460-z.

Egeru, A. 2011. "Role of Indigenous Knowledge in Climate Change Adaptation: A Case Study of the Teso Sub-Region." *Eastern Uganda. Indian Journal of Traditional Knowledge* 11 (2): 217–224.

Enock, C. M. 2013. "Indigenous Knowledge Systems and Modern Weather Forecasting: Exploring the Linkages." *Journal of Agriculture and Sustainability* 2 (1): 98–141.

Fernández-Llamaz, Á., I. Díaz-Reviriego, A.C. Luz, M. Cabeza, A. Pyhälä, and V. Reyes-Garcia. 2015. "Rapid Ecosystem Change Challenges the Adaptive Capacity of Local Environmental Knowledge." *Global Environmental Change: Human and Policy Dimensions* 31: 272–284. doi:10.1016/j.gloenvcha.2015.02.001.

Finucane, M. 2009. "Why Science Alone Won't Solve Climate Crisis: Managing the Climate Risks in the Pacific." *Asia Pacific Issues* 89: 1–8.

Gyampoh, B. A., S. Amisah, M. Idinoba, and J. Nkem. 2009. "Using Traditional Knowledge to Cope with Climate Change in Rural Ghana." *Unasylva (English ed.)* 60: 70–74.

Hair, B., B. J. Babin, A. H. Money, and P. Samouel. 2003. *Essentials of Business Research*. New York: Wiley.

Ingty, T. 2017. "High Mountain Communities and Climate Change: Adaptation, Traditional Ecological Knowledge, and Institutions." *Climatic Change* 145 (1–2): 41–15. doi:10.1007/s10584-017-2080-3.

Intergovernmental Panel on Climate Change (IPCC). 2018. "Summary for Policymakers." In *Global Warming of 1.5 °C. An IPCC Special Report on the Impacts of Global Warming of 1.5 °C above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty* (MassonDelmotte, V., Zhai, P., Pörtner, H.O., Roberts, D., Skea, J., Shukla, P.R., Pirani, A., Moufouma-Okia, W., Péan, C., Pidcock, R. Eds.). Geneva, Switzerland: World Meteorological Organization.

Intergovernmental Panel on Climate Change (IPCC). 2013. "Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation: A Special Report on Working Group I and Working Group II of the Intergovernmental Panel on Climate Change, 2010." Accessed January 10 2021). http://www.ipcc.ch/ipccreports/ar4-system.

Jamshidi, O., A. Asadi, K. Kalantari, and H. Azadi. 2018. "Perception, Knowledge and Behaviour towards Climate Change: A Survey among Agricultural Professionals in Hamadan Province, Iran." *Journal of Agricultural Science Technology* 20: 1369–1382.

Jiri, O., P. L. Mafongoya, C. Mubaya, and O. Mafongoya. 2016. "Seasonal Climate Prediction and Adaptation Using Indigenous Knowledge Systems in Agriculture Systems in Southern Africa: A Review." *Journal of Agricultural Science* 8 (5): 156–172. doi:10.5539/jas.v8n5p156.

Jordaan, A. J., D. Sakulski, and A. D. Jordaan. 2013. "Interdisciplinary Drought Risk Assessment for Agriculture: The Case of Communal Farmers in the Northern Cape Province, South Africa." *South African Journal of Agricultural Extension* 14: 44–58.
Joshua, M. K., C. Ngongondo, L. Chipeta, and F. Mpembeka. 2011. "Integrating Indigenous Knowledge with Conventional Science: Enhancing Localised Climate and Weather Forecasts in Nessa, Mulanje, Malawi." *Physics and Chemistry of the Earth, Parts A/B/C* 36 (14/15): 996–1003. doi:10.1016/j.pce.2011.08.001.
Jury, M. R. 2013. "Climate Trends in Southern Africa." *South African Journal of Science* 109 (1/2): 1–11.
Kabanda, T. A. 2004. "Climatology of Long-Term Drought in the Northern Region of the Limpopo Province of South Africa." PhD Thesis, Unpublished, School of Environmental Sciences, University of Venda, South Africa.
Kalanda-Joshua, M., C. Ngongondo, L. Chipeta, and F. Mpembeka. 2011. "Integrating Indigenous Knowledge with Conventional Science: Enhancing Ruralised Climate and Weather Forecasts in Nessa, Mulanje, Malawi." *Physics and Chemistry of the Earth Parts A/B/C* 36 (14): 996–1003. doi:10.1016/j.pce.2011.08.001.
Kephe, P. N., M. B. Petja, and T. A. Kabanda. 2016. "Spatial and Inter-Seasonal Behaviour of Rainfall in the Soutpansberg Region of South Africa as Attributed to the Changing Climate." *Theoretical and Applied Climatology* 126 (1-2): 233–245. doi:10.1007/s00704-015-1569-9.
Kijazi, A. L., L. B. Chang'a, E. T. Liwenga, A. Kanemba, and S. J. Nindi. 2013. "The Use of Indigenous Knowledge in Weather and Climate Prediction in Mahenge and Ismani Wards, Tanzania." *Journal of Geography and Regional Planning* 6 (7): 274–280. doi:10.5897/JGRP2013.0386.
Kimani, E. W., G. M. Ogendi, and P. M. Makenzi. 2014. "An Evaluation of Climate Change Indigenous Coping and Adaptation Strategies for Sustainable Agro-Pastoral Based Livelihoods in Baringo County, Kenya." *IOSR Journal of Environmental Science, Toxicology and Food Technology* 8 (8): 38–59. doi:10.9790/2402-08833858.
Kimmerer, R. 2002. "Weaving Traditional Ecological Knowledge into Biological Education: A Call to Action." *BioScience* 52 (5): 432–438. doi:10.1641/0006-3568(2002)052[0432:WTEKIB.2.0.CO;2]
Kom, Z., N. S. Nethengwe, S. Mpandeli, and H. Chikoore. 2020. "Climate Change Grounded on Empirical Evidence as Compared with the Perceptions of Smallholder Farmers in Vhembe District, South Africa." *Journal of Asian and African Studies* 55 (5): 683–698. doi:10.1177/0021909619891757.
Kom, Z., N. S. Nethengwe, S. Mpandeli, and H. Chikoore. 2022. "Determinants of Small-Scale Farmers' Choice and Adaptive Strategies in Response to Climatic Shocks in Vhembe District, South Africa." *GeoJournal* 87 (2): 677–700. doi:10.1007/s10708-020-10272-7.
Mafongoya, P. L. and Ajayi, O. C. (Eds) 2017. *Indigenous Knowledge Systems and Climate Change Management in Africa*. Wageningen: CTA, 316.
Mafongoya, P. L., O. Jiri, C. P. Mubaya, and O. Mafongoya. 2017. "Using Indigenous Knowledge for Seasonal Quality Prediction in Managing Climate Risk in Sub-Saharan Africa." In *Indigenous Knowledge Systems and Climate Change Management in Africa*, edited by P. L. Mafongoya, and O. C. Ajayi, 43–66. Wageningen, the Netherlands: CTA
Maldonado, Julie, T. M. Bull Bennett, Karletta Chief, Patricia Cochran, Karen Cozzetto, Bob Gough, Margaret Hiza Redsteer, Kathy Lynn, Nancy Maynard, and Garrit Voggesser. 2016. "Engagement with Indigenous Peoples and Honoring Traditional Knowledge Systems." *Climatic Change* 135 (1): 111–126. doi:10.1007/s10584-015-1535-7.
Maponya, P. I., and N. S. Mpandeli. 2013. "Perception of Farmers on Climate Change Adaptation in Limpopo Province of South Africa." *Journal of Human Ecology* 42 (3): 283–288. doi:10.1080/09709274.2013.11906602.
Maponya, P., and S. Mpandeli. 2012. "Climate Change and Agricultural Production in South Africa: Impact and Adaptation Options." *Journal of Agricultural Science* 4 (10): 48–60. doi:10.5539/jas.v4n10p48.
Masinde, M. 2015. "An Innovative Drought Early Warning System for Sub-Saharan Africa: Integrating Modern and Indigenous Approaches." *African Journal of Science, Technology, Innovation and Development* 7 (1): 8–25. doi:10.1080/20421338.2014.971558.

Masinde, M., and A. Bagula. 2011. “ITIKI: Bridge between African Indigenous Knowledge and Modern Science of Drought Prediction.” *Knowledge Management for Development Journal* 7 (3): 274–290. doi:10.1080/19474199.2012.683444.

Masipa, Tshepo S. 2017. “The Impact of Climate Change on Food Security in South Africa: Current Realities and Challenges Ahead.” *Jamba (Potchefstroom, South Africa)* 9 (1): 411. doi:10.4102/jamba.v9i1.411.

McPherson, J. M., D. J. Sammy, J. Sheppard, T. A. Mason, J. Brichieri-Colombi, and A. Moehrenschlager. 2016. “Integrating Traditional Knowledge When It Appears to Conflict with Conservation: Lessons from the Discovery and Protection of Sitatunga in Ghana.” *Ecology and Society* 21 (1): 24. doi:10.5751/ES-08089-210124.

Mokwena, L. 2009. *Municipal Response to Climate Change in South Africa: The Case of eThekwini, the City of City Cape Town, and the City of Johannesburg*. Johannesburg: Centre for Climate Studies.

Mpandeli, S., E. Nesamvuni, and P. Maponya. 2015. “Adapting to the Impacts of Drought by Smallholder Farmers in Sekhukhune District in Limpopo Province, South Africa.” *Journal of Agricultural Science* 7 (2): 115–124. doi:10.5539/jas.v7n2p115.

Mugambiwa, S. S. 2018. “Adaptation Measures to Sustain Indigenous Practices and the Use of Indigenous Knowledge Systems to Adapt to Climate Change in Mutoko Rural District of Zimbabwe.” *Jamba (Potchefstroom, South Africa)* 10 (1): 388. doi:10.4102/jamba.v10i1.388.

Mugambiwa, S. S., and J. R. Rukema. 2019. “Rethinking Indigenous Climate Governance through Climate Change and Variability Discourse by a Zimbabwean Rural Community.” *International Journal of Climate Change Strategies and Management* 11 (5): 730–743. doi:10.1108/IJCCSM-11-2018-0074.

Municipal Demarcation Board Annual Report. 2005/2006. South Africa. Accessed May 21 2018. http://www.demarcation.org.za.

Naci, R. 2009. *Traditional Peoples and Climate Change. Planning for Climate Change*. 1st ed. New York: Routledge.

Ncube, B., and A. Lagardien. 2015. *Insights into Indigenous Coping Strategies to Drought for Adaptation in Agriculture: A Karoo Scenario*. Cape Peninsula University of Technology, Cape. https://www.wrc.org.za/wp-content/uploads/mdocs/2084-1-14.pdf

Nganzi, P., T. C. Kajumba, M. Barihaihi, J. Bataze, and G. Mujuni. 2005. *Use of Indigenous Knowledge in Weather Forecasting in Uganda: National Survey Uganda National Meteorology Authority*. Kampala, Uganda: Uganda National Meteorology Authority.

Nganzi, P., T. C. Kajumba, M. Barihaihi, J. Bataze, and G. Mujuni. 2015. “Use of Indigenous Knowledge in Weather Forecasting in Uganda: National Survey.” *Uganda National Meteorology Authority*. Kampala, Uganda: Uganda National Meteorology Authority.

Parrotta J. A. and M. Agnoletti. 2012 “Traditional Forest-Related Knowledge and Climate Change.” In *Traditional Forest-Related Knowledge. World Forests, Vol 12*, edited by J. A. Parrotta and R. L. Trosper, 491–533. doi:10.1007/978-94-007-2144-9_13.

South African National Biodiversity Institute (SANBI)2013. “Climate Change and the Agricultural Sector.” Climate and Impacts Factsheet Series, 4.

Ubisi, Nomcebo R., Paramu L. Mafongoya, Unathi Kolanisi, and Obert Jiri. 2017. “Smallholder Farmer’s Perceived Effects of Climate Change on Crop Production and Household Livelihoods in Rural Limpopo Province, South Africa.” *Change and Adaptation in Socio-Ecological Systems* 3 (1): 27–38. doi:10.1515/cass-2017-0003.

Vilakazi, B. S. 2017. “Indigenous Knowledge Systems Available to Physico-Chemical Properties on Selected Smallholder Farms of KwaZulu-Natal.” Masters of Science Thesis, Soil Science School of Agricultural, Earth and Environmental Sciences, University of KwaZulu Natal Pietermaritzburg, South Africa.

Ziervogel, G., and A. Opere. 2010. *Integrating Meteorological and Indigenous Knowledge-Based Seasonal Weather Forecasts in the Agricultural Sector*. Weather Change Adaptation in Africa Learning Paper Series. Ottawa, Canada: International Development. Research Centre.

Ziervogel, Gina, Mark New, Emma Archer van Garderen, Guy Midgley, Anna Taylor, Ralph Hamann, Sabine Stuart-Hill, Jonny Myers, and Michele Warburton. 2014. “Climate Change Impacts and Adaptation in South Africa.” *Wiley Interdisciplinary Reviews: Climate Change* 5 (5): 605–620. doi:10.1002/wcc.295.