



Spatial distribution of indigenous climate indicator development for rural smallholder farmers in Nkomazi local municipality, South Africa

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Abstract

This study aimed at smallholder farmers to use their indigenous knowledge in combination with modern climate indicators when making farming decisions in Nkomazi Local Municipality, South Africa. Twelve villages were sampled in Nkomazi municipality based on their use of IKS with 100 participants applying both qualitative and quantitative research methods. ArcMap v10.7.1 software was used to map the distribution of indigenous climate indicators in these villages, and SPSS v25.0 software was used to analyse the quantitative data. Qualitative data was analysed through thematic analysis which is used to interpret patterns of meaning within qualitative data. The most used indicators smallholder farmers relied on for weather predictions included animals (31%) followed by plants (26%). The Poynton model predicted negative results with a 5⁰C temperature increase, meaning that if the hot temperatures continue rising, the farmers' indigenous indicators will decline or disappear, making it difficult for rural smallholder farmers to make informed farm-level decisions. Therefore, the study suggests an integration of Indigenous Knowledge Systems (IKS) and local knowledge to adapt to climate change, have access to updated agricultural information and ability to make informed farm-level decisions.

Keywords Indigenous knowledge · Climate indicators · Smallholder farmers · Spatial distribution

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1 Introduction

Long before the introduction of conventional agriculture, Indigenous Knowledge (IK) based agriculture assured the production of a variety of foods (Ogle and Grivetti 1985). Local people, including smallholder farmers, are custodians of local and Indigenous Knowledge Systems (IKS) (Willett 1993). These farmers are knowledgeable of their situations including what works and what does not work for their farming systems, their available resources and how one change impacts other parts of their system (Ubisi et al. 2017). Indigenous knowledge is vital for resource-poor agriculture, as it enhances food security for smallholder farmers at a household level. Indigenous agriculture is based on the understanding local people have and it changes through innovativeness and creativity as well as through contact with other local and international knowledge systems (Warren 1991). In rural settings, indigenous knowledge systems represent mechanisms to ensure minimal livelihoods for smallholder farmers. Resource-poor smallholder farmers always planned for their agricultural production and conserve natural resources with the instruments of indigenous knowledge (Naanyu and Macopiyo 2013). This development has been a matter of survival to indigenous people in rural settings and has been representing generations of experience, careful observations and trial and error experiments (Akullo et al. 2007). These factors highlight the importance of creating an information dissemination network that will also preserve IKS for weather forecasting within local municipalities.

2 Description of the study area

The study was conducted in twelve villages of the Nkomazi Local Municipality, Mpumalanga province, within Ehlanzeni district (25.7097° S, 31.7195° E). Nkomazi Local Municipality is found on the eastern part of Ehlanzeni District Municipality of Mpumalanga Province, South Africa (Fig. 1). The Nkomazi Municipality is 4786km² in extent, which is 23% of the Mpumalanga Province and Ehlanzeni District Municipality landmass respectively (Census 2011). This Province receives summer rainfall, with mild winter and hot humid summer (Census 2011). The rainfall received varies between approximately 750 and 860 mm (IDP 2014). Nkomazi municipality is mostly a rural area, the municipality suffers from a high rate of unemployment; as a result, it is struggling to attract investments (IDP 2014). Other factors adding to the high rate of unemployment is the shortage of skills and illiteracy rates, which is generally applicable throughout the country, unemployment is at the heart of poverty within the municipality (IDP 2014). Furthermore, most people in the rural and farm areas are more involved in agricultural activities for livelihood.

3 Methodology

Documentation, identification and analysis of local climate indicators used for seasonal forecast in Nkomazi Local Municipality were conducted. Majority of participants in Nkomazi were mainly Swati and Tsonga people. Twelve villages (Ntunda, Mzinti, Mbuzini, Jeeps Reef, Driekoppies, Magogeni, Tonga, Boschfontein, Kamaqhekeza, Buffelspruit, Sibange and Madadeni) were sampled based on the accessibility to the villages and their willingness to participate. Hundred participants were randomly selected based on their

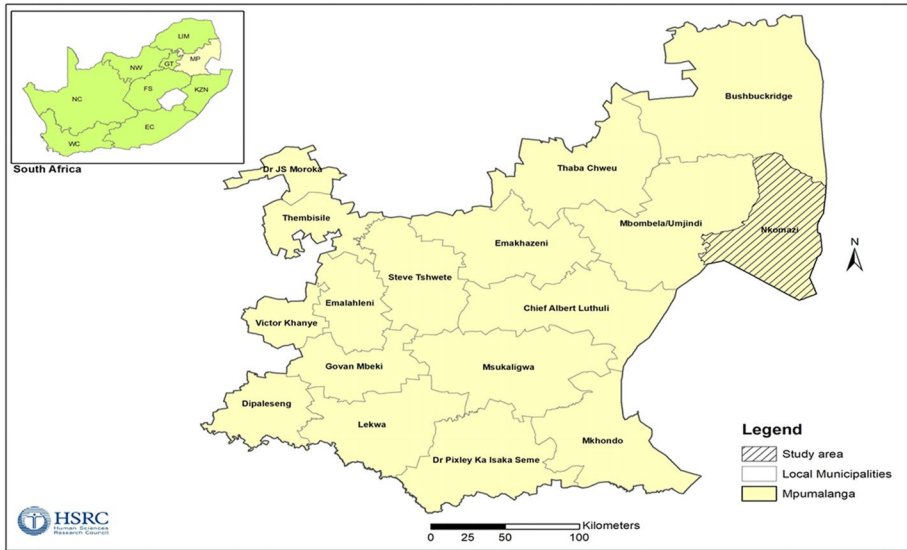


Fig. 1 Description of the study area

farming activities, who were mainly crop producers and the age factor contributed as well, only people who were 50 years and above participated in this study as there are the most carriers of IKS. ArcGIS 10.7.1 was used as an available software to map the geographic distribution of the indigenous climate indicators used by smallholder farmers in those villages. To create a prediction model with increasing temperature, Poynton model was used.

4 Data collection

The study was based on the primary data collected in Nkomazi Local Municipality, Ehlanzeni district. Qualitative methods were used to collect data through key informant interviews and eight focus group discussion made up of 8 to 12 participants. Each session had at least one elder known for rain prediction expertise and considering age as well, participants were 50 years and above. Discussions were first held separately between men and women to ensure active participation, especially from women who were not free to express themselves in the presence of men due to cultural norms, also because different genders may have different knowledge and experiences on the types of IK used for different purposes.

Qualitative research method was employed mainly to seek farmers' perceptions of climate change, understanding their indigenous knowledge systems, their indigenous climate indicators, and their responses to climate change as well as the role of IK on their farming systems. This method was appropriate for this study as smallholder farmers were regarded as experts of their situation by the community they form part of and have first-hand experience, so we aimed at finding meaningful answers and experiences of farmers concerning their indigenous knowledge systems on crop production.

Focus group discussions were conducted and facilitated by a trained facilitator in conducting focus group discussions. A recorder and pictures were used to document indigenous climate indicators used by smallholder farmers over the study area in each session. A

written and oral consent was requested from farmers before the beginning of each session. Qualitative data obtained from the focus group discussions and key informant interviews were thematically analysed. The interviews were conducted in Swati and English as common languages in the area. Data was compiled, transcribed and categorised into different trends, themes, concept and patterns.

4.1 Data analysis

Quantitative data was analysed through SPSS. Focus group discussions were analysed through content analysis by identifying themes, concept, patterns and trends. ArcMap for mapping the distribution of IKS in the different villages was also used.

5 Results and discussions

5.1 Socio-economic profiles of the respondents

The study findings revealed that there were more female (63%) respondents than males (37%) in Nkomazi Local Municipality. The participants' ages ranged from 50 to 90 years. About 10% of the smallholder farmers had primary education, another 10% with matric and only 2% had post-secondary education with diplomas. Majority (63%) of the farmers relied on farming activities as their main source of income. On average 24% of the farmers were earning between 86.99US\$–115.98US\$ per month. Only 4% of the participants relied on full-time job for their income.

5.2 Seasonal calendar with months and activities happening

Table 1 shows months of the year recorded in English and siSwati, as well as activities taking place in agricultural timing as used by Nkomazi smallholder farmers before the influence of climate change. The Swati names of the months are as derived from interviews with the farmers.

During the focus group discussions, smallholder farmers highlighted the different agricultural activities happening each month for their crop production. However, these farmers did highlight that a lot has changed; they no longer do things like before, due to prolonged droughts and delayed rains. Some farmers stated that they have noted some changes in some plants species expected to drop their leaves at a certain period around August and grow new leaves by November. These observations were used as for detecting rainfall season. This period was used to prepare fields for maize plantation, as farmers would expect wet season based on their indigenous knowledge.

5.3 Events documented from indigenous knowledge

Smallholder farmers revealed some of the major climatic events they experienced from 1970–2018. This information was reconstructed through the participants' memories (Table 2). However, during the discussions, there were debates on whether the weather changes were due to angry ancestors as locals were “losing their traditional roots” because they were no longer practising their local rituals like the olden days and punishment from

Table 1 Months of year with agricultural activities as recorded before the influence of climate change

Months of the year in English	Months of the year in siSwati	Agricultural activity
• January	• Bhimbidwane	• Harvesting season (maize)
• February–March	• iNdlovana	• Harvesting season (maize)
• March	• iNdlovulenkulu	• Harvesting season (maize)
• April	• Mabasa	• Drying up the harvested maize
• May	• iNkhwenkhweti	• Drying the harvested maize and storing it for next season, while planting vegetables
• June	• Nhlaba	• Planting season for vegetables
• July	• Kholwane	• Store harvested maize grain for planting season
• August	• iNgc	• Start with field preparation while waiting for spring rains
• September	• iNyoni	• Expecting early spring rains for soil preparations
• October	• iMphala	• Continue with soil preparations and tillage
• November	• Lweti	• Planting season of maize mainly
• December	• iNgongoni	• Continue with planting season and soil preps

God or just a natural climate change process. Table 2 further highlights some events remembered by farmers.

Nkomazi farmers noted that during the 1970s rainy season were on time with a normal temperature distribution allowing them to have good production. However, during the 1980s *"the country was hit by an extreme drought that we could produce enough maize for our sustainability, ended up getting yellow maize donated to us by our neighbouring countries"*. Furthermore, the farmers revealed that in the 1990s, they started observing prolonged hot seasons with new crops species emerging such as purple sweet potatoes, macadamia nuts as well as new mango fruits, as well as the foot mouth disease on livestock. In the early 2000s, the respondents noted that though they had droughts seasons they were also hit by floods as well as malaria and cholera incidences escalating, with local remedies no longer effective. These effects continued until around 2012 causing waterborne diseases such as diarrhoea. The farmers further highlighted that the extreme weather events such as increased temperatures lead to major crop losses as well as drying of wetlands and huge damage on infrastructure such as schools and roads from floods. *"We have observed some wetlands that used to retain water for long but now are exposed, as well as the disappearance of some plants and animal, were used for climate forecasting; these are the obvious indicators of climate change"*.

5.4 South African historical climatic recorded climatic events

The limitation to available long-term meteorological station with sufficient coverage to give sufficient illustrations of the variations of a region's climate in both space and time has been the greatest restriction to the recording of historical climate. However, South Africa is better off, as it has a good network of temperature and rainfall recording stations compared to the rest of Africa. Therefore, this makes it easy to do trends and variability investigations over multiple decades. (Department of Environmental Affairs 2013).

Table 2 Recorded events recalled

Years	Event took place
1970–1979	<ul style="list-style-type: none"> Had rainy seasons on time with good crop production; still had the indigenous climate indicators available for weather predictions. Temperature and rainfall were normally distributed with normal weather seasons, winter was cold and summer was hot as expected
1980–1989	<ul style="list-style-type: none"> Had experienced extreme drought in the country, had yellow maize donated from outside countries to cope with food scarcity
1990–1999	<ul style="list-style-type: none"> Started experiencing prolonged hot seasons, with emergence of new crop species such as purple sweet potatoes, macadamia nuts as well as new mango fruits. With the emergence of foot mouth disease on livestock
2000–2011	<ul style="list-style-type: none"> Increased droughts, as well as floods, were experienced during this period, with a change in rainfall patterns and rivers starting drying-up as well as floods around 2006. Started having malaria outbreaks cholera
2012–2018	<ul style="list-style-type: none"> Prolonged droughts, loss of crop production due to water scarcity with a lot of Malaria outbreak cases leading to death of people

However, recently the climate trend analyses focused on few weather stations of SAWS as well as the Computing Centre for Water Resources of the Department of Water and Sanitation (DWS) in some cases also stations (Midgley et al. 2016). Below are the scientific records of the South African climatic trends for 1960–2012 (adapted from; Department of Environmental Affairs 2013);

- There has been an increase of the mean annual temperatures by roughly 0.7 °C which is double the observed global average reported by the forth Assessment Report of the Intergovernmental Panel on Climate Change
- Overall, there have been great decreases in cold extremes and increases in hot extremes mainly in the Northern and Western interior of the country
- There has been a shift in rainfall seasonality and intensity
- There has been a reduction in rainfall in almost all hydrological zones for the autumn months. There are fewer rainy days, which implies an increased dry spell duration as well as an increase in the intensity of rainfall events.

These records indicate that there have been changes in rainfall and temperatures over the past five decades in South Africa, as detected in the SAWS and ARC weather station data (Midgley et al. 2016).

Regarding Table 2, there is a similarity of the historical climatic events observed by the indigenous smallholder farmers with meteorologists. However, the smallholder farmers highlighted that they started noticing and experiencing drought between the 1980s, while the scientific findings had records from the 1960s. This is because indigenous smallholder farmers could only respond based on their memories without any documentation. Nonetheless, both knowledge systems highlighted similar key observations, which were increased dry spells duration, change in rainfall patterns, increase on the mean annual temperatures, fewer rainy days and a shift in seasonality.

5.5 Smallholder farmers' seasonal calendar for crops grown in different seasons

Nkomazi smallholder farmers cultivate different crops in different seasons. During the focus group discussions, farmers highlighted some of their main crop grown in the area. This includes crops such as maize, groundnuts, sugar-beans, butternut, green pepper,

tomatoes, okra, spinach, cabbage, green beans, lettuce and chillies. Figure 2 was taken during the focus group discussions highlighting the different crops grown with some in Swati names.

5.6 Indigenous climate indicators used by Nkomazi smallholder farmers for weather prediction

Nkomazi smallholder farmers observe climate variability based on their experiences by interacting with the environment. The study findings highlighted that indigenous knowledge exists among Nkomazi smallholder farmers; they use local climate indicators for weather forecasting and seasonal predictions. The indigenous climate indicators used to predict weather from the twelve villages; Ntunda, Mzinti, Mbuzini, Jeeps Reef, Driekoppies, Magogeni, Tonga, Boschfontein, Kamaqhekeza, Buffelspruit, Sibange and Madadeni were animal behaviour, plant phenology and atmospheric indicators in weather forecasting.

Table 3 highlights the different percentages of indigenous climate indicators used in the twelve sampled villages in Nkomazi. Out of the four categories of indigenous indicators, animal indicators (31%) had the highest percentages among the others. Smallholder farmers from Mbuzini relied mostly on animal indicators (cows) (64%) than Buffelspruit. Plant indicators were second most used indicators, with Tonga having the highest percentages (63%), followed by Buffelspruit at 50%. However, it was revealed that some villages did not use plants as indicators for weather predictions, which were Sibange and Jeppes Reef. Atmospheric indicators were ranked third (24%), while human ailments (19%) were ranked lowest among the four categories. Similar findings were observed by Risiro et al. (2012); Nkomwa et al. (2014) and Basdew et al. (2017) that rural smallholder farmers use indigenous climate indicators for weather predictions. Another reason for animal indicators being ranked the highest among the others was that, in those villages, farmers had a lot of livestock mainly cows as well, which they could assess their behaviour for weather predictions.

5.7 Spatial distribution of indigenous climate indicators in Nkomazi

The negative effects of climate change have altered geographical range of some indigenous indicators. Changes in climate variability drives the distribution of indigenous climate indicators at an area. In Nkomazi Local Municipality, smallholder farmers have noted some change in climate variability affecting the distribution of certain indicators especially plant species. Farmers highlighted that in the past 50 they have observed the disappearance of some species as well as a shift in climate zones. Plant species interact with the environment differently, and its distribution depends on the climate. Therefore, any change on the climate variability affects its distribution, which as a result affects the decision making of farmers for their farm practices.

5.8 Dominating indigenous climate indicators used for weather prediction in Nkomazi

The baseline information on the distribution of indigenous climate indicators was estimated using data collected from the study area. Plant species are immobile organisms, which makes it a bit challenging to easily notice any shifts in their distribution. However, due to climate change experienced in the area over the past decades, farmers have noticed a

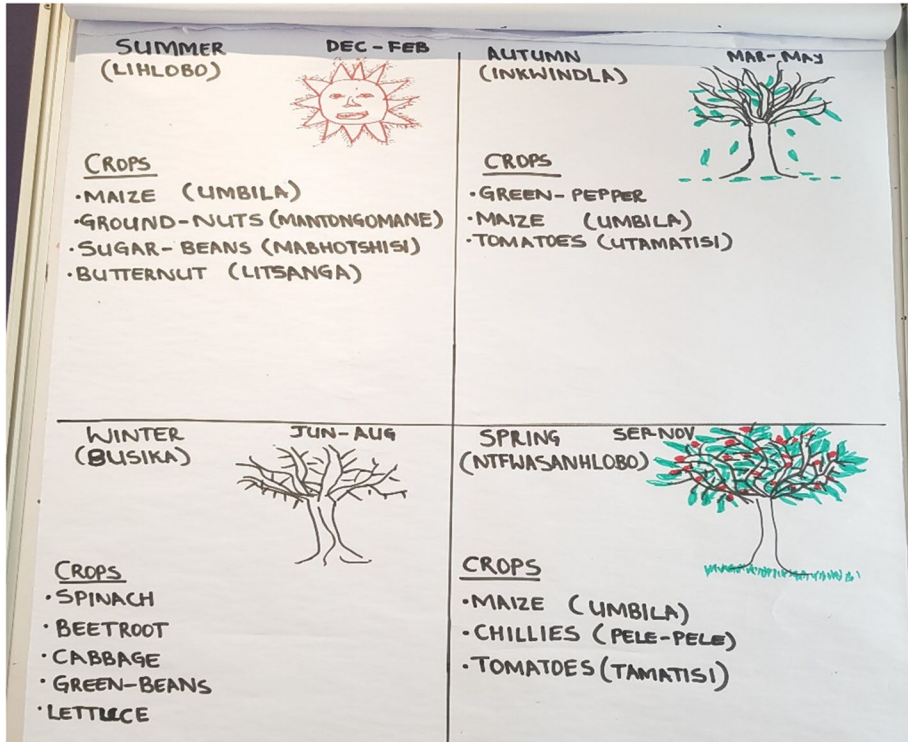


Fig. 2 Crops grown in Nkomazi Local Municipality

Table 3 Indigenous climate indicators in Nkomazi villages

Village name	Animal indicators (%)	Plant indicators (%)	Atmospheric indicators (%)	Human ailments (%)
Tonga	13	63	0	25
Magogeni	50	17	33	0
Driekoppies	33	33	17	17
Mbuzini	64	29	0	7
Mzinti	38	31	8	23
Ntunda	14	21	36	29
Boschfontein	33	17	17	33
Kamaqhekeza	40	20	20	20
Buffelspruit	0	50	25	25
Sibange	20	0	60	20
Madadeni	43	29	29	0
Jeppes Reef	29	0	43	29
Total % per indicator	31	26	24	19

change in the distribution of some plant species. Studying the distribution map above, the Western sites of the municipality were mostly dominated by the use of mango tree to predict the weather changes, whilst the Eastern sites were dominated by the use of secretion of too much sweat as predictors. However, Overall Tonga has the highest indicators in the province. Ntunda has the lowest indicators in the municipality.

6 Poynton Indigenous indicator model

According to the Department of Environmental Affairs, South African temperature is expected to increase greater than 4°C across the country and greater than 6°C in the Northern interior, Central and Western sites before the end of this century 2099 (DEA 2013). The department further elaborated that the country is expecting an increase in the number of heat-wave days and very hot days to be common. Therefore, this means that there are high chances for the loss or decline of potential indicators in the area for weather predictions. However, though they were five categories of indigenous climate indicators identified in the study area, focus will be given to only two categories (plant and animal indicators) for modelling purposes, because they were ranked as mostly used indicators than the others. The model aims at predicting the distribution of the indigenous climate indicators utilised by Nkomazi smallholder farmers for weather predictions with increasing temperature at an estimate of 5°C. The model will assist in predicting the location and distribution of plants and animal indicators in the twelve villages sampled. This will help assess the possible changes in the climate conditions that are relevant to species distribution.

According to Poynton (1964), it's critical to learn about how climate fluctuations affect distribution patterns and to create appropriate conservation plans that consider how previous climatic fluctuations have affected distribution patterns. The Poynton model for predictions is further elaborated in a study done by Schreiner et al. (2013), where they were using modern models to test Poynton's predictions. Therefore, in this study the Poynton model approach was used to predict the distribution of the plant and animal indicators with a 5°C temperature increase. This model is based on the assumption that the current distributions of the indigenous climate indicators for weather predictions in Nkomazi are at equilibrium with the current climate conditions in the area. This model predicts a shift in areas where the indicators are currently dominant with a 5°C temperature increase. Therefore, it predicts the relationship between temperature increases with the distribution of indigenous climate indicators in the study area. This highlights the prediction of the distribution of the indicators as to whether the impacts of climate change with increasing temperatures will allow the indicators to adapt to new climate conditions or disappear.

Therefore, based on the model predictions the observed distribution of plants and animals' indigenous climate indicators will decline due to temperature increase and climate change scenarios, and due to difficulties keeping up with the changing environment. Similar findings were observed in South Korea where a prediction model was used to predict the distribution of subalpine species and, as a result, the model predicted a decrease of the species distribution by 2050 and 2070 due to climate change (Graham et al. 2011). Therefore, these findings support what was highlighted by Cherotich et al. (2012) that the increase in climate has a negative impact on the distribution of the indigenous knowledge indicators. Again, it also supports the fact that the two knowledge systems need to be integrated as we cannot solely rely on one knowledge system but take advantage of the strength, innovativeness and creativity of both knowledge systems.

7 Conclusions

In Nkomazi Local Municipality, smallholder farmers estimated the onset of growing season through the observations of natural climate indicators. These indigenous communities have been applying unique indigenous knowledge systems, culture and expertise since the olden days. However, the study findings highlighted that climate variability has been unpredictable resulting in replanting of crops. As a result, this has caused some strains on the majority of smallholder farmers who are resource-poor to meet expenses of replanting lost crops. The study highlighted the spatial distribution of the indigenous climate indicators used by smallholder farmers in Nkomazi Local Municipality using the Geographical Information System (GIS) tools. It was revealed that animal indicators (birds) ranked the most used indicator than others, especially in Mbuzini. However, the farmers also revealed increasing temperatures due to climate changes were among their major concerns. Therefore, the Poynton model was used to predict the impact of the increasing temperature and its effects on smallholder farmers' production. The model predicted negative results with increasing temperature, meaning that farmers would lose their indicators for weather predictions to make farm-level decisions, causing a misunderstanding on what and when to plant certain crop species. Therefore, as a result, this will have a negative impact on their food security status, as there is a shift on their seasonal calendar, which they rely on for weather predictions. These challenges revealed the need for an integration of indigenous knowledge and modern science to help adapt to climate change and improve their food security status.

Author contribution Nomcebo Rhulani Ubisi is the principal author of the study and article with a hundred percent contribution in all aspect.

Unathi Kolanisi contributed as the academic supervisor.

Obert Jiri contributed as the academic supervisor.

Frederick Tshitangano contributed to the prediction model component.

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Data availability Data and material will be made available on request.

Declarations

Ethics approval and consent to participate Ethics approval was granted by the ethics committee at UKZN and each participant did sign a consent form.

Consent for publication Consent for publication was granted by all authors.

Competing interests No conflict of interest.

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