Assessing and documenting the use of Indigenous Knowledge Systems in weather and seasonal climate forecasting: A case study of Moletjie villages Limpopo Province, South Africa

By

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DEDICATION

This work is dedicated to my daughter Koena Chokoe, who has shown me so much love and patience.

DECLARATION

I declare that dissertation hereby submitted by me to the University of Limpopo, for the degree of Master of Science in Geography and Environmental Studies has not previously been submitted by me for a degree at this or any other university; That is my work in design and in execution, and that all material contained herein has been duly acknowledged.

…………………………..…..   07/ October /2022………………..

Chokoe Serole Angela (Ms)   **Date**

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ABSTRACT

The purpose of this study was to assess and document the use of the Indigenous Knowledge System (IKS) in weather and seasonal climate forecasting in Moletjie, Limpopo Province. The objectives of this study were to document the biological, meteorological, and astrological indicators used to forecast local weather and climate conditions. In addition, the study sought to determine the effectiveness of indicators used in forecasting local weather and climate conditions and to represent the spatial distribution of indigenous weather knowledge using a Participatory Geographic Information System (P-GIS). Both qualitative and quantitative research approaches were used. Surveys and in-depth interviews were used to obtain primary data. The secondary data collected from formally published material (books and journals), served to compliment the primary data. Purposive sampling was used to obtain data from participants with knowledge about Indigenous Knowledge (IK) in seasonal and weather forecasting. From the study, the distribution of indigenous indicators used by Moletjie smallholder farmers was mapped using ArcGIS 10.6. Results show different types of human, biological, meteorological, and astronomical indicators utilized by communities to forecast weather and climate as such they were captured, characterized, and documented. Smallholder farmers considered indigenous knowledge indicators to be more accurate and reliable in their forecasting than scientific projections, which were described as inaccurate and received late. The research found that plants and birds used in this case are in danger of extinction at an alarming rate because of climate change and anthropogenic activities. The study derives key insights from how smallholder farmers in Moletjie village use the IK weather forecast to make farming decisions to ensure farm productivity. It also demonstrates that the smallholder farmers share their trust in modern technology and have confidence and the readiness for the use of scientific forecasting and climate projections which are expected to add value when integrated with IK.

Keywords: Integrated, Indigenous Knowledge System, Participatory Geographic, Information System, Smallholder Farmers.

ABBREVIATIONS

CSC	Climate Services Centre
DRR	Disaster Risk Reduction
ENSO	El Niño Southern Oscillation
ICT	Information Communication and Technology
IK	Indigenous Knowledge
IKS	Indigenous Knowledge System
IPCC	The Intergovernmental Panel on Climate Change
ITCZ	Inter-tropical Convergence Zone
GCMs	General Circulation Models
GIS	Geographic information systems
LOGIC	Long-term Operational Group Information Centre
NFC	National Forecast Centre
RRA	Rapid Rural Appraisal
SCF	Seasonal Climate Forecast
SAWS	South African Weather Service
SADC	Southern African Developing Community
SARCOF	Southern African Regional Climate Outlook Forum
SPSS	Statistical Package for Social Sciences
SSA	Sub-Saharan Africa
P-GIS	Participatory Geographic Information System
P3DM	Participatory three-dimensional modelling
WMO	World Meteorological Organization

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CHAPTER ONE: INTRODUCTION

1.1. Introduction

An Indigenous Knowledge System (IKS) is a collection of indigenous peoples' knowledge from a certain geographical location that has endured for a long period (Mapara, 2009). Since time immemorial, Indigenous Africans have depended on IKS for close observations of natural phenomena in weather forecasting. This chapter presents the background of the study, the problem statement, its rationale, and the purpose of the study.

1.2. Background of the Study

Local populations in various parts across the world have historically relied on Indigenous Knowledge (IK) to manage natural disasters and maintain their natural environment. This implies that strengthening indigenous capacity is key to empowering local neighbourhoods and ensuring involvement in the growth process that is effective (Boko *et al.,* 2007). When new ideas can indeed be viewed in relation to existing practices, people are more likely to adopt them. IK has long been utilized by smallholder farmers to better understand the meteorological character and climatic regimes beneficial to make yield and irrigation cycle decisions (Zuma-Netshiukhwi *et al.,* 2013).

Plant phenologies, as well as the behaviour of birds and animals, are frequently used in local forecasting to combine empirical observations and weather predictions. Local forecasting is profoundly localised, resulting from intimate engagement with the microenvironment whose rhythms are linked with seasonal change cycles. Farmers develop a knowledge base in the manner of the Indigenous Knowledge System (IKS) as a result of their vulnerability induced by climate fluctuations. This knowledge is a collection of information passed down through generations that are known or obtained through experiences and observations. The knowledge is matched to the needs and conditions of the local community, (IGAD, 2006). Outsiders had long ignored and insulted indigenous knowledge, particularly in the African context.

However, there is a rising acknowledgment of IK as extremely useful and it is the knowledge that is underutilized that contributes to countries that are developing, notably Africa (UNEP, 2006). As a result, recommendations for scientific and Indigenous knowledge to be integrated are being made. Furthermore, the majority of African and worldwide agencies acknowledge that local knowledge and its organization serve as a foundation for sustainable and cost-effective participatory development strategies (Nyong *et al.,* 2007).

Pastoralists and peasant farmers in Africa, particularly people who live in arid areas, have developed their own forecasting systems from direct observation of surrounding nature's behaviour (Speranza *et al.,* 2010). The significance of merging both scientific and indigenous climate forecast knowledge available for farm-level decision-making is growing, as demonstrated by Ubisi (2019) in Mpumalanga province, South Africa. This would result in projections and suggestions which are useful at the local level, increasing the possibility that the knowledge will be employed more in future planning at the South African Weather Service (SAWS) to forecast climate.

Smallholder farmers in Zimbabwe were more ready to utilize seasonal climate forecasts when they were shown alongside and when compared to indigenous climate forecasting, according to research (Patt & Gwata, 2002). Similarly, research conducted in Nigeria discovered that smallholder farmers can plan for future weather by understanding indigenous weather methods for rain, sunlight storms, whirlwind, and harmattan [a very dry, dusty easterly wind or north-easterly wind that blows over Africa's north-western coast from December to February] (Ajibade & Shokemi, 2003).

Indigenous knowledge is still present in many indigenous or local cultures throughout Africa as well as the rest of the world. Societies have used IK in their daily lives, but with the advent of modern weather predicting technologies, these old ways have tended to be overlooked (Mhita, 2006). Despite the availability of recent technologies for forecasting weather conditions in a given region for the next day or month, indigenous weather knowledge has remained a significant method of local weather forecasting and can be used to improve worldwide meteorological information and weather forecasting (Ubisi,2019). For a very long time, people have attempted to predict the weather using a variety of ways, some of which have proven to be highly effective and successful (Makwara,2019).

This information is on the verge of extinction as a result of a lack of systematic documentation and research that is coordinated into its significance. The minute elderly people who already are the caretakers of this knowledge die, the knowledge that was acquired over many years will be lost (UNEP, 2008). Therefore, the promotion of indigenous knowledge is required in light of climate change, which makes scientific approaches not much reliable, especially in non-urban areas with insufficient weather forecasting tools(Auma, 2016).

1.3. Problem Statement

IKS remained very valuable and significant in decision-making not only in the preparation of natural disasters but also reducing the impacts of severe climate events (Auma, 2016). There have been advances in modern weather forecasting which have caused an improvement to predict rainfall by using statistical methods or dynamic forecasts. Despite these advances, there is a necessity for IKS methods to complement modern weather forecasting to provide reliable information (Enock, 2013). There have been cases of inaccuracy in forecasts, particularly when the predicted event somehow doesn't occur with the magnitude that is projected (Ebert *et al*., 2000). Current meteorological methods are likely to generalise the results further mostly, with the scarceness of weather observations in the country. With the increase in computational resources numerical weather prediction models can run with higher resolution.

The majority of smallholder farmers in South Africa live in rural and remote areas and are resource poor. They lack the required support from extension officers, and their poor infrastructure such as roads is causing difficulty for extension officers to interpret climate information, causing them to struggle to adapt and cope with climate change (Ubisi, 2019). The lack of reliable weather forecast information in Moletjie village makes production planning difficult for farmers. This can result in poor harvests even when the rain is expected. South African Weather Service issues seasonal climate forecasts and it is a WMO designated global producing centre of long-range forecasting. These predictions are made across large spatial scales, they consider temperature and rainfall quantities that are not comparable within a season variation. The seasonal forecasts are presented probabilistically. It is unknown how much indigenous knowledge is used in Moletjie community to forecast climate.

Documentation of traditional weather forecasting has been done, but only a few studies show how Indigenous Knowledge (IK), and science can be able to integrate with each other (Luseno *et al.,* 2003). Meteorological documentation and complementation of IKS into weather services operational forecast is the one encouraging programme that needs to be investigated. Chang'a *et al.* (2010) stated that indigenous weather and climate forecast are in danger because of the deficiency of documentation and the mortality of elderly individuals who have got the knowledge. Indigenous knowledge is encountering the threat of remaining excluded even though it possesses amongst others the key to deal with the threats caused by climate change.

This study assesses and documents the use of IKS in seasonal climate forecasting in Moletjie village and how it influences the decisions made by smallholder farmers and other stakeholders. The research aims to gather useful information on the many forms and sources of climate information, indications of IK weather and climate forecasting, the spatial distribution of indicators, and the reliability of IK weather forecasts.

1.4. The Rationale of the Study

Livestock production and subsistence farming are still important means of sustenance in the livelihoods of Moletjie village. Bahlaloga clan (Royal family) are custodians of certain cultures and customs, and it is assumed that they are knowledgeable of IKS. Researchers such as Adibade *et al*. (2003) and Risiro *et al*. (2012) have documented traditional knowledge of weather forecasting, analysed its structures, and observed its effect on the socio-economic status of the communities where it is applied. It appears that assessment and documentation of the practice of IKS in weather and seasonal climate forecasting in Moletjie villages, however, has not been conducted, therefore the need to undertake this research.

In the African continent, the agriculture sector employs a greater percentage of the populace and is mostly dependent on natural rain while prone to climate change and variability. The accessibility of dependable services providing weather and climate information together with operational and well-organised forecast information broadcasting systems are vital to backing decision-making processes depending on different levels. According to Ajani *et al. (*2013), progressive information of weather data merged with agro-advisories enriches the ability of small-scale farmers to manage climate extremes and adapt to climate change which progresses the managing of climate-related threats in farming. Nonetheless, in the African continent, major gaps still happen in the distribution of specific locations, duration, sustainable climate, and seasonal weather forecast information that positively focuses on the desires of smallholder farmers. Modern climate forecasts commonly provide for larger-scale areas and are more generalised, and therefore less efficient for farm-level decisions.

Weather is an important controlling aspect of the very existence of mankind and influences many things in the world such as farming, health, and daily activities (Barry *et al*., 2009). Indigenous systems of weather forecasting have taken place since the olden time, however, with the upcoming scientific techniques of weather and climate forecasting, these indigenous techniques are likely to be overlooked. Villagers and farmers have come up with a knowledge foundation for forecasting weather conditions based on animals and plant observations (Roncoli *et al.,* 2003).

The importance of weather forecasting indicators also differs with various farming productions. The early cautionary methods have been verified that are essential in planning for climatic conditions such as imminent rain, floods, hurricanes, and droughts. In Western African countries, Tall *et al*. (2008) proved that seasonal rainfall prediction information, when utilized can help to minimise the loss of existence and infrastructure generated through floods. The perception of how local communities observe and variability in rainfall forecasts remains the keynote to integrate with scientific weather forecasts.

IKSs provide tools for designing an innovation by means of observation, investigation, and communication of knowledge permitting farmers to adapt to climate change conditions. The application of IKS to forecast weather and climate is in danger of becoming extinct due to a lack of sustained efforts towards sustainable use and a shortage of harmonised studies to explore their accuracy and reliability

(Codjoe *et al*., 2014). IKSs need recalibration due to climate change (Speranza *et al.,* 2010). According to Intergovernmental Panel on Climate Change [IPCC] (2010), the reformed IK may attest valuable insight into the potential for particular adaptation policies that are economical and sustainable. There is limited literature available on the cultural aspect of weather and climate in South Africa. Only a few articles published in popular books (Alcock, 2010) and journals could be found (Mapara, 2009). The derivation of a further source of data is that of oral tradition which is, unfortunately, always limited by time, language, and distance. So much knowledge has already passed, and potential informants are no longer alive.

The perception of how the use of indigenous weather knowledge can be implemented practically as a resource management tool in rural areas and villages is very limited. This study pursues to close the information gap on the link between the use of traditional weather knowledge, accuracy, and application for sustainable utilization of the environment.

1.5. The aim of the Study

The aim of the study is to assess and document the use of the Indigenous Knowledge System in weather and seasonal climate forecasting in Moletjie, Limpopo Province.

1.6. Objectives

- To document the biological, meteorological, and astrological indicators used to forecast local weather and climate conditions in the study area.
- To determine the effectiveness of indigenous knowledge indicators used to forecast local weather and climate conditions in the study area.
- To represent the spatial distribution of indigenous weather knowledge using a Participatory Geographic Information System (P-GIS).

1.7. Hypotheses

I. In seasonal climate forecasts, the research area's community does not use indigenous knowledge

II. Indigenous weather knowledge indicators are inaccurate, untimely, and unreliable in their forecast.

III. Indigenous weather knowledge indicators are not equally distributed spatially in the study area.

1.8. Outline of the dissertation

The structure of the report is divided into five chapters, with the first chapter introducing the background of the study, objectives, problem statement, and limitations of the study. The second chapter examines the literature on scientific weather forecasting, indigenous weather forecasting systems, different types of indicators used to predict the weather, and the use of IKS and participatory GIS. Other African studies on the possibility of integrating seasonal climate projections with traditional knowledge are also discussed. Chapter 3 describe the characteristics of the study area and different methods that have been used to collect and analyse data. Data analysis, study findings, and discussions are presented in Chapter 4. Chapter 5 summarizes the findings, conclusions, and recommendations that may be made from the research.

CHAPTER TWO: LITERATURE REVIEW

2.1. Introduction

This chapter provides an overview of Indigenous Knowledge Systems (IKS) in weather and seasonal climate forecasting in South Africa and elsewhere in the world. It assesses the information gap between previous studies done on indigenous knowledge and seasonal climate forecast. The review also covered the empirical studies done about the indigenous climate and weather indicators employed by smallholder farmers and also the distribution of indigenous seasonal climate indicators.

2.2. Indigenous Knowledge Systems and Characteristics

Since time immemorial, African societies and the rest of the world have been using IKSs for many reasons that depend on the desires of the population. Indigenous Knowledge (IK) is made of information, skills, and ways of doing things based on local resources by the society of an area. It is established as a result of observations and everyday knowledge over time. Ajibade and Shokemi (2003), indicate that IK is based on methods formed by community members as oppositional to the knowledge domain which is scientifically proven. This expertise helps the community to interact with its surrounding environment (Berkes, 2012).

Local communities are characterised by their complex practices and the relationship between themselves, animals, and their environment, indigenous knowledge is connected to society and the living environments that describe them (Hammersmith, 2007). Mapara (2009) describes IKSs as “a body of knowledge, or other bodies of knowledge, of the indigenous people of particular geographical areas that they have survived on for a very long time”. According to Berkers (2012), these bodies of knowledge are formed through culture and the relationships put together, shaped, and passed down to future generations by means of oral transmission, cultural acts such as rituals, and customs. IKS created communicative strategies acquired through transmitting and preserving knowledge acquired by society throughout generations. IKS is the foundation for local communities in terms of decision-making in many countries. IKS is valued, no longer solely by the community in which it develops, but then again by researchers and institutions who are determined to enhance environmental states within rural communities. IKSs common well-known terms include common knowledge, the indigenous method of knowing, farmer's knowledge, folklore, and ethno-science (Nyota & Mapara, 2008& Kolawole *et al*.,2014).

IKS practices are mainly used in agriculture, botany, zoology, medicine, security, and craft skills, to bring peace, mandate, and harmony between humans and their living environment in different parts of the world, such as Africa (Maware, 2010).

According to Ellen and Harris (1990), IKS is:

- Verbally transferred. Therefore, when put in writing it changes some of its meaning.
- The outcome of the reality of a daily engagement lifestyle is consistently developed by experience. This knowledge produces generations of intensive reasoning and everyday life practice is usually empirical in the "laboratory of survival."
- Empirical instead of scientific knowledge or theoretical knowledge.
- Repeating with time is an important attribute of culture. Repetition helps with the dynamics of life.
- Ever-changing. It is created as properly as recreated, located, and disappears. However, it is frequently represented as being stationary.
- Distributed through interaction with people and social gatherings. It is unequally spread within a population through gender and age.
- Frequently focused on persons and might also gain a point of consistency in cultural rituals; although, its dissemination is usually uneven.
- Surrounded by verbalised cultural beliefs and they are separated by the use of technology.
- Shared by many people from different cultural backgrounds and by worldwide science.

2.3. Indigenous Knowledge of Weather Forecasting

Mapara (2009) defines IKS as a technique of inheritors of certain cultures dwelling in a certain geographic region that lived on for a long time. Mugabe (2010) emphasizes that indigenous weather knowledge is assessed, predicted, and interpreted by the use of meteorological, biological, and astronomical indicators. Whereas Anandaraja *et al*. (2008) recognise that IKS is changing through the local instrument of creativeness also as being in interaction through different local worldwide knowledge systems.

Farmers use ethno-meteorological knowledge to devise climate variability adaptation measures. Roudier *et al*. (2014) demonstrated that farmers value their experience over the years and naturally can be inclined towards indigenous forecasting as opposed to modern forecast. Orlove *et al*. (2010) carried out a study on how farmers depend on historical weather observation, patterns, and indicators to prepare forecasts on weather and climate. Alvera (2013) stated that it is important to identify, collect, and develop IK. They proposed that educators are able to pass from the acquainted to the unskilled, from the real to the intellectual in the technique of promoting sustainable farming.

IK has played a pivotal role in the survival of neighbourhoods from natural disasters and has helped in preserving the natural environment. Communities that live in areas prone to drought and flooding have developed continuous wisdom on reducing the risk of disasters and management through immediate warning systems and awareness (Roncoli *et al*., 2002). Farmers employed this knowledge to determine when the rainy season begins and ends, which helped them, manage their farming activities (Enock, 2013 & Jiri et al., 2015).

According to Mahlangu and Garutsa (2014), IKS is used to enhance water conservation and management practices such as water harvesting and preservations are used by locals in the Eastern Cape province of South Africa to enhance water conservation in vulnerable soils. Preservation of food techniques such as fermentation and sun-drying were utilized by smallholder farmers in Kenya to ensure that there is food security (Naanyu, 2013). Smallholder farmers have used intercropping, seed selection and soil conservation with no-tillage approach to reduce drought risks (Altieri, 2004).

Communities from various parts of southern Africa developed coping methods to deal with accelerated variations in climate, usually reflected by the increased frequency of floods and droughts. Manyatsi (2011) stated that the communities in Swaziland use different methods of weather prediction to manage hydrological disasters. The community uses the nesting position of the *Ploceus ssp* bird to foretell flooding. When *Cuculus solitaries'* birds cry, they indicate the beginning of the rainy season around August to November. Soon after hearing the cry, farmers bring together their ideas. According to the study taken in African Sahel by Nyong *et al*. (2007), indigenous knowledge showed major importance in combating climate variation through the development of mitigation and adaptation strategies.

Many African communities depend on IK for their farming activities. Every village has its own specific set of IK indicators for weather forecasting. Other communities in the Philippines depend notably on the use of indigenous weather predictions to arrange and put together farming activities and in the prevention of natural disasters (Galacga & Balisakan, 2009). Farmers use these to prepare their farmlands while they still have time to make sure that the vegetative cover is established earlier than the heavy rainfall season. Indigenous weather knowledge often aids to prevent soil erosion during the period of heavy rains.

Several researchers indicate that various farmers from various parts of Africa use special local indicators including but not limited to plants, animals, insects, moon, sun, stars, spiritual manifestations of prophecy, visions, and wind to predict the seasonal climate (Roncoli *et al.,* 2002; Ziergovel & Opere 2010). Chang'a Yanda and Ngana (2010) study discovered that farmers in Tanzanian use warning signs such as the migration patterns of insects, birds, and the solar system in climate forecast. Kihupi *et al.,* (2002) also revealed that indigenous weather prediction has always been an important part of their strategies for adaptation in case of imminent natural disasters.

2.4. Forecasting and Indigenous Knowledge Indicators

The majority of communities still depend on traditional methods of climate forecasting, which primarily use biological, climatological, and astronomical indicators, and some also depend on their traditional healers "rainmakers" (Enock, 2013). Local communities have set up a complex method of gathering, predicting, interpreting, and making decisions concerning the local climate. A study by Ajibade and Shokemi (2003), found smallholder farmers in Nigeria use folklore knowledge to interpret weather systems including rainfall, cyclones, thunderstorms, and sunlight to plan for the future. Local farmers also use certain trees to forecast weather for the short and long term, as well as seasonal forecast outlooks (Okonya *et al.,* 2013). IK is significant to any preparation methods at the lowermost level and allows residents to act appropriately.

The Hausa population living in the Northern region of Nigeria created a great substantial resource out of IKSs to manage the susceptibility to dry spells in the sub-tropical to dry zones of the Sahel (UNEP, 2002). Rural communities of Hausa mostly rely on indigenous climate knowledge for everyday seasonal forecasts. Most of these indicators are originated from nature and each region has its own. Farmers in Nigeria use indigenous methods to complement planning their agricultural activities.

Risiro *et al*. (2012) argue traditional knowledge practitioners and attentive community members observe the signs of impending rain in the sky, wind patterns, clouds, and floral cycles. Whereas traditional knowledge reveals whether long-term cyclical weather patterns is prevailing, star pattern and moon crescents provide information on the arrival of seasons.

According to several studies, IK is used in rural areas to predict weather forecasts, and some of the events are interpreted using animal behaviour and vegetation changes (Ingram, Kirshen & Roncoli, 2002). Smallholder farmers in Free State have been using crops and livestock as a climate change adaptation measure, observing cloud formation and how cows and calves behave in the pasture as a signal that rain might fall within a day (Zuma-Netshiukhwi *et al.*,2013). These climate indicators were utilised to plan for the rainy season in the short term. Moreover, farmers are also threatened and vulnerable to other extremes by weather conditions such as drought and heavy rainfall. Smallholder farmers experience many inadequacies as a result of a lack of long-term IKS signals for forecasting climate and other unpredicted climatic conditions.

2.5. Biological Indicators

2.5.1. Plants

Western countries have documented dandelions (*Taraxumcun offcionale*) and tupilus (*Tulipa gesneria*), which bend over their petals earlier before the rainfall (Acharya, 2001). According to Risiro *et al*. (2012), there is a variation of biological indicators that are used to predict climate changes in the Chimanimani district on the eastern side of Zimbabwe. Certain floras such as *msasa mnondo* (*Julbernardia globiflora*), and (*Brachystegia spiciforms*) transform their structure according to the season. Their leaves are actively cut off during the dry season, and they develop new leaves when the wet season approaches. Plenty of fruits from plants like sugar fruit (*Uapaca kirkiana*) and Mobola plum (*Parinari curatellifolia)* indicate that drought will occur in the upcoming season. The few fruits produced are caused by the wind which often goes before the wet season and might also shed off leaves as a result of fewer fruits (Makwara,2019). A study conducted by Speranza (2009) indicated that in the Makueni District in Kenya, signs from plants depend on tree conditions and the abnormal flowering of particular plants. If plants yield more fruits than normal, drought will have an impact on the upcoming season. Indicators can be controlled by the time, e.g., the delayed flowering of the Acacia tree. In the community of Mahenge district south of Tanzania, a heavy blossoming of a mango tree is considered as a sign of the onset of drought season (Kijazi, 2011).

2.5.2. Animals, Birds, and Insects

Animals usually create sound earlier at the beginning of heavy rains as a kind of signal to indicate the presence of heavy winds and sound waves generated at those frequencies, and also the change in barometric pressure. There is the knowledge that animals may also be reacting to refined variants of the earth’s electromagnetic field that shows up before severe occasions like windstorms. Acharya (2011) carried out research that implies that animals might be reacting to micro temblors or ultrasounds not sufficiently loud to be heard by human beings. Smallholder farmers predict rainfall by observing an inflammation on the camel’s leg because swellings are most likely caused by higher relative humidity (FAO, 1998). Roncoli *et al*. (2002) observed that Fulani herders from the west of Burkina Faso whose domestic animals feed in fallow parts, observing the nesting position of birds, discovered that when the nest hangs on top of the trees, they will experience heavy rainfall and when nests hang in the upper parts, which indicates that rainfall will be insufficient.

In Australia, if a lapwing bird (*Tatihari*) hatches its eggs on the ground's surface, it means that good rains are likely to happen, and when it lays on the lower part of the ground poor or no rains are predictable. According to FAO (1998), when a bird lay one egg, it means that it will rain for a month. If a bird lays two eggs, it means that it will rain for a period of two months. Shoko (2012) observed that cicadas, the rain cuckoo, and the ground hornbill are the most popular birds' indicators used in the Mberengwa district.

Certain organisms including frogs and millipedes are considered at the commencing of the wet season. When the migratory birds appear, it is a sign that the summer season is approaching (Risiro *et al*., 2012). In countries like Botswana and Zimbabwe, smallholder farmers wait for the sounds of insects coming out of hibernation as an indication of the beginning of a new season (Mapfumo *et al.,* 2016). According to Jiri *et al.,* (2015), in Southern Africa, several indicators are common, which aid in the conservation of a variety of animals throughout the region. Manyatsi (2011) recognised that when insects such as locusts, butterflies, and grasshoppers throughout the planting season are in large numbers then, so a dry spell should be expected. An impending sign of rainy weather encourages farmers to begin land preparation in expectation of the wet season.

2.6. Meteorological Indicators

Several researchers found that IK for the local weather forecast differs with temperature, relative humidity, and wind conditions (Speranza *et al*., 2010 & Risiro *et al*., 2012). The presence and absence of specific cloud types can be used to predict the weather. Scientific climate monitoring also uses the presence or absence of specific cloud types and rainfall pattern indicators for weather prediction (Luseno *et al*., 2003). In the Manicaland province of Zimbabwe, the community knows that when the wind breeze is on the easterly border of Mozambique it means that the rainfall season is approaching and if it continues, it means more rainfall. Muguti and Maposa (2012) stated that the community of Masvingo province can predict the rain from the southern blowing winds. Early prediction methods have shown to be vital in planning for local weather activities, especially in cases where there are floods, cyclones, and droughts. A study by Tall *et al.* (2012) has shown that West Africa has a lower rate of loss of lives as a result of flooding. The awareness of indigenous weather knowledge needs to be integrated whilst planning climate change adaptation strategies in Sub-Saharan Africa (SSA). According to Roncoli *et al*. (2003), the majority of small-scale farmers from rural areas have acquired a traditional method for forecasting climatic and weather occurrences based on observations of natural resources.

According to a study conducted in the country of Zimbabwe, smallholder farmers identified five regimes that indicated various rainfall stages (Mapfumo *et al*., 2016). These various stages included the beginning and end of the winter season and the rainy season begun. Nevertheless, Mapfumo *et al*. (2016) acknowledged that changes in rainfall patterns have altered these markers, Information from seasonal rainfall forecasts is used which has led to them being less reliable and misleading smallholder farmers. These are also significant in guiding their farming practices (Jiri *et al.,* 2015).

2.7. Astrological Indicators

2.7.1. Stars as an Indicator of Rain

Alcock (2013) noted that some South African farmers still use stars as indicators to forecast the weather by carefully noting the position of stars that twinkle. The position of the stars will indicate the direction of the wind the next day. It is completely unbelievable considering that there are strong upper-level winds carrying dust and other particles, with a different temperature and density to the surrounding air and can result in the star twinkling. According to Burden (2011), faded stars without the appearance of the cloud are associated with rainfall the following day. It is mentioned by Alcock (2010) that in Lutzville in the Western Cape, a shooting star moving in the north direction is an indicator of rainfall.

A similar belief at George is that a shooting star moving from the sea towards the Outeniqua Mountains means that rainfall is approaching. A shooting star moving from over the mountains to the sea (in a southerly direction) is an indicator of drought (Alcock, 2010). According to Van der Merwe (1987), the positioning of the Pleiades and Orion's Belt in April was of importance for rain in Bushman land.

2.7.2. The Moon and Sun

Alcock (2010) stated that the white community of South Africa also uses the observation of the full moon to predict the weather. It is said that rainfall may appear on several occasions when there is a sudden decrease in temperature. According to forest folklore, it is mentioned that there is frequent rainfall around the full moon in Knysna Forest (Matthee, 2006). In addition, it is believed that rainfall is uncommon around the full moon, even though it might rain at that time, then good rains will be evident. There will be rain after the full moon during the first half of the calendar month. Furthermore, there will be rainfall after the full moon only if it occurs before noontime and the other way around.

According to Alcock (2010), a limiting interpretation of weather is that rain only occurs when the moon changes its phase. It is believed that there will be no rainfall around the full moon, just about 2-3 days earlier than the full moon up until 2-3 days after the moon (Burdern, 2011). Burdern (2011) mentioned that the opposite within the same time frame has also been documented, namely, that will be a change in weather during this period. The above mentioned are examples of folklore that have been probably introduced into South Africa from other western countries.

People predict the weather by noticing the halo phenomenon around the sun. If there is a halo around the sun that had an increased diameter, then in a few days, rainfall is likely to occur (Rivero-Romero et al., 2016). According to (FAO, 1998) the indigenous weather observation accuracy can be as high as 50%. Farmers interpret the upcoming season by using astrological indicators such as the angle of the sun. According to Risiro *et al.* (2012), the Milky Way shifts its position with the season, and the halo shape around the full moon is a good indicator of coming rainfall within the coming weeks.

2.8. Indigenous Forecasting in cultural and spiritual importance

Traditional stakeholders such as the chief and headmen continue to play an important role in indigenous forecasting for smallholder farmers. Smallholder farmers trust and follow the chief's advice because they have faith in the chief and community elders, ritual specialists, for example, have connections with spiritual beings that provide guidance based on the upcoming season (Makwara, 2019 & Githungo *et al.,* 2009). The chief's advice may include specific crops to be grown throughout the season. However, there is evidence that community elders' main predictions revolve around the arrival of rainfall, with estimates that span from days to weeks (Roudier *et al.,* 2014). A study according to Orlove *et al*. (2010), also revealed that there is a correlation between IK and believing in God and spirits. Indigenous forecasting is important to smallholder farmers because it is believed that rain has religious and cultural importance; for example, the lack of rain indicates that God and the spirits are dissatisfied with society at large. While an abundance of rain indicates that the community has pleased God and the spirits.

2.9. Challenges of Using IKS

Regardless of the practicality of IK in climate and local weather prediction, the use of indigenous weather forecasting is endangered because there is a shortage of documentation of the weather knowledge and organised studies to investigate the accuracy and reliability of the forecast (Githungo et al.,2009 & Makwara,2009). Even though IKs are localised and more familiarised with the farmer’s settings, this knowledge is disappearing through climatic variability, population increase, and urbanisation (Masinde & Bagula, 2012). The challenge with the use of IK is that is viewed to be a standard routine (normal). Hence, further studies have to be conducted to measure the benchmark (Makwara, 2019). Luseno *et al*. (2013) stated that a number of documenting research have been conducted, however, there are few current research papers on the contributions of IK to climate variability which indicate that science and IKs can go together. According to IDRC (2010), indicators used in weather prediction used in local communities are verbal, restricting the pertinence of IKS over large areas.

2.10. Seasonal Climate Forecasting

2.10.1. Indicators for Seasonal Climate Forecasting

According to Ziervogel and Calder (2013), weather information is given as a seasonal forecast, and it is defined as the total quantity of rain predicted throughout the season or over a certain period. The El Niño Southern Oscillation (ENSO) phenomenon describes the unusual warming of the surface of the ocean in the tropical Pacific and it controls inter-annual climate variability in southern Africa. Blunden and Arndt (2016) defined the ENSO as a recurring climate phenomenon characterised by a rise in sea surface temperature and the atmospheric pressure of waters in the central together with eastern tropical. Mienke and Stone (2005) defined El Niño as the considerable warming of the tropical Pacific Ocean, which increases rain in the eastern Pacific and decreases rain in the western Pacific along with southern Africa.

The Inter-tropical Convergence Zone (ITCZ) is an area characterised by convective activities causing rain throughout the summer months in southern Africa (Vogel & O'Brien, 2003). The climate indicators such as temperatures, sea surface, and Land-sea characteristics are affected by specific weather systems. These periphery conditions mostly change slowly, and they are useful in providing a piece of forecast information for diverse weather system possibilities (Mason *et al*., 1996). The ability to foresee the next seasons in response to climate change has begun to influence agricultural decision-making (Mienke & Stone, 2005). Seasonal forecasting is being employed on both empirical and physical models.

Ocean currents influence the areas adjacent to them on seasonal climate. The cold Benguela Current is present on the west coast and influences the places next to it. It produces cold air above the ocean that has very little moisture(Field *et.al*, 2014). Even with little rain, fog can occur on the west coast. The warm Agulhas current (Mozambique current) to the east warms the air, makes it more humid and unstable, and increases rainfall (Mason, 2001). Oceans moderate coastal temperatures, making summers less hot and winters less cold than in the interior. Coastal areas have a maritime climate.

According to Orlove and Tosteson (1999), the information's reliability and potential utility differ with the region, that is, the location of the area relative to atmospheric flow, and according to the social, economic, and political conditions in which it is distributed and applied. Masinde and Bagula (2012) mentioned that the forecast is released in terciles namely: below normal (BN), normal (N), and above normal (AN) with the possibility of rain falling into one of three categories as predicted by the forecast.

Attempts to forecast the Indian summer monsoon were among the first attempts to link weather to global climate anomalies (Walker 1924). Using a variety of statistical modelling techniques, significant seasonal predictability of the Indian monsoon has been identified (Kung and Sharif, 1980).

However, in the absence of a monsoon, the land-sea contrast and the dramatic changes in topography associated with the escarpment are unlikely to be as influential in influencing the annual circle of rainfall as they are over the Indian subcontinent (Kung & Sharif, 1980). As a result, the prospects for developing successful seasonal forecasts using GCMs may be better in the Southern African region.

Over the Sahel (Hulme *et al*., 1992), other parts of Sub-Saharan Africa, and the Brazilian North-Nordeste, sea-surface temperature, and wild vector anomalies have been successfully used to provide statistical seasonal rainfall forecasts. Modelling inter-annual variations in rainfall over the Sahel and North-East Brazil using observed sea surface temperatures has also been demonstrated (Rowell *et al.,* 1995). A higher resolution and parameterization of surface moisture flux are required for more accurate rainfall simulation (Hulme *et al.,* 1992).

2.10.2. Forecast Producers in southern Africa

The variety of meteorological services and university research groups in the Southern African Developing Community (SADC) region produces forecasts. Every year, the World Meteorological Organization (WMO) mandated the SARCOF process to combine these projections to get a regional perspective. These provide a region for configuring, producing, and deploying local forecasts. The region's forecast production is described first, and then for South Africa. The SARCOF is the process for WMO regional seasonal climate forecast prediction and application that

SADC's 16 member countries have put in place. The SADC Climate Services Centre(CSC) provides operational, regional services for monitoring and forecasting weather extremes. Meteorological, environmental, and hydrometeorological products are developed and disseminated by the Centre. The outputs of the Centre help to improve disaster risk management in the region and guarantee that Member States are better prepared for weather and climatic disasters, as well as conservation and protection of natural resources.

2.10.3. Processes of Regional Institutionalization

SARCOF promotes information exchange and interaction between forecasters, decision-makers, and users of climatic information for the region. Its primary goal is to help in the development of technical and scientific capabilities in developing, distributing, and implementing climate forecast information in the region's weather. SARCOF meetings are held annually. The workshop on capacity-building held prior to the SARCOF; aims to improve ‘’forecaster’s technical competence in periodic climate forecasting. The workshops allow members to acquire knowledge in climate modelling, such as downscaling techniques, explanations, and how to apply traditional knowledge.

Since the early 1990s, various South African research groups have been investigating suitable seasonal climate prediction methods (Mason *et al.,* 1996). This was motivated by the loss of life and infrastructure damage as a result of drought and floods (Klopper, 1997). As part of its membership in the World Meteorological Organization (WMO), the South African Weather Service (SAWS) is the country's national meteorological service. It is South Africa's primary provider of weather and climate information under WMO obligations. In 1997, the SAWS established the Long-term Operational Group Information Centre (LOGIC) as one of its services. In order to commence a continuous forecast product range, this center 2003 was merged with the SAWS Central Forecast Office under the division of longstanding forecasting. The new Disaster Risk Reduction (DRR) plays a major role of is in charge of providing national weather services to various domestic forecasting centers as well as the media.

2.10.4. South African Seasonal Forecasting

A seasonal climate prediction is a probabilistic statement about the state of the atmosphere over the course of a season (i.e., 3 months). It differs from weather forecasting, which provides a deterministic statement of the atmosphere over a day or two, and climate change projection (Figure 2.1), which provides a probabilistic statement on climate conditions over a long period of time [(ranging from 20 to 40 years or more) (Johnston *et al*., 2004)]. Seasonal climate predictions, on the other hand, typically provide future seasonal climate information as deviations from the climatic mean, i.e., anomalies. The main climate variables communicated in seasonal climate forecasts are rainfall and temperature. Seasonal climate forecasts in Africa generally refer to the traditional seasons of summer, autumn, winter, and spring (Lawal, 2015).

According to Lutgens and Tarbuck (2010), describes climate forecasting as a scientific estimation of the future climate conditions which are conveyed regarding changing variables including temperature, precipitation, and wind. This statement of weather is expected to manifest in a unique location at some point in a stated period (Buckle, 1996).

Forecasts are mostly classified into three types:

1. This includes forecasts for the coming days -Weather forecasts

2. This involves forecasts for the coming months-Seasonal climate forecasts

3. This is about the forecast for the future climate -Long-term climate forecasts (Blench, 1999). The accuracy of a forecast is inversely proportional to the lead time used in the forecast. Therefore, the longer the lead time the less precise the forecast will be.

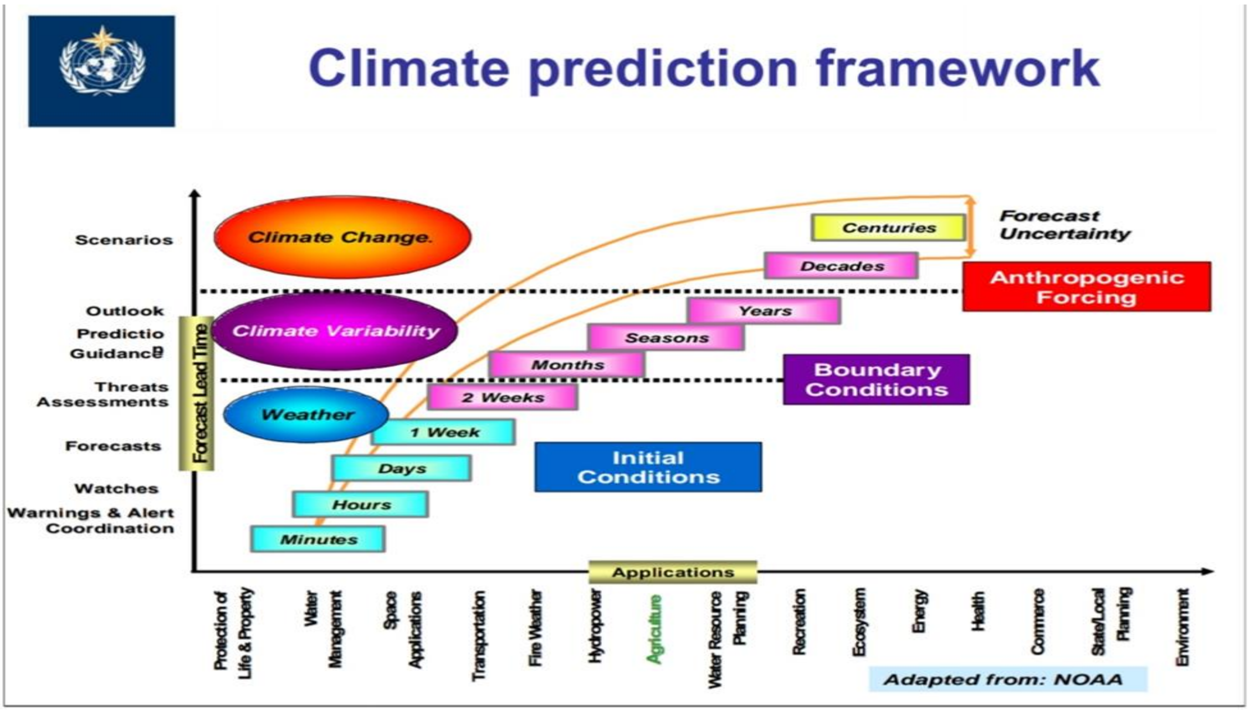

Figure 2.1: A Climate Prediction Framework. Adapted from NOAA

Over the last three decades, advances in climate system understanding, combined with improved computing and telecommunications capabilities, have enabled the provision of weather forecasts ranging from a few hours (nowscasts) to predictions and scenarios spanning decades and centuries. Even if there are uncertainties, these forecasts and predictions provide significant benefits to a wide range of socio-economic sectors. Uncertainties should not be used to justify not using forecasting or prediction in decision-making.

Prediction is dependent on the availability of models that are appropriate for the task at hand. In meteorology and climatology, there are two types of models: empirical and theoretical (Tyson & Preston-Whyte, 2000). Empirical models are usually descriptive or statistical and are based on observational data (Landman& Goddard,2002). While they provide useful and often necessary insights into the nature of the phenomena being studied, they rarely provide a solid foundation for prediction(Beraki *et.al,* 2014). Nonetheless, they are widely used in applied meteorology and climatology, for example, in agro-climatology to estimate crop yield. In general, empirical models are the least powerful of the modelling approaches available. Theoretical models are far more powerful, and deductive, and are derived from the fundamental equations that govern the physical processes under consideration.

2.10.5. Importance of Seasonal Forecasting

According to Klopper (2002), the seasonal forecast has a definite level of economic, water, and disaster risk management sectors even though they are not always reliable. The economic benefits of climate forecasts were shown during the past events of ENSO (Sonka *et al.,* 1988). Klopper (2002) stated that societal, environmental, and financial activities will in part direct the sensitivity towards climate events and regulate the kind of data to respond to. Climatological statistics have social benefits such as having a stable environment, living, traveling, and working conditions. For humans to travel from one place to another, they should have local weather statistics of the area. For example, if people want to travel to Zimbabwe, they should be aware of the seasonal forecast because a wet season will be characterized by malaria. Again, if the area is likely to be cold, they must be prepared with warm clothing.

Climate information can be used in many ways in South Africa; however, the agriculture sector is mostly affected by local weather variability (Kotir, 2011). Smallholder farmers use local weather data as a tool to plan for future activities, for example, when to sow, fertilizer usage, and stockpile management (Klopper, 2002). Seasonal climate forecasts provide farmers with the opportunity to adopt developed innovations, increase manufacture, restore soil nutrition, and take advantage of profit-making businesses especially when there are favourable weather conditions. The reason is to protect farmers' relations and their farmsteads from the long-lasting impacts of extreme weather phenomena (Vermeulen *et al*., 2010).

2.10.6. Seasonal Climate Forecasts and their limitations

Weather forecasts are typically distributed for a large number of similar rainfall regions (larger than 9,000 km^2) spanning three months, therefore these drastic changes in weather forecasting make it difficult for users to predict geographical coverage's borderline (Githungo *et al*., 2009). In addition, the scale and precision of available products and services information and farmers' needs are all mismatched.

These factors have restricted smallholder farmers' adoption of seasonal forecasts (Vermeulen *et al*., 2010).

Manatsa *et al*. (2012) conducted a study in the Chiredzi district, the study revealed that smallholder farmers were unconvinced of seasonal rainfall estimates and expressed tremendous concern about their accuracy. This was indicated by a (17%) amount of use among the smallholder farmers. Forecasting abilities are not only poor but also highly skewed with strong certainty, toward normal conditions in forecasts that are consistently near normal, However, this level of certainty is never used in drought forecasts, resulting in occasional above-normal rains and droughts. Manatsa *et al*. (2012) also noted that the Chiredzi area's inherent climate variability over short distances, and forecast information, even within communities, lose relevance, especially at the national level. The forecast data is unclear about the length of the season and does not explain intra-seasonal differences well. This explains the lack of additional intra-seasonal fluctuations in predicted evidence, in particular, wet and dry spell distribution (Githungo *et al.*, 2009)

2.10.7. Integration between IKS and Seasonal Climate Forecast (SCF)

IKS and seasonal climate together have advantages and disadvantages, and the main mission is how to put these two varieties in a way to respect their importance while bringing their strong points (IDRC,2010) Kihupi *et al*. (2003) stated that the forecasts can be probably more valuable if methods are combined so that they can assist generations to stay throughout the heavy rainfall and droughts into the current management decision-making approaches. The author further indicated that variables such as temperature, relative humidity, and wind speed are responsible for fluctuations observed by the locals in the community, then the seasonal climate forecast statistics from different stations can be summarised into mean value correlating with a derived context (Kihupi *et al*.,2003)

The table below is Adapted from IDRC (2010), which shows the comparison between IKS and SCF (Table 2.1).

Table 2.1: Comparison between IKS and SCFs

Indigenous Knowledge System	Seasonal Climate Forecast
Use of physical warning signs and nature.	The use of climate and local weather models to measure meteorological signs.
There are no records of the forecast.	They are well-recorded and technologically advanced forecasts.
Down-scaling and Up-scaling are complicated	Down-scaling and Up-scaling are fairly easy.
Observed indicators are not measured.	Indicators are measured.
Transmission of the information is verbally transmitted.	Transmission is written.
Weather interpretations are centred on the community and sacred beliefs.	Hypothetical interpretation.
Trained by observation and practice.	Trained by talks and interpretations.

Several reviewers have disagreed that the way weather forecasts are presented, and distribution is ineffective, although they can increase the threat because of inappropriate action by decision-makers, especially for subsistence farmers with limited resources. Kurukulasuriva and Rosenthal (2003) stated that the lack of scientific climate knowledge, managing these small-scale farming methods developed to survive with local weather variability, frequently leads to a wealth of indigenous knowledge in weather forecasting and climate-related. Alexander *et al.* (2011) stated that integrating IK into climate forecasting and climate variabilities plans may have a significant improvement in high-quality adaptation techniques that are economical, participatory, and sustainable.

2.11. Indigenous Knowledge and GIS

A Geographic Information System (GIS) is an organized group of computer software, hardware, and geographic information arranged efficiently to capture, store, inform, examine, demonstrate and analyse different forms of geographically referred information. In contrast to a hardware map, where "what you see is what you get," a

GIS map is able to incorporate multiple data (Gold, 2006). IK has significant spatial aspects. However, how GIS may be applied to indigenous knowledge management has received little attention up to this point. A system like this can help to manage indigenous information and make it more useful (Lawas & Luning, 1996). because this can be elaborated by the fact that traditional knowledge is spatial in nature, GIS can help to incorporate indigenous knowledge into local decision-making processes (Marozas,1991).

Gonzalez (1995) has elaborated on the significance of using GIS together with knowledge-based systems to file indigenous knowledge. Lawas and Luning (1996) found that GIS applications were being used at the local level, in Northern Luzon whereas Marozas (1991) investigated how GIS is used in American Indian land and water rights lawsuits. Madsen (1994) has demonstrated how GIS and remote sensing can be used to exploit indigenous peoples, especially non-indigenous groups. New Zealand (Harmsworth, 1995) showed how indigenous people can enhance their own cultural imprint on existing applications when they develop and use GIS tools. Furthermore, such tools supplement the indigenous knowledge systems that have traditionally been utilised to conserve and transmit knowledge, with an emphasis on the connection with people, spaces, cultural activities, knowledge, and the spoken word (Harmsworth, 1998).

2.11.1. Participatory GIS

Participatory GIS (PGIS) refers to a spatial decision-making instrument that uses GIS technology to assist the public to participate in decision-making processes affecting their communities (Jankowski, 2009). A variety of data acquisition techniques, including Rapid Rural Appraisal (RRA), village immersion, a farmer-based interview schedule, observations and field visits, analog maps, the utilization of a question checklist, and aerial pictures are all examples of rapid rural appraisal methods, which are used in to collect primary data. Such integrated information retrieval methods have proven effective in obtaining reliable information from farmers.

2.11.2. Approaches and Applications of PGIS

PGIS has been used for a wide range of applications, including the examination of differential flood vulnerability in the Thulamela Municipality and the integration of previous and current flood experiences into a traditional GIS to study differential household heavy rainfall vulnerability. The study used both quantitative and qualitative methods such as focus groups, mental mapping, and GPS-based transect to examine the local dynamics of flood vulnerability at Milaboni and Dzingahe villages. The main focus of political ecology is understanding how different power relations affect a household’s flood vulnerability, while PGIS provides the platform for including socially differentiated local knowledge. A database was created using a participatory GIS approach to analyse flood vulnerability by combining local and expert knowledge Nethengwe,2007).

The participatory mapping for adaptation to climate change was utilised in the case study of Boe Boe in Solomon Island to investigate the potential of Participatory three-dimensional modelling (P3DM) for adaptation planning. The P3DM exercise process consisted of two elements. Students and community members cut, pasted, and layered different pieces of carton boards, which later were then glued together to form a 3D blank model. Following the physical construction, villagers began to visualize and add their local spatial knowledge to the model. The community discussion and interpretation of the challenge centered on the participative 3D model (Picollela, 2013).

The Pretty Lake area of Virginia Beach and Norfolk was selected as a study area as a case study area by the Citizen Engagement Working Group to signify the use of PGIS as a stakeholder inclusion tool for integrating indigenous knowledge into the evaluation of heavy rainfalls and sea level rise risks. The weTable tool, which was used in combination with the PGIS application, was to be a significant tool that can gather and document local knowledge, specifically in accenting community strengths and challenges. It was also revealed that it can be used for encouraging community by visualizing the problem and understanding the magnitude of sea-level rise and flooding. The participatory mapping demonstration project illustrated how participatory mapping may directly include locals in the development of sociospatial data, generate knowledge, and stimulate learning and discourse on difficult issues such as flood resilience and sea level rise (Yusuf *et al.*,2018).

The exploratory application of integrating PGIS into a coastal community climate risk valuation process was applied at the Shore of Lake Superior in Minnesota. Stakeholders were involved in providing relevant data and information through the co-production of science to the locals. Engaging with the stakeholders in a PGIS-based climate change risk assessment method provides for the spatial representation and visualization of locally relevant data and information. Stakeholder views of risk thresholds were gathered through the use of PGIS focus groups, pre, and post-surveys, and the severity of the climate-related risk to locations with built infrastructure, natural assets, recreation areas, and tourism attractions. The exercises PGIS generated an important discussion between stakeholders and illustrated how explicit spatial data and information can be collected more efficiently from stakeholders to inform effort mitigation and adaptation (Bitsura-Meszaros *et al.*, 2019).

PGIS methodology is necessary to represent the spatial distribution of indigenous climate indicators in the chosen study area. The initial base maps were created using existing aerial and spatial data in anticipation of the PGIS mapping effort and then enhanced with local feedback. Quantitative and qualitative data collected through Household surveys, focus groups, and interviews were collected by the use of GPS to represent the sampled households.

2.12. Conclusion

This chapter looked at scientific and IK forecasts, how they are generated, how they are disseminated, and previous research on forecast usage. It has been discovered that extensive forecasting can limit the quality and reduce user confidence, necessitating the need to reduce downscale forecasts at the local level.

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CHAPTER THREE: METHODOLOGY

3.1. Introduction

This chapter outlines the research design and study area, as well as the procedures used to conduct the study, and provides a specific methodology utilized for data collection and analyses, as well as data presentation.

3.2. Description of the Study Area

The study will be conducted in Moletjie area, Limpopo Province, South Africa. Moletjie is a village located at 23.40˚S and 29.5˚E, approximately 30 km east of Polokwane (Fig.3.1). It comprises many scattered rural dwellings. The study will, however, only be conducted in three (3) villages; Moletjie Moshate, Mabokelele, and Ga-Ngoasheng, under Kgoshi Kgabo Moloto the 3rd Traditional Authority. The population is largely the Bapedi tribe and practices mainly Christianity and ancestral traditional religion. Some clans are the custodians of certain cultures and practices. The locality is hilly and the community practised subsistence farming.

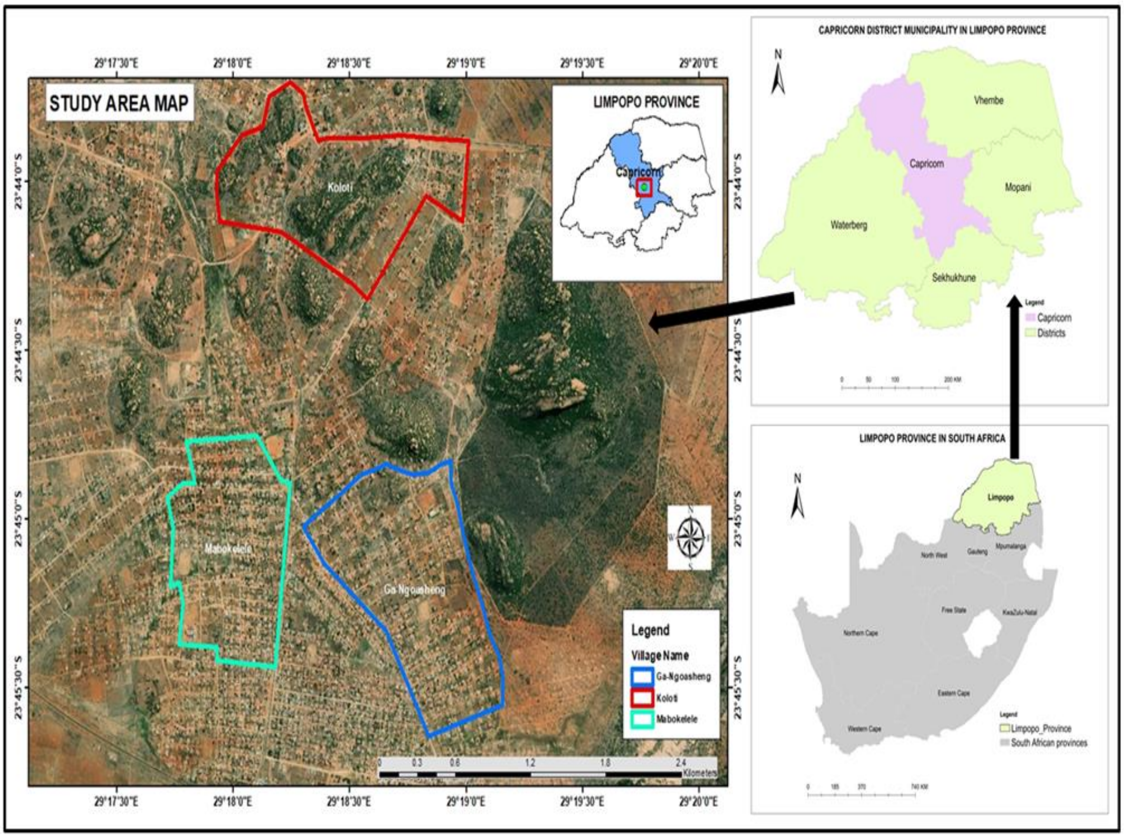

Figure 3.1: Map showing the location of the study area

3.3. Research Design

The study adopted a mixed-method, which is a combination of qualitative and quantitative data. For the qualitative research approach, an ethnographic research method was adopted because it includes documentation, experience sharing, and observations of phenomena to understand indigenous knowledge that reflect the weather, climate, and meanings that guide the life of cultural groups within their environment. Meanwhile, quantitative methods such as surveys were employed to interpret the numerical data study of indigenous weather knowledge. In order to document IKS, qualitative data and quantitative data were gathered using in-depth interviews and questionnaires designed for household interviews with questions that cover objectives of the research. The collection of both qualitative and quantitative data at roughly the same time allows for a thorough examination of the research problem (Creswell, 2014).

3.4. Data Collection

This research study was focused on both primary and secondary sources of information. Primary information such as the use of IKS on weather prediction from various experiences was collected through in-depth interviews and surveys. Conversely, secondary data such as how IKS has been used in another place to predict weather and climate were taken from formally published material (books and journals). Primary data were gathered in the field through questionnaires and key informant interviews.

3.5. Sampling

According to the 2011 Census of Population and Housing, the absolute population of Moletjie is 5,740. A total of 45 people were purposively drawn from residents of Moletjie Moshate, (Koloti), Mabokelele, and Ga- Ngoasheng village, respectively. Fifteen (15) participants from each selected village were interviewed and issued questionnaires. This was assumed that they have gained adequate information on IKS and the traditional ways of predicting the weather. Nonetheless, purposive sampling possibly has the rudiments of partiality because the respondents' selection depends on the researcher (Etikan *et al*., 2016).

An exploratory qualitative approach was used to select respondents to get in-depth information knowledge based on experiences with weather prediction using the IKS. In-depth interviews consisted of people varying from 60 and above and whose place of origin was Moletjie or who have been residents in the area for at least 40 years and above were interviewed. The belief was the longer the person stayed in the area, the more they were familiar with their living environment. The questionnaires focused on key informants who were at least 60 years of age and above because this group was the conservator of indigenous weather knowledge.

A qualitative method such as questionnaires was used first to elicit information on whether the person has any understanding of IKS on the weather and seasonal forecasting from the sampled respondents. Data was pre-analysed by identifying individuals that would be further interviewed for in-depth qualitative data because it was from those few identified individuals that the researcher got rich and in-depth information on IKS for documentation. This strategy was ideal since the researcher needed to comprehend the respondents' interpretations and responses. Because the respondents were fluent in Sepedi, the language was employed in the interviews. The objective was to give people the freedom to express themselves. During the interview, the researcher took personal notes and recorded them on audiotape and afterwards transcribed them.

3.6. Data Analysis

Participatory Geographic Information System (P-GIS) approach was employed in this study to spatially analyse the varied knowledge from respondents about IKS and weather prediction for local villages using ArcGIS 10.6 software. To establish the context, qualitative data sets were selectively merged (as a local information layer) into a PGIS database for indigenous weather knowledge distribution. These data sets included a base map of the indicators of IKS and resource distribution was used. Quantitative data sets from household interviews were linked with the GPS position of the sampled households in the study area villages for subsequent analysis.

Qualitative data were analysed using the thematic approach method. The indicators or behavioural signs were noted down also as the equivalent forecast from the indicator. The indigenous weather indicators for the research are divided into the following categories:

- Biological indicators such as plants, animals, birds, and insects.
- Meteorological indicators such as temperature, rainfall, clouds, and wind.
- Astrological indicators such as the moon, and stars.
- Human alignment.

The data was then presented in narrative form by the researcher, which formed the foundation of the thesis. These aided in supplementing quantitative data findings.

Quantitative data gathered was coded and analysed using Statistical Package for Social Sciences (SPSS) and the Excel package version 25.0. Descriptive statistics such as frequency and mean were used to summarise demographic information (such as age, gender, period of residence, the level of education), the frequency of use of IKS, and its relevancy. Descriptive statistical analysis of questionnaire survey data was displayed in a form of bar charts and graphs to define the demographic data which include age, period of residence, the level of education, and the frequency of use of IKS.

3.7. Ethical Consideration

To ensure that this research was ethically appropriate and adhered to the University of Limpopo Research Ethics Committee (TREC) since the study involves human participation; the institution's ethics committee accepted the research proposal. Local Authorities (Chief, headman) granted consent to conduct research in their area and respondents participated voluntarily.

3.8. Conclusion

The study area, sample selection procedures, and data collection and analysis methodologies were all covered in this chapter. The primary focus was on the research topic: Assessing and documenting the use of indigenous knowledge systems in weather and seasonal climate forecasting. Data was collected in Moletjie villages in Limpopo province, South Africa. Data collection was mostly focused on smallholder farmers' responses and was carried out through focus and survey questionnaires, to compare their responses.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1. Introduction

In this chapter, the study's results are presented and discussed with reference to the purpose of the study, which was to assess and document the use of the Indigenous Knowledge System in weather and seasonal climate forecasting in Moletjie, Limpopo Province.

The results start by profiling participants and thereafter report on the documentation of the biological, meteorological, astrological, and human alignments indicators used to forecast local weather and climate conditions in the study area. This is followed by the determination of the effectiveness of indicators used to forecast local weather and climate conditions and finally representation of the spatial distribution of indigenous weather knowledge using a Participatory Geographic Information System.

From the analytical perspective, it was assessed how forecasts were derived from indicators. The indicators or behavioural signs were documented, and the indicator's corresponding forecast. The indigenous weather indicators for the study were classified as follows.

- Biological weather forecasting Indicators
- Atmospheric weather forecasting indicators
- Astronomic Weather Forecasting Indicators
- Human alignments

4.2. Demographic Characteristics of Respondents

Farmers' socioeconomic status can influence how they use seasonal forecasting in crop management decisions. This section assesses the household characteristics and assets that may have an influence on the usage of climate forecast information.

4.2.1. Age

Respondents of various ages (from 60-96) were represented, with a significantly larger percentage in the oldest age group (66-78) accounting for 26.27%. Figure 4.1 shows that the oldest age group, those aged 60 and up, accounted for 13.33% of the respondents. This means that data was gathered from people of varied ages, providing a general understanding of each age group.

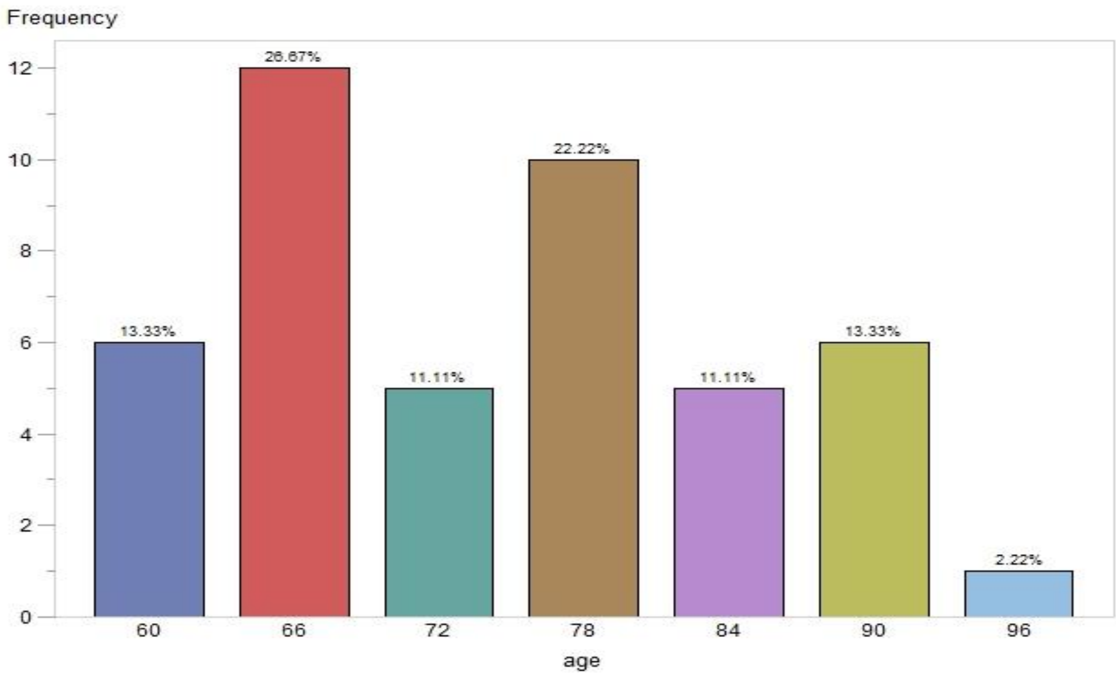

Figure 4.1: Distribution of respondents by age

4.2.2. Gender

When the gender distribution of respondents was determined, it was discovered that females outnumbered males. As seen in figure 4.2, the number of females interviewed was somewhat higher at 55.5% than males at 44.44%. In terms of data collection, this implies a well-balanced view as far as the study was concerned.

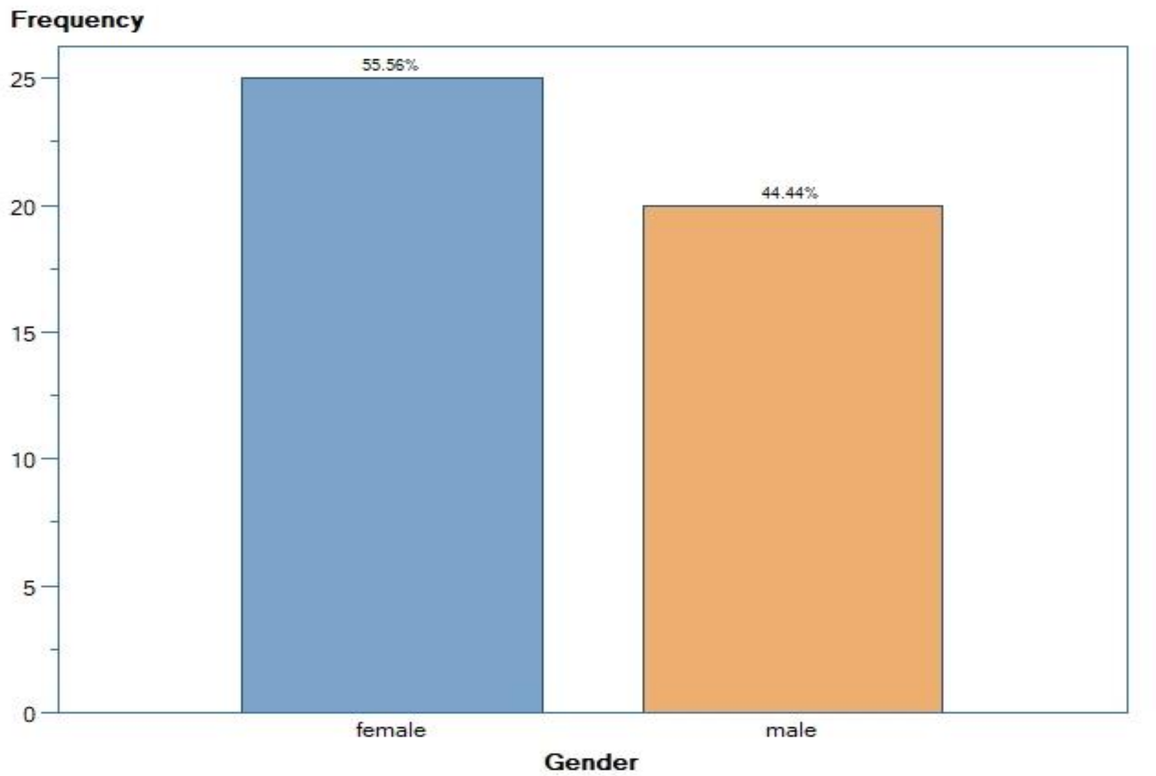

Figure 4.2: Distribution of the respondents by gender

4.2.3. Level of Education

Figure 4.3 shows that a large proportion of respondents had completed primary and secondary school. 44.44% of respondents were completely illiterate, 31.11% had primary level education, 17.78% had secondary education, and 6.67% had tertiary education. Farmers' education level and personal qualities influence how they act on the information they get. Patt and Gwatta (2002) contend that farmers who are young and well-informed are more willing to accept changes to experiment with innovative ideas than senior smallholder farmers.

Understanding basic ideas in predicting and making decisions about what and when to plant requires a high level of education. It had also been obvious that individuals who are illiterate or just had a primary education had higher faith in IK forecasts than scientific forecasts, which may be due to their failure to comprehend scientific forecast concepts.

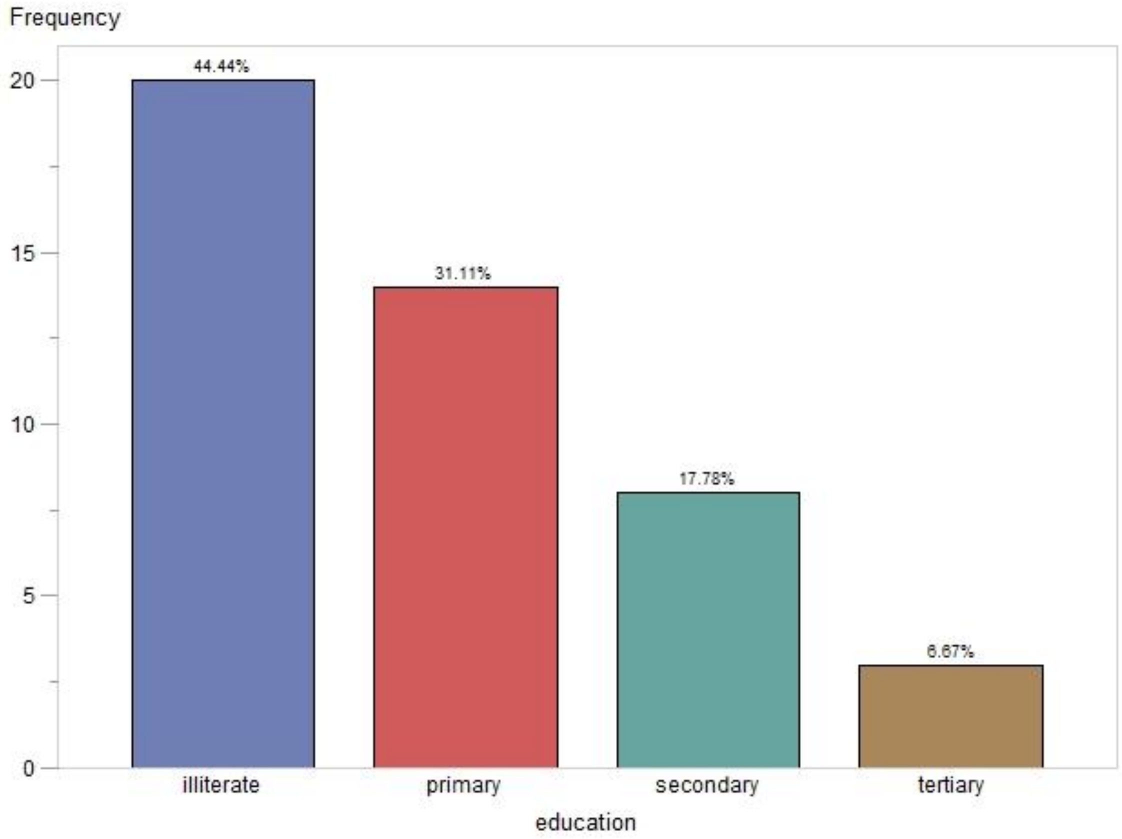

Figure 4.3: Education level of respondents

4.3. Indigenous Weather Indicators

4.3.1. Plant Indicators

According to Elia et al. (2014), small-scale farmers in rural communities utilise plant phenology to predict the weather in a variety of ways. From the interviews conducted, Moletjie smallholder farmers believe that the presence of more intense blossoming of Peach trees from July to November pre-empts a significant amount of evenly distributed rainfall in the next season (Figure 4.4). According to 76% of the respondents who were purposively targeted, the buddying of new leaves is an indicator of seasonal quality. It was also indicated that the spectacular flowering of Wild Fig trees is a sign of plentiful rainfall in the coming season. 24% of participants stated that when the fruit is more ripe than usual, it indicates that a good rainfall pattern will prevail. Table 4.1 summarises plant indicators used in the community to predict the weather, such as flowering, fruit-bearing, and seasonal morphology changes.

Figure 4.4: Mango, Peach, Mophato trees

The average flowering of the Mango tree, which translated to normal Mango fruits, was a good predictor of a good rainy season. High blooming and fruit production by Mango trees, on the other hand, is widely regarded as an indication of an imminent poor rainy season in the coming season because they produce many flowers that drop off. During the dry season, these trees shed their leaves as well. One popular explanation for the reason why trees produce plenty of fruit during a drought season is that it is God's method of assuring human existence during times of food shortage (Alvera, 2013). Whenever the *Acacia nilotica* tree blooms with an abundance of white flowers, heavy rains are predicted, and the rains normally fall within the next few days (Speranza *et al*., 2009). According to Speranza et.al (2009), late flowering acacia trees are a sign of drought conditions. The flowers fall as a result of the rainfall.

Table 4.1: Plant indicators and their predictions (IKS) as used in the Moletjie Village

Tree type	***Description***	***Weather condition***
Peachtree	blooming of plants	Indicator of good rains during the summer season
Mango tree	Plenty of fruits or excessive flowering	indicates a bad rainfall season
Acacia (A*cacia nilotica)* – *Mushu/ Mooka*	Heavy budding of acacia species tree/ Dense white/yellowish flowers sprouting Few flowers	During the summer, this is an indicator of good rains. The flowers bloom before the first rains and continue to bloom throughout the rainy season, signalling the end of a long period of dry spells. The number of flowers can indicate how much rain has fallen. The more flowers there are, the more rain there will be. Insufficient rains are expected.
Wild fig tree	Greenness of leaves plants shedding off leaves	Imminent rainfall onset dry season
Mophato	The high amount of white flowers	Good rains are coming
Mohlatso	Plenty fruits	Good rain season
All trees	Time of foliage	When trees begin to sprout new leaves, it usually indicates that rain is on the way. Early leaf sprouting indicates that rainfall will arrive early that year, while late foliage signifies late rains, which normally translates to a short rainfall season.

4.3.2. Animals Indicators

Farmers use the behaviour of animals to characterize weather and climate. Birds, locusts, ants, frogs, and worms are just a few examples of the most common indicators (Table 4.2 and Table 4.3). Bird behaviour can also be used as a barometer to determine when and how long a rainy season will last. According to (Mapara, 2009), people can also forecast whether or not it will rain in the next hour or two if they hear *Mohlolapula* (Rainbird). Farmers emphasized the emergence of a bird called *Peolwane* (swallow) as an indicator of rainfall expected in a day, whereas the croaking sound of a frog was a signal of immediate rainfall. This is comparable to what Elia et al. (2014) observed in the United Republic of Tanzania. On the one hand, the rainy season is believed to be impending when migratory birds begin to surface in the environment. The constant singing, both during the day and at night, heralds the start of the rainy season. The migration of migratory birds, particularly the southern hornbill, indicates that there will be a lot of rain. Respondents indicated that large swarms of swallows and white storks in the area, as observed by Svotwa et al. (2007) and Makwara (2019), indicated the onset of a promising rainfall season. A stork soaring high in the sky is indeed associated with a fruitful season. Human beings can predict whether or not the rains will end by looking at their fowls and different birds, according to (Mapara, 2009). Respondent mentioned that even a regular chicken (*Kgogo*) raised in the home can be used to forecast rainfall patterns. People can expect a drizzle (*mosarasarane)* for at least the next few days when it rains, the birds and chickens go out there to feed. The duration of the rainfall will not continue the entire day if the birds and fowl didn’t go out to feed. (Manamike, 2011) adds that when birds and hens walk around while it is pouring, people interpret this as a sign of the abundant rainfall in that season.

Table 4.2: Birds and animal indicators as applied to the Moletjie Villages

Indicator	***Description***	***Weather condition***
Cuckoo rain- bird	In the months of October and November, the bird sings, especially in the afternoons.	The onset of rain is imminent, and the season is expected to be rainy.
Swallows-*Peolwane*	Flying at a low altitude	Imminent rainfall onset
Ground Hornbill- *lekgotutu*	Making sound	Cloudy and humid conditions
White stock bird- *Mankutsweu*	Presence of white-bellied stock birds	good season and imminent rainfall
Boraa / Dithaa	The appearance of the bird	Incoming rainfall
Hlanhlane	The appearance of migratory birds	Incoming rainfall
Mankabotsana	Presence of migratory birds	Imminent rainfall
Mamati	The appearance of the bird	Incoming rainfall
Hlahlamedupi	Singing of the bird around September month	Incoming rainfall
Sebata / pela	Appearance around the mountainous area	The Winter season is coming

Cicadas and other insects chirping (*cryptotympana postulata*), and crickets (*gryllus sp*.) were linked to increased temperatures at the onset of the rainy season began in November. During this hot period, mosquitoes will be at their most energetic, as well as their biting behaviour will be at its peak. Farmers also reported an increase in the number of ants and termites (*Tšhošwane* and *Makeke*) harvesting grass and storing it in their habitat, indicating a good rainy season. As a result of the impending rains, crickets and spiders become more energetic, indicating a good harvest (Makwara, 2013). In Nissa Malawi, Kalanda-Joshua et al. (2011) observed the presence of grasshoppers (*Tšie*) and birds to signify the drought season. Grasshoppers in abundance, known locally as *Ditšie* in Moletjie, on the other hand, represent a good harvest year. According to Roncoli et al. (2002), the presence of a large group of Mayflies (Tšhintšhi) during the planting season for maize predicts an impending good season. Chang'a et al. (2010)'s study confirms the current findings that farmers in Tanzania's southwestern highlands use butterflies, ants, and termites to forecast the upcoming farming season.

Table 4.3: Insects/other animals and their predictions as applied in Moletjie villages

Indicator	***Description***	***Weather condition***
Crickets	Chirping the whole night	high temperatures and rains are expected in the coming weeks
Mosquitoes	The presence of mosquitoes	Temperatures are extremely high. Rain is likely to fall within the next day or two.
Toads – Matlametlo	A lot of croaking	Rain is predictable
Millipedes	Presence of millipedes	indicates imminent rains
Cicadas	Chirping all day and night	Temperatures are extremely high, and rain is on the way. They only appear after the trees have leaved.
Butterflies	Butterflies' presence	The rainy season has begun
Dragonflies	The appearance of dragonflies	Appearance signifies imminent rainfall
Grasshopper -*Mamati*	Abundance of grasshopper	The rainy season has arrived.
Caterpillars	Caterpillars have severely infested the majority of tree species.	eminent drought
Spiders	Spiders running around	Indicates the beginning of the rainy season
Red ants	The emergence of red ants, as well as the rapid expansion of anthills	Good rains are coming
Armored cricket	Appearance of crickets	Indication of the dry season especially drought

4.3.3. Atmospheric Indicators

Before or during the rainy season, temperature, humidity, and wind direction can help predict when and how much rain will fall. Both IKS and SFCs use these meteorological weather parameters (IDRC, 2010). As the rainy season approaches, weather changes including thunderstorms, are formed form when warm air currents rise above the earth’s surface creating cumulonimbus clouds. These clouds produce lightning, hail, occasionally tornadoes, strong north winds, and high temperatures which have been highlighted as a sign of impending heavy rains in the coming season (Table 4.4). Smallholder farmers in the southern Free State observed the emergence of dark clouds as a warning of impending heavy rains (Zuma-Netshiukhwi et al.,2013). It is widely recognised that dark clouds are indicators of heavy rains; moreover, this clarification is also supported by science.

Southern Africa receives the majority of its rainfall in the austral summer, except for a location in the southwest. The ENSO is known to influence summer rainfall in southern Africa (drier than normal circumstances during El Ni no episodes and wetter than normal conditions during La Nina events(Kane, 2009). ENSO is currently neutral, and the forecast shows that it will most likely continue neutral during the spring, with a possible change to a weak La Nia during early summer. During the spring and summer seasons, ENSO begins to have a larger impact on summer rainfall. As a result, the greater possibility of a weak La Nia during early summer is likely to favour above-normal rainfall during that time period (Fauchereau *et. al*,2009)

Minority, on the contrary, observed northerly wind blowing, bringing heavy rain. The direction of the wind can also be used to predict the weather as the rainy season approaches. Winds that blow from practically every direction from the end of October to early November trigger whirlwind activity. Light rains may fall, but the amount is usually insufficient to begin any type of farming activity.

Extremely high temperatures, which typically occur from September to December, also signalled heavy rains. The observations aided in the preparation of the land for the upcoming summer season. This is consistent together with Risiro et al.'s (2012) findings. Furthermore, the farmers identified cold temperatures as a sign of low rainfall in the upcoming season, while mist in the morning signalled clear skies throughout the day and the possibility of light rains. In contrast to these results, Chimanimani, Zimbabwe farmers reported that a hazy morning indicates that daytime temperatures are extremely high (Risiro et al., 2012). These inconsistencies could be attributed to the different geographical area.

Between September and October, temperatures are at their highest and were also reported to indicate good rains. Farmers, on the other hand, are now subjected to extended cold seasons that are crippling into October as a result of prolonged dry seasons. Furthermore, low summer rains indicate a warmer winter, whereas high summer rains indicate a cold winter. Smallholder farmers were generally of the opinion that high summer rainfall resulted in cold winters and the other way around. The findings of Charles et al. (2014) contradict these observations because the farmers made various observations regarding rainfall variations.

Table 4.4: Atmospheric indicators and their predictions as applied in Moletjie Village

Indicator	***Description***	***Weather condition***
Temperatures	Extremely high temperatures Extremely cold winters	Rain could fall within the next few hours or two. Indicates below normal rains
Wind	Dark clouds accompanied by very strong winds	A storm is imminent, and plenty of rains are expected.
Rain	Heavy rains in the summer Summer rains are less frequent.	The following season will have a cold winter. Warmer winters are expected in the coming season.
Clouds	Cloud formation over the southwest Dark clouds are forming. Strong winds and dark clouds.	Season of abundant rainfall Heavy rains are forecasted. Heavy rain is expected.
Air movement	The formation of a whirlwind Northerly winds Easterly winds	Weather conditions are extremely hot. Strong winds

		There will be less rain.
Visibility	In the morning, there is mist and dew. Haze is present.	During the day, it is sunny. Weather conditions are hot and dry.

4.3.4. Astronomic Indicators

The moon's appearance in the sky aids farmers in predicting seasons. The moon undergoes a variety of size, shape, and colour changes, according to the respondents (Table 4.5). The findings from Moletjie respondents stated observing a half-moon in the east is a sign of no rainfall but seeing a crescent-shaped downward indicates heavy rain in the next three days. These results are consistent with those of Ubisi et al. (2017) in Limpopo Province and Risiro et al. (2012) in the country of Zimbabwe. According to the farmers, a crescent moon with a halo surrounded by water was a sign of good and consistent rains. Basdew et al. (2017) stated that, comparable findings in a study done in Limpopo, South Africa. The full moon indicates dry weather. Whenever the moon seems to be red, the villagers predict heavy rain; when it is bright white, they predict light rain.

Furthermore, it was mentioned that the full moon predicts drought and dry spells during the upcoming season, which is known locally as *Ngwedi.* The moon, according to some farmers, served as a disaster warning system that guided them. Smallholder farmers have also claimed to have used visibility and changed the position of stars to their advantage, *(known as Sekgopotšana)* to predict weather patterns in a given season. Observing the sun or the Milky Way in the northern direction signalled the beginning of winter. Furthermore, the smallholder farmers said that when the Milky Way realigns itself and is slightly more towards the centre, it marks the start of the summer season. Farmers in Chibelela village predicted rain based on the position and visibility of stars, according to Elia et al. (2014). Additional observations revealed that when the sun was in the northwest it signalled the start of the summer season, and when it was positioned to the southwest at the beginning of the rainy season, it signalled the impending rain.

Table 4.5: Astronomic indicators and their predictions as applied in Moletjie Village

Indicator	***Description***	***Weather condition***
Rainbow	The rainbow's appearance during the rain event.	The rains have stopped.
Moon Moon (*Ngwedi wa Naka*)	A halo appears around the sun or moon. A quarter moon or its complete absence. Clouds encircle the moon. During the rainy season, there is a full moon. When *Ngwedi wa Naka* standstill	Indicates a favourable season with normal or above-average rainfall. During this time, rain is expected. A small amount of rainfall Dry conditions are expected. It's the winter season
Milky way Star constellation *Sekgopetšana* *Mphatleletšana* Canopus *(Naka)* Pleiades *(Selemela)*	The stars rise early At night, under clear skies, the movement of the stars from west to east The star's appearance The appearance of the morning star (*Naledi ya masa*) Appearance around the end of May Appearance around June	Early-onset of the rainy season Impeding rainfall in three days Rain is expected Indicates the beginning of the winter season Indicate good rainfall and ploughing season Indicates cold weather
Lighting	Lighting during the rainy season	Indicating the dry period

4.3.5. Human Ailments and Other Indicators

Human ailments such as itchy foot and back pain were thought to be good weather predictors. When a person suffers from these ailments the most, it indicates that extremely cold, strong wind, and heavy rains are likely to occur within a short period of time. Farmers in Moletjie Moshate believe that lightning during rainy seasons can occur naturally or be manmade. According to them, natural lightning only destroys trees and lizards while witchcraft-induced lightning can be used to kill specific people or livestock. Most participants believe that witches have the ability to control lightning. The people of Moletjie village are also known for their distinctive diet. Letlametlo (toad) dishes stand out, and *Matlametlo* (plural of *letlametlo*) is most commonly found after a heavy storm (Table 4.6). Disembowelling a *letlametlo* is the first step in preparing it for cooking. For fear of lightning, the bowels are usually buried. It is believed that if they are not buried, lightning will strike the location where they were discovered (Morokolo, 2014).

Table 4.6: Human ailments and other indicators and their predictions as applied in Moletjie Village

Indicator	Description	Weather condition
Sweat	Sweating on cloudy days	Imminent rainfall
Joints	Painful joints	Humid conditions in a few hours
Childbirth	Birth of many girls Birth of many boys	Good rains are expected Associated with drought
Toad	The bowels are usually buried for fear of lightning	If they are not buried, lightning will strike the location where they were discovered

4.3.6. Rainmaking Ceremony

The chief Kgabo Moloto lll and other traditional stakeholders continue to play an important role in indigenous forecasting for Moletjie's smallholder farmers. Most participants agreed that rainmaking ceremonies, when done correctly, can bring some rain. These are organised by the village's Kraal head and Traditional healers

(Dingaka) called Baroka ba Moshate from Moshate wa Ga- Komape during October of each year. Rain-making ceremonies are held in sacred forests at Moshubaba Heritage, at Moletjie Ga- Matamanyane. It entails making a traditional beer, grilling meat, singing, and dancing. After Baroka performed their rituals, they are given a black bull and a black sheep. The ancestral spirits will answer if they are pleased by sending rain soon after the function (Muguti & Maphosa, 2012). However, certain taboos must be avoided in order for the Ancestors to respond positively. Incest, abortion, and homosexuality are examples of these. Other taboos may enrage the Ancestors and cause drought and even river drying.

4.5. Climate Change Observations

The vast majority of smallholder farmers in rural areas mainly rely on IKS to guide their farming techniques. The difficulty with IK is that it only has a few indigenous climate prediction indicators for long-lasting climatic occurrences, whereas IK indications only provide temporary forecasts (Zuma-Netshiukhwi et al., 2013). Several issues about IK's relevance for adaptation in the future, among other obstacles affecting farmers, include the disappearance of some of their indigenous climatic indicators, resulting in reduced farmer certainty. Small-scale farmers, the majority of whom are indigenous knowledge holders, depend primarily on farming for sustenance; yet they are more vulnerable to the effect of climate variability.

4.5.1. Local Observations and Impacts of Climate Change

Respondents in Moletjie Village indicated that 48.89% have heard about climate change, while 51.11% haven’t about it. Smallholder farmers have suffered several extreme events as a result of climate change (Figure 4.5). The most significant impact of climate change on farmers was an increase in crop failure (48.89%). Farmers' lives have suffered as a result of this impact, as they are mainly dependent on agriculture for a living. Human illnesses and disease outbreaks have been mentioned as a climate change impact by some farmers (40%), whereas 11.11% are unaware of any impact.

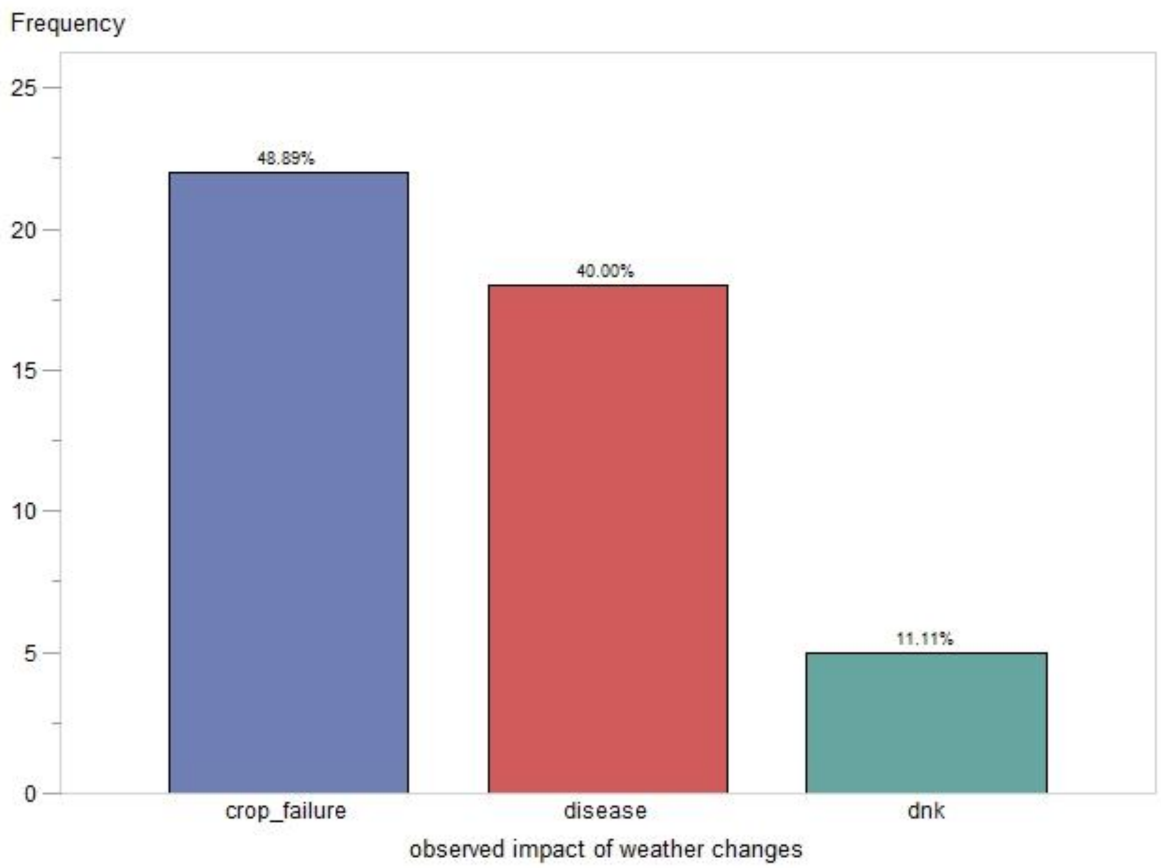

Figure 4.5: Impacts of Climate Change on Moletjie Village Farmers

4.5.2. Moletjie Smallholder Farmer's Observations of Weather Changes

More than 53.33% of Moletjie smallholder farmers regarded the most severe impact of climate change to be extremely hot seasons, followed by extremely wet seasons (24.44%), and 22.22% said they had not observed any changes in their area.

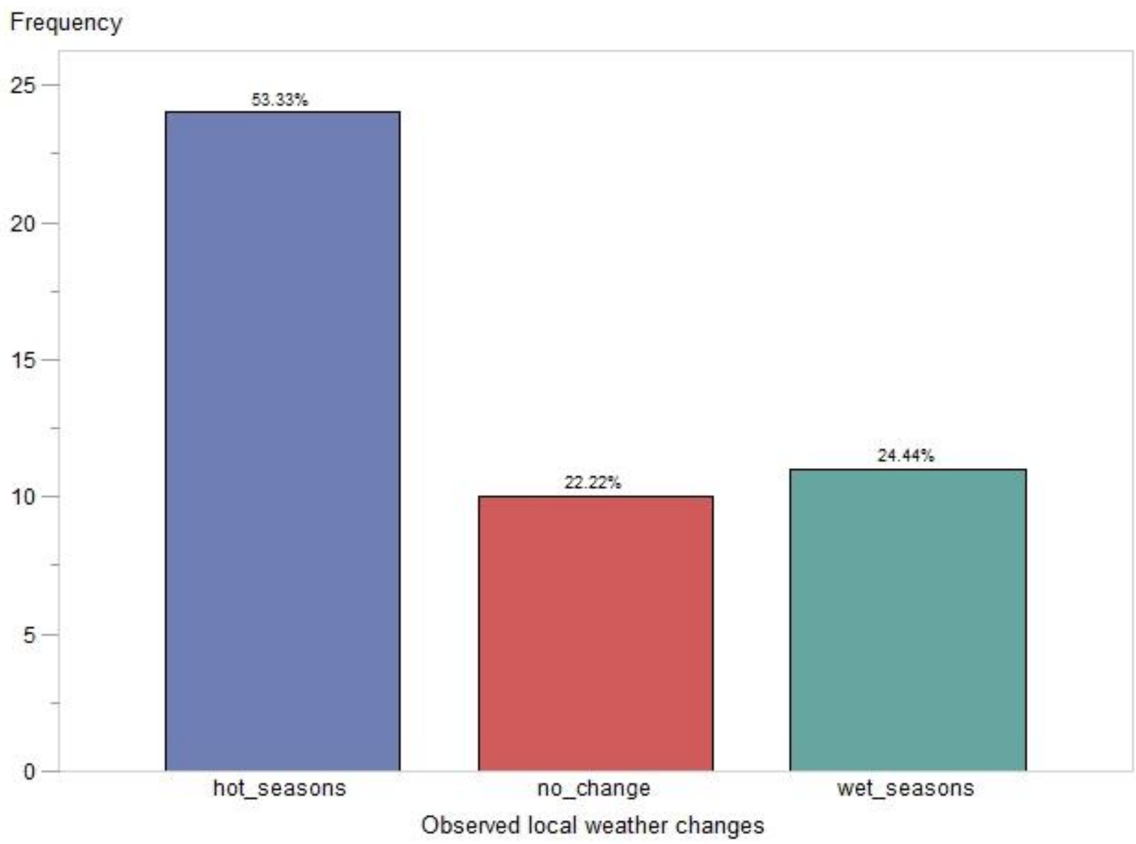

Figure 4.6: Farmer observations of climate change and its impact

4.5.3. Farmer Decisions on the Types of Crops to Grow

Data from focus group discussions and key informant interviews revealed that both young and old farmers have comparable perspectives on crop selection. They stated that the aridity of their surroundings encourages them to plant crops that are resistant to droughts like beans and maize. The practice of planting selected crops in that area influences the response to seasonal climate forecasts. Even though the seasonal conditions do not look favourable for maize and beans, farmers will still plant these crops since they are not familiar with alternative crops that thrive with minimal rainfall. Moreover, young farmers stated that they want to plant crops for profit but are unable to do so due to harsh weather and unstable seasonal conditions.

4.6. Perception of Reliability of the Indicators

The data clearly demonstrate the importance of indigenous weather forecasts in ensuring sustainable livelihoods in this community (Table 4.7). The forecasted weather event is expected to occur once they are observed. People would begin to prepare their crops in accordance with the forecasted weather. According to the study by Shoko (2011), most communities place a high value on indigenous climate forecasts.

Table 4.7: Rating reliability of the biological and human alignment indicators used by the community

Biological indicators	Percentages (%)	Reliability
Plants behaviour	24.46	1
Animals' behaviour	28.88	1
Birds	20	1
Insects	13.33	2
Human alignment	15.55	1

Legend: Excellent= 1 Good= 2 Satisfactory= 3 Poor= 4 Very poor=5

The results in Table 4.7 show the rating for biological and human alignment used by the community of Moletjie, plants behaviour 24.46%, animals' behaviour 28.88%, birds 20%, insects 13.33%, and human alignment 15.55% respectively. Based on respondents' observations, these are the most reliable biological indicators IK indicators used to forecast seasonal climate.

Table 4.8: Rating reliability of the meteorological indicators used by the community

Meteorological indicators	Percentages (%)	Reliability
Clouds	20	1
Humidity	22.22	1
Sky	11.11	2
Temperature	28.88	1
Wind	17.77	1

Table 4.8 shows the reliability rating for meteorological indicators, clouds 20%, humidity 22.22%, sky cloud 11.11%, temperature changes, and the direction of wind 17.77% respectively. The results show excellent ratings for star 44.44%, moon 37.77%, and sun 17.77% respectively. The reliability of astronomical indicators results is presented in table 4.9 below.

Table 4.9: Rating reliability of the astrological indicators used by the community

Astrological indicators	Percentages (%)	Reliability
Moon	37.77	2
Star	44.44	3
Sun	17.77	1

4.7. Accuracy of the Forecast

The majority of respondents ranked the accuracy of indigenous weather forecasts as "good to satisfactory." As previously stated, the community believes that the IK forecast is accurate and provides them with the information they require to make farm-level decisions. Because of the wide global coverage, scientific forecasts are from time to time seen as inaccurate. Furthermore, after the forecast is created and the event does not take place to the projected extent, farmers lose trust, and so the forecast's use is jeopardised. There is no doubt regarding the IK indicators' accuracy in the research area. The findings support Patt and Gwatta's (2002) argument that probabilistic forecasts covering a larger area can cause misperception and deter users from using the prediction in decision-making. This is the reason why the local community views in the study region consider IK forecasts to be more accurate than scientific projections.

4.8. Access to IK Forecast Information

Farmers who are aware and forewarned about predicted seasonal conditions might reduce risks during bad seasons and benefit from new opportunities during good seasons. In order for this to happen, processes and regulations that enable the development, distribution, and use of seasonal forecasts must be in place. As illustrated in figure 4.7, the main forecast dissemination channels found in the study region included word of mouth from farmer to farmer, particularly for advice from elders, and radio.

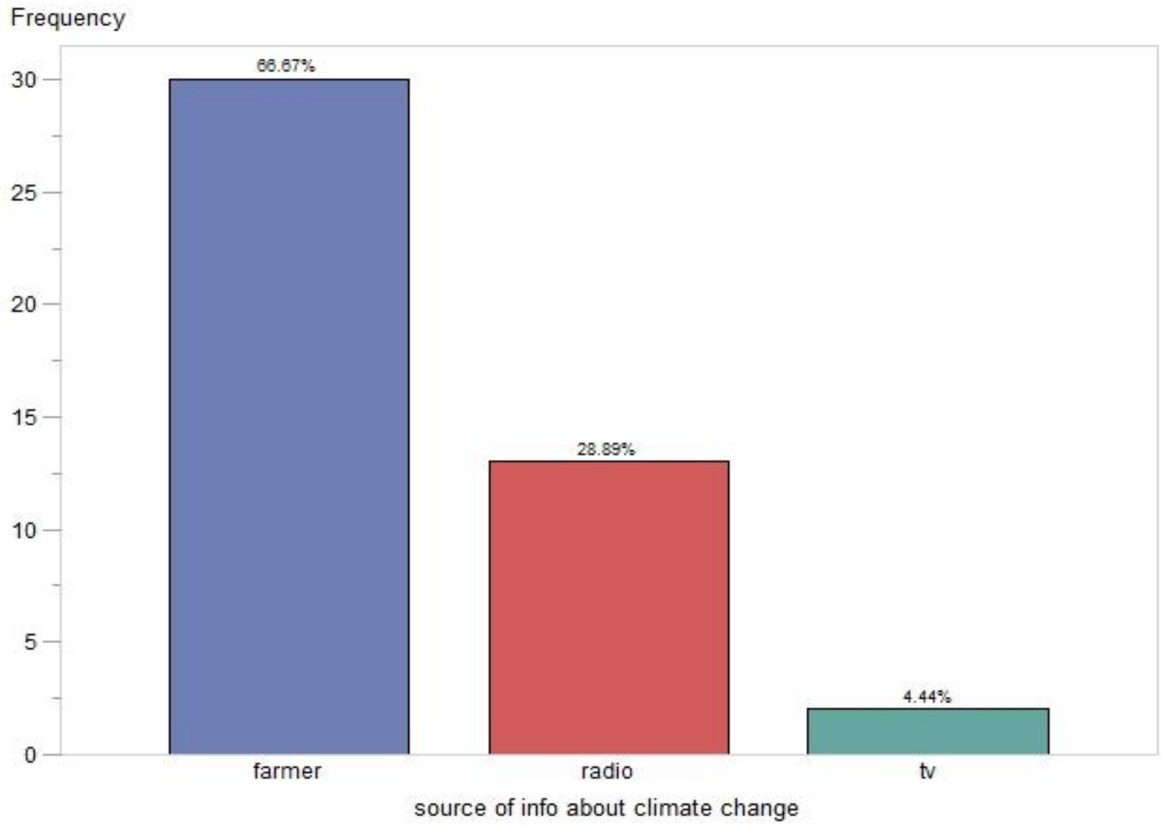

Figure 4.7: Mode of dissemination of IK forecasting for farmers

Figure 4.7 demonstrates that farmer to farmer (66.67%), Radio (28.89%), and Tv (4.44%) are the most dependable sources of IK forecast information. 40% of respondents get IK prediction information that helps them plan their farming activities, while 44.44% use it for rainfall distribution and 15.56% for others. Due to the fact that only a few people are well-informed on how to interpret and analyse the indicators used for forecasting, most farmers get their information from village elders. Other smallholder farmers begin to prepare their land soon after observing their neighbours do so.

4.9. Seasonal Calendar with Months and Activities Happening

Months of the year and their use by farmers in the study area as "forecasting elements" in agricultural time prior to climate change. These months are in Sepedi names, and they contain elements of the English descriptions gathered from farmer interviews for each of these twelve months.

Table 4.10: Months of the year and their use in agricultural timing

The month of the year in English	*The month of the year in Sepedi*	*Agricultural activities*
January	Pherekgong	Farmers are planting field crops as planned.
February	Dibokwane	Most crops have reached (or are nearing) maturity.
March	Hlakola	This month has been abundant in agricultural fresh produce.
April	Mopitlo	Seasonal conditions are changing as vegetation dries up, temperatures drop, and rains become less frequent.
May	Moranang	Extremely cold temperatures with noticeable frost effects
June	Ngwatobošego	Tree discoloration and leaf shedding are prominent, as are severe windy conditions.
July	Mosegamanye	Crop residue decomposition on land that had been previously cultivated
August	Phato	Conditions ranging from dry to wet, as well as the budding of trees and other natural vegetation The fields have been farmed.
September	Lewedi	Certain trees and plants are

		growing and flowering. First rains is required for field preparations only
October	Diphalane	Certain crops are beginning to sprout**.**
November	Dibatsela	Farmers are working in the fields, which is increasing agricultural activity.
December	Manthole	Due to grass growth, the footpaths are fading.

4.10. Events Documented from Indigenous Knowledge

Among the major climatic disasters that occurred over the years were documented by smallholder farmers. During the year 2000 to 2005, there was an increase in droughts and floods, as a result of a change in rainfall patterns and rivers beginning to dry up, as well as flooding in 2006. Cholera and Malaria outbreaks began. Droughts lasted from 2012 to 2018, resulting in crop losses owing to water shortages.

4.10.1. Indigenous Climate Indicators Used by Moletjie Smallholder Farmers for Weather Prediction

Climate variability is observed by Moletjie smallholder farmers based on their interactions with the environment. According to the study findings, indigenous knowledge exists among Moletjie smallholder farmers; they use local climatic indicators for weather forecasting and seasonal projections. The indigenous climate indicators used to forecast weather in the three villages of Moshate, Mabokelele, and Ga Ngoasheng were animal behaviour, plant phenology, atmospheric indicators, and human alignments.

Table 4.11: Biological and human alignment indicators used in Moletjie to forecast weather

Village	Plant behaviour	Animal behaviour	Birds	Insects	Human alignment

Moshate	2	4	4	3	3
Mabokelele	4	5	4	2	0
Ga-ngoasheng	5	4	2	1	3
Overall (%)	24.44%	28.88%	22.22%	13.3%	13.3%

Table 4.12: Meteorological indicators used in Moletjie to forecast weather

Village	Clouds	Humidity	Wind	Temperature	Sky colour
Moshate	5	4	0	4	2
Mabokelele	2	6	5	2	0
Ga-ngoasheng	2	1	2	7	3
Overall (%)	20%	24.44%	15.55%	33.33%	11.11%

Table 4.13: Astronomical indicators used in Moletjie to forecast weather

Village	Star	Moon	Sun
Moshate	5	9	1
Mabokelele	6	4	5
Ga-ngoasheng	9	4	2
Overall (%)	44.44%	33.33%	17.78%

Tables 4.11, 4.12, and 4.13 show the percentages of indigenous climatic indicators utilized in the three Moletjie villages sampled. Star indicators (44.44%) which fall under astronomic indicators received the highest percentages among all indigenous indicators (Table 4.13). Ga Ngoasheng smallholder farmers rely more on animal indicators (5%) than Mabokelele and Moshate. The temperature which falls under the astronomic indicator came in seconds in the three sampled villages at 33.33% same as the moon at 33.33%. Animal behaviour under biological indicators at 28.88% then follows the humidity under a meteorological indicator at 24.44%.

However, it was discovered that Mabokelele, did not employ sky colour as a weather indicator and it is the least used indicator under a meteorological indicator at 11.11%. Insects were ranked 13.3% same as human alignments. Similar findings were observed by Basdew et al. (2017) that rural smallholder farmers use indigenous climatic indicators to predict the weather.

4.11. Spatial Distribution of Indigenous Climate Indicators in Moletjie

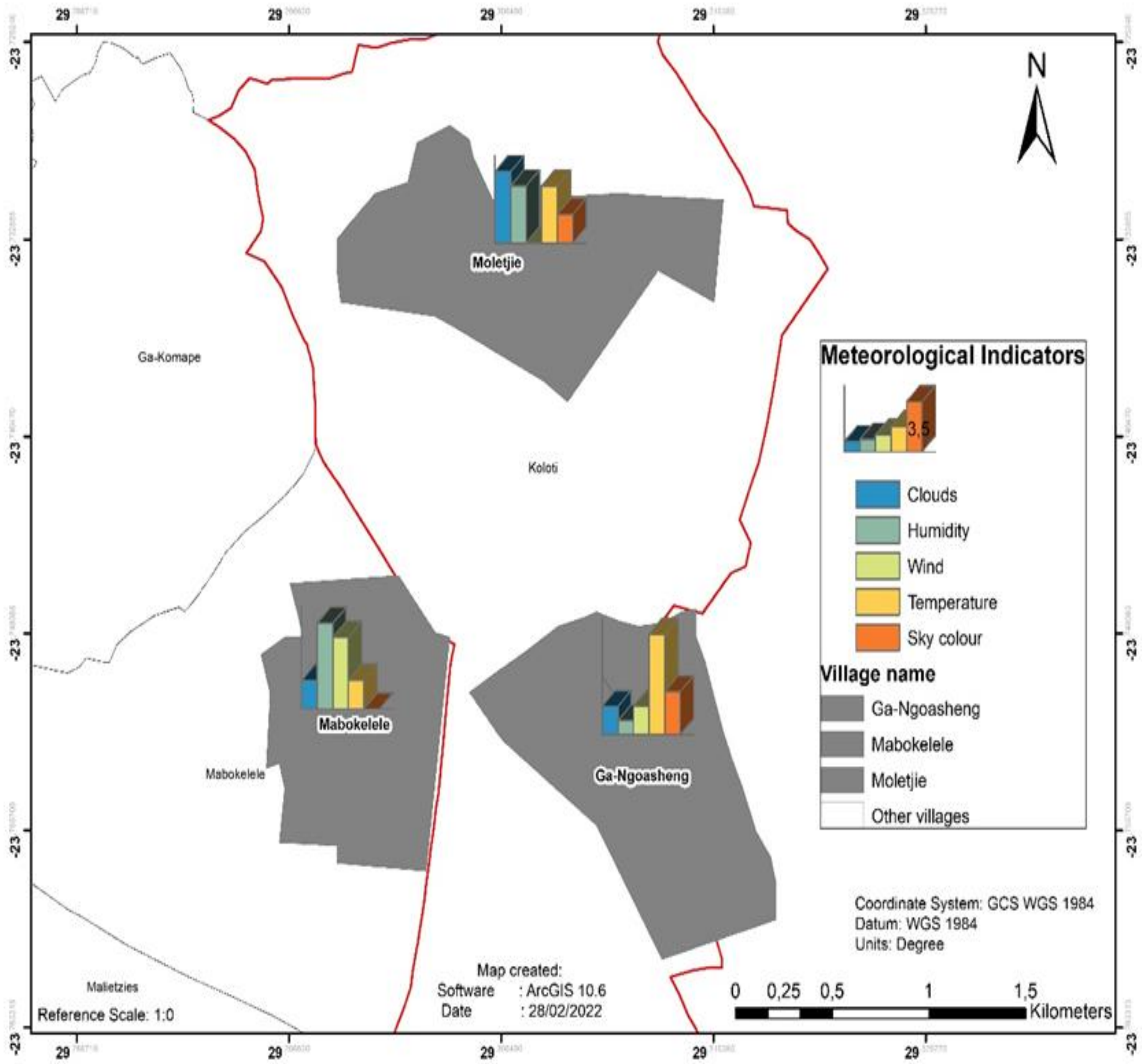

Figure 4.8: Spatial distribution of meteorological climate indicators in Moletjie

Climate change's detrimental consequences have shifted some indigenous indicators' geographical range. Climatic variability influences the distribution of indigenous weather indicators in a given location (Figure 4.8). Smallholder farmers in Moletjie village have noticed significant changes in climate variability affecting the distribution of various indicators, particularly plant species (Figure 4.9). Farmers noted that over the last 50 years, they have witnessed the extinction of several species as well as climate zone shifts. Plant species interact with their surrounding environment in different ways and their distribution is influenced by climate. Plant species are immobile organisms, making it difficult to detect changes in their distribution. As a result, every change in climate variability impacts its distribution, which in turn influences farmers' decision-making for their farming practices.

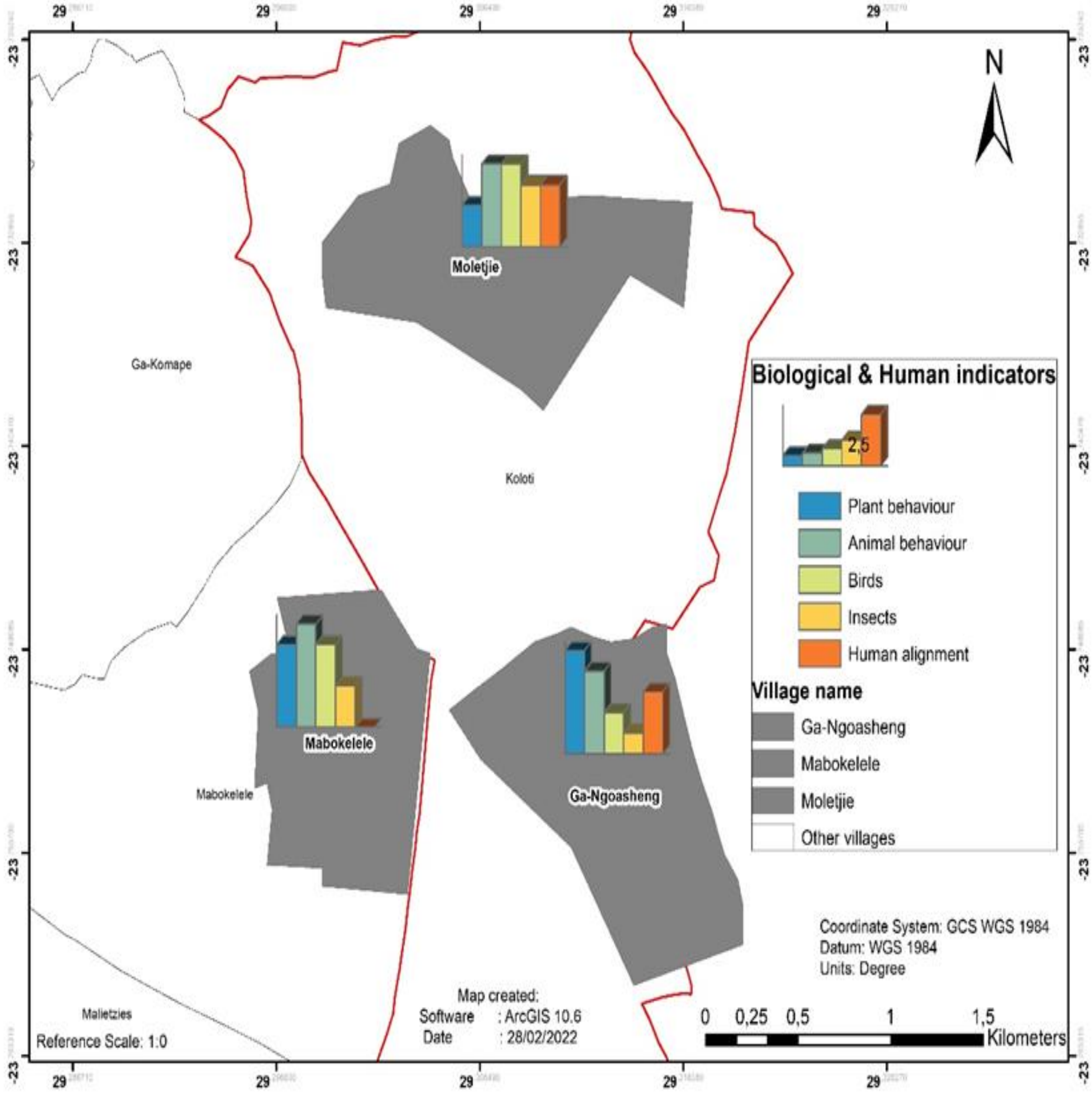

Figure 4.9: Spatial distribution of biological and human climate indicators in Moletjie

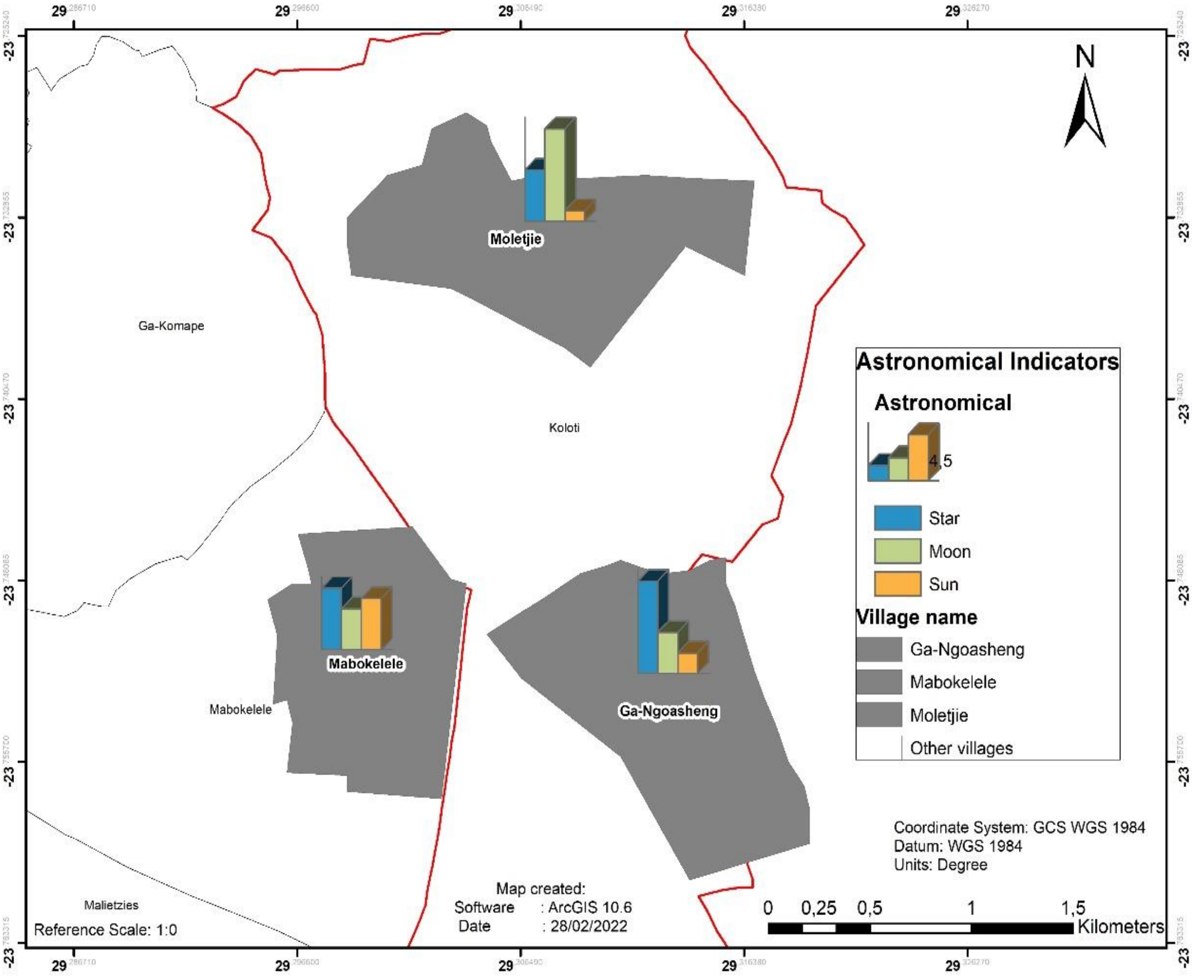

Figure 4.10: Spatial distribution of astronomical climate indicators in Moletjie

Using data acquired from the study area, the data on the distribution of indigenous climate indicators were calculated. According to the distribution map (Figure 4.10), Ga-Ngoasheng, and Moshate were dominated by the use of the moon and star which were categorised as astronomical indicators to predict weather changes, whilst GaNgoasheng was dominated by the use of temperature.

Figure 4.11: Participatory Set-Up in Moletjie Moshate.

The PGIS application, using the focus group tool, was discovered to be useful for obtaining information and documenting local weather knowledge, such as by highlighting and identifying community challenges that affect the distribution of IK. It was also discovered to be beneficial for promoting society discussions, visualizing the problem, and comprehending the severity of resource over-exploitation. In figure 4.11, participants were identifying what and where natural resources exist in the study area. The PGIS project demonstrated how participatory mapping may directly include locals in the creation of socio-spatial data, generate knowledge and stimulate learning in the context of a complex issue.

4.12. Conclusion

The results, interpretations, and discussions were all covered in this chapter. The focus was mainly on reporting on assessing and documenting the use of the

Indigenous Knowledge System in weather and seasonal climate forecasting for this study that was conducted in Moletjie, Limpopo Province of South Africa. Data collection was primarily based on smallholder farmers' responses and elders and was carried out through focus group discussions and questionnaires. Comparative analysis was also made of relevant studies elsewhere.

CHAPTER FIVE: SUMMARY OF FINDINGS, CONCLUSION, AND RECOMMENDATIONS

5.1. Introduction

The findings, conclusion, and recommendations of this study are summarized in this chapter. The primary objective of this study was to assess and document the use of indigenous knowledge systems in weather and seasonal climate forecasting. The key objectives guided the summary of findings, conclusion, and recommendations presented in this chapter.

5.2. Summary of the Main Findings

IK was found to play a significant role in seasonal climate forecasting. This study revealed farmers' substantial indigenous knowledge of rainfall prediction, as well as their awareness of its reliability. A large percentage of smallholder farmers are familiar with the indicators used in seasonal weather forecasts, and many of them use them in agricultural planning.

The first objective was to document the biological, meteorological, and astrological indicators used to forecast local weather and climate conditions in Moletjie area. From the findings, it was observed that there are indicators utilised for seasonal climate forecasting such as animal behaviour, plant behaviour, clouds, temperature, wind, human alignments, and astronomical data. The research study also revealed that age had an effect on the ability to interpret the IK indicators. The focus group contributed a great deal of valuable knowledge.

The second objective was to determine the effectiveness of indicators used to forecast local weather and climate conditions in the study area. Farmers regarded forecasts as significant for agricultural output, and the survey results reveal that the community has access to both IK and scientific forecasts. The majority of forecasts were obtained from farmer to farmer, on radio, and on television.

The third objective was to represent the spatial distribution of indigenous weather knowledge using a Participatory Geographic Information System. Smallholder farmers in Moletjie village predicted the start of the growing season by observing indigenous weather indicators. Since ancient times, these indigenous communities relied on their unique indigenous knowledge systems, culture, and expertise. The Participatory GIS application, by means of the focus group tool, was proven to be efficient for collecting and documenting local weather knowledge, for instance by emphasising communal assets and identifying community defies that affect the distribution of IK.

5.3. Conclusion

In Moletjie village, mango trees indicate the amount of fruit they bear determines whether it is a drought or a normal season. A large amount of fruit indicates a dry spell, while a small amount of fruit indicates average rainfall. Cicadas and rain cuckoos, and the arrival of migrating birds are all-time markers that are the only ones noticeable at the time of the first rains. Wet spells are related to the old and new moon phases. The star is an essential indicator of the amount of rain forecasted in the village.

The study also discovered that farmers' perceptions of the forecast had an impact on how they use these forecasts. Because of how they observe the weather, the majority of farmers rely on indigenous knowledge to predict the weather. They believe that IK forecasting methods are more reliable than scientific ones.

Using Geographical Information System (GIS) techniques, the study highlighted the spatial distribution of indigenous climatic indicators utilized by smallholder farmers in Moletjie village. It was discovered that astronomic indicators (moon) were the most commonly used indicators, particularly in Moshate. However, the farmers also stated that rising temperatures as a result of climate change were one of their primary concerns. This study has therefore achieved its objectives and thus refutes all the hypotheses.

5.4. Limitations of the Study

I. The study was limited to only three of the geographical areas of Moletjie namely Ga-Ngoasheng, Mabokelele, and Moshate.

II. The study was impacted by the national lockdown, the movement of people was restricted, and data collection was impossible because the whole population was vulnerable. Therefore, sampling was purposively limited to the key custodians of indigenous knowledge.

5.5. Recommendations

- Given that the interpretation of the IK forecasting indicators varies with age, it is necessary to document and pass on knowledge of how to utilize these indicators to create weather forecasts for younger individuals for present and future generations.
- The community of Moletjie village should be taught about Indigenous knowledge systems in weather prediction, with a focus on young people and schoolchildren, so that they may begin observing their natural environment and using traditional indicator predictions to plan for farming practices.
- More research is required to authenticate indigenous knowledge indicators against seasonal climate forecasts and to determine their reliability in the context of climate change. IKs can be integrated with scientific weather forecasting for the benefit of the community
- Government support for the expansion of IKS should be provided, with local, regional, and national IKS centers.
- To ensure its long-term viability, policymakers should develop educational strategies that acknowledge IKS components to be integrated into the school curriculum (secondary, tertiary, and extended training institutes).

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APPENDIX I: QUESTIONNAIRE

This questionnaire will be administered to assess and document the use of indigenous knowledge systems in weather and seasonal climate forecasting: a case study of Moletjie in Limpopo Province, South Africa.

SECTION A: Respondent's data

Location (Settlement): ....

GPS coordinates ……………………………………………………………………

Questionnaire no: ………………..

1. Name of respondent.............

2. Age of respondent (in years) ………….

3. Please indicate your gender

Male……….   Female ……...

4. A higher level of education

Primary …… /Secondary……. /Tertiary…. /Illiterate….

3. How long have you been residing in this area?

………………………………………………

4. Are you are a farmer?   Yes…………….   / No …………

If it is a Yes, how long have you been a farmer?

……………………………………

5. What type of farming do you practice?

………………………………………………

7. What kind of crops do you mostly plant?

…………………………………………………………………………………………

8. Which season do you mostly do your farming and harvesting for those crops?

…………………………………………………………………………………………….

SECTION B. Climate Change Observations

a. Have you ever heard about climate change?

0=Yes	1=No

b. Do you receive information on climate change?

Yes	No

c. What is your most reliable source of information on your farming systems?

Radio	TV	Farmer to Farmer	Internet	Family member	Extension officers	Other specify

d. What major changes in weather have you observed in your community over the last 10 years?

Floods	prolonged droughts	very wet seasons	very hot seasons	haven't observed changes	Other specify

e. What is the main impact of these changes on the local community?

Crop failure	Livestock deaths	Human disease outbreak	Food insecurity	Do not know	Other Specify

f. Have you experienced low crop yields over the past 10 years?

Yes	No

If answered No, skip to g

g. How severe has the loss been over the past 10 years?

Very severe	Moderately severe	Not severe	Other specify

h. What do you think where the causes of the yield decline?

Natural causes (droughts, hails, floods)	Pest damage	Disease outbreak	Lack of farm inputs	Lack of water	Don't know

SECTION C. Climate forecast information

a) Are you aware of the Indigenous Knowledge (IK) forecast? Yes……… / No……….

If yes which of the indicator listed below have you used.

Signs/ indicators	Indication	Time of occurrence	Reliability of the indicator
Animal behavior			
Plant behavior			
Wind direction			
Astronomic indicator			
Sky color			
Clouds			
Other (Specify)			

Code of reliability. 1. Excellent 2. Good 3. Satisfactory 4. Poor 5. Very poor

b) Do you remember (years) when these indicators were observed, and people advised on the expected weather?

Yes………… No……… If yes complete the tables bellow

Year	Indicator	Interpretation/probable effect	Expected weather

c) How do you get the forecast information? (Tick where appropriate and if more than one please shows by ticking against them)

Mode of dissemination	Tick
Television	
Radio	
Village elders	
Rainmakers	
Own knowledge	
Other (Specify)	

d) Do you believe in the forecast? Yes…………. / no………….

If no, why? Not accurate, not timely other

e) Do you understand the forecast? Yes………. / no……………

f) If no, why? Language ……. not detailed…… very general ……. others …….

g) How would you rate the seasonal climate forecast? Fair Very useful

Not useful Other

h) Which is the most useful forecast information you need?

Rainfall distribution ……………….

When to start planting ……………

When the season begins ………...

Adequacy of rain…………………

Any other….

APPENDIX II: In-depth Interview Guide for the Elders of the Community

1. Do you have any reasons as to why a particular weather event occurs after a certain indicator has been seen?

2. Do you remember years when particular indicators were seen, and the weather scenario expected failed to materialize?

3. What response strategy do you engage in for extreme weather scenarios?

4. How effective is the use of IK in seasonal climate forecast?

5. Has IK forecast been able to improve farming productivity in the study area?

6. Are the IK indicators known by all members of the community or are they only known by specific people (elderly people)?

7. How would you ensure that IK is not lost for future generations?

8. What limits the use of IK in seasonal climate forecasts?

9. What is your opinion on both scientific and IK seasonal climate forecast systems?

APPENDIX IV : LETTER OF APPROVAL FROM UNIVERSITY OF LIMPOPO

UNIVERSITY OF LIMPOPO

University of Limpopo
Department of Research Administration and Development
Private Bag X1106, Sovenga, 0727, South Africa
Tel: (015) 268 3935, Fax: (015) 268 2306, Email:anastasia.ngobe@ul.ac.za

TURFLOOP RESEARCH ETHICS COMMITTEE

ETHICS CLEARANCE CERTIFICATE

MEETING: **27 July 2021**

PROJECT NUMBER: **TREC/111/2021: PG**

PROJECT:

Title:	Assessing and Documenting the Use of Indigenous Knowledge Systems in Weather and Seasonal Climate Forecasting: A Case Study of Moletji Villages Limpopo Province, South Africa
Researcher:	SA Chokoe
Supervisor:	Dr TL Dube
Co-Supervisor/s:	Dr B Petja (WRC)
School:	Agriculture and Environmental Sciences
Degree:	Master Science in Geography

PROF P MASOKO
CHAIRPERSON: TURFLOOP RESEARCH ETHICS COMMITTEE
The Turfloop Research Ethics Committee (TREC) is registered with the National Health Research Ethics Council, Registration Number: **REC-0310111-031**

Note:

i) **This Ethics Clearance Certificate will be valid for one (1) year, as from the abovementioned date. Application for annual renewal (or annual review) need to be received by TREC one month before lapse of this period.**

ii) **Should any departure be contemplated from the research procedure as approved, the researcher(s) must re-submit the protocol to the committee, together with the Application for Amendment form.**

iii) **PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES.**

Finding solutions for Africa

APPENDIX V : APPROVAL BY MOLETJIE MOSHATE TRIBAL AUTHORITY

MOLETŠI
Traditional Authority

LIMPOPO PROVINCE, CAPRICORN DISTRICT

THE NATION OF BAHLALOGA

Enq:Tel: 015 023 0091

P.O Box 1601, Koloti, 0709
EMAIL: serokaam@ gmail.com

KGOSHI K.S. MOLOTO III
28 -09- 2021
P.O. BOX 1601, KOLOTI, 0709
MOLETSI TRADITIONAL AUTHORITY

To whom it may concern

Sir/Madam

SUBJECT: PERMISSION TRO CONTACT A RESEARCH.

Moletsi Traditional Authority under the Leadership of His Majesty Kgoshi Kgabo Moloto III hereby confirms that Ms Serole Angela Chokoe [redacted] as been granted a permission to conduct a research in our area of Moletsi, as there is no objection from our Traditional Authority.

Hope you shall find this in good order.

Kindly regards

Senior Admin Officer
A.M Seroka

Senior Traditional Councilor