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INDIGENOUS APPROACHES TO FORECASTING RAINFALL FOR ADAPTATION OF BAMBARA NUTS (*VIGNA SUBTERRANEA*) PRODUCTION PRACTICES IN SELECTED VILLAGES OF VHEMBE DISTRICT

By

Amukelani Eulendar Hlaiseka

(Student Number: 16016738)

A dissertation submitted in fulfilment of the requirements of the Masters in Rural Development (MRDV) Degree

Institute for Rural Development

School of Agriculture

University of Venda

Supervisor	**:**	Prof J. Francis
Co-supervisor	**:**	Mrs M.A. Mathaulula

2018

DECLARATION

I, Amukelani Eulendar Hlaiseka, hereby declare that this dissertation for Masters in Rural Development (MRDV) submitted to the Institute for Rural Development, School of Agriculture, at the University of Venda has not been submitted previously for any degree at this or another University. It is original in design and in execution, and all reference material contained therein has been duly acknowledged.

Student ______________________ **Date** ________________________

Hlaiseka A.E.

To my parents Tinyiko Hlaiseka and Lucky Hlaiseka who have been a constant source of affection, motivation and prayers. Khanimamba (Thank you) for believing in me.

ABSTRACT

This study originated from the realisation that non-conventional crops such as Bambara nuts (*Vigna subterranea)* were becoming increasingly important in addressing food insecurity and malnutrition in the smallholder farming sector of countries in sub-Saharan Africa. Moreover, some of the smallholder crop farmers were observed to be continuing to rely on indigenous techniques to forecast rainfall and adapt agricultural activities in response to climate variability. However, it was not clear how climate change influenced the productivity of *V. subterranea*. Nor were the indigenous approaches that farmers used to forecast rainfall on this phenomenon well understood. Thus, a study was carried out to identify and document indigenous approaches that smallholder farmers used to forecast rainfall and adaptation practices relating to *V. subterranea*. The study was conducted in Xigalo and Lambani villages located in Collins Chabane Local Municipality of Vhembe District in Limpopo Province. The villages served as case study areas that helped to compare the native approaches that the Va-Tsonga and Vha-Venda used to forecast rainfall in the course of producing *V. subterranea*.

A multi-case study research design, which was exploratory in nature was adopted. Convenience and snowball sampling techniques were used to identify and select respondents. The triangulation of participatory methods, techniques and tools guided the collection of qualitative data. Key informant interviews, learning circles, photovoice, one-on-one interviews and narrative inquiry techniques were applied during data collection. Smallholder farmers and the elderly members of communities were the respondents. Nine key informants in Xigalo and Lambani villages were interviewed. One retired and two currently serving government extension officers were also interviewed. Separate learning circles comprising mainly elderly men and women were also organised. Each learning circle was made up of 7-10 respondents.

Atlas.ti version 7.5.7 software was used to analyse the qualitative data following the thematic content analysis approach. It was observed that the respondents were aware of climate variability events that affected *V. subterranea*. Some of the events were shifts in rainfall patterns, heavy rainfall, extreme temperatures, scarcity of summer rainfall, the disappearance of lunar signs and the seasonal cycle variations. Eighteen types of phenological signs used to predict rainfall were identified. The most common signs included the Milky Way Galaxy of stars, musical sounds of birds and frogs, moon shapes, cumulus and cumulonimbus cloud types. A close relationship between conservation of *V. subterranea* and adaptation strategies was said to exist. It was evident that most commonly used conservation strategies were rainmaking ceremonies, planting after the summer rains, hoeing weeds, soaking seeds before planting, hilling or earthing up around the base of the *V. subterranea* plant and storing the legumes in traditional vessels and sacks. The need for integrating western scientific knowledge with native forecasts to inform the production of *V. subterranea* was uncovered. In addition to this, the needs of Tsonga and Venda communities should inform local policy interventions. Lastly, adaptation strategies that address food insecurity with *V. subterranea* being part of the agro-ecosystem deserve attention in scientific investigation and policymaking.

Key words: Adaptation, Bambara nuts (*Vigna subterranea*), climate variability and change, indigenous approaches, rainfall

ACKNOWLEDGEMENTS

It was a great opportunity for me to learn and advance my personal development throughout the time when I pursued the Masters in Rural Development degree. I am indebted to many people who contributed to my success. I wish to express my deepest gratitude to my Supervisor, Prof. J. Francis, for the scholarly lessons and consistent motivation and nudging where this was necessary. He conveyed a spirit of continuous learning that moulded me into an independent researcher. Thank you, Mrs M.A Mathaulula for your co-supervision. Your positive attitude and encouragement did not go to waste.

My sincere gratitude goes to the postgraduate students in the Institute for Rural Development. Like the true family that we are now renowned for, you were always willing to help me find answers to research and personal-related questions.

Many thanks to the community members of both Xigalo and Lambani areas for serving as respondents during data collection. This dissertation is a product of the crucial insights you shared about forecasting rainfall within the context of *Vigna subterranea*.

The Water Research Commission project, titled *Seamless forecasting of rainfall and temperature for adaptation of farming practices to climate variability* partly funded the study. Supplementary funding was sourced from the Research and Publications Committee of the University of Venda (Registration number SARDF/17/IRD/07).

Special gratitude is due to my parents and siblings who believed so much in me. I enjoyed their spiritual and emotional support because it helped maintain my psychological wellbeing especially when I needed it most in order to complete my studies.

Last but not least, I thank the Almighty God for bestowing grace and divine wisdom to all those who were by my side during the course of my journey towards the Masters in Rural Development degree. May His glory last forever!

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ABBREVIATIONS

FAO	Food and Agriculture Organisation
IKS	Indigenous Knowledge System
IK	Indigenous Knowledge
IRD	Institute for Rural Development
KII	Key Informant Interviews
LDARD	Limpopo Department of Agriculture and Rural Development
LC	Learning Circles
LKII	Lambani Key Informant Interviews
LLC	Lambani Learning Circles
SDGs	Sustainable Development Goals
SKS	Scientific Knowledge System
SK	Scientific Knowledge
UN	United Nations
UNIVEN	University of Venda
XKII	Xigalo Key Informant Interviews
XLC	Xigalo Learning Circles

CHAPTER 1 INTRODUCTION

1.1 Background

Increasingly, people are relying on both the print and electronic media for climate information that meteorologists observe and update regularly. Despite these advances and adoption of western science, a study conducted in Zimbabwe (Soropa *et al*., 2015) shows that some smallholder farmers in rural communities still rely on their indigenous knowledge to forecast the nature of forthcoming seasons. It is not clear whether the increase in reliance on electronic sources of information for forecasting climate is associated with its efficacy or accessibility. Yaro (2012) carried out a study that revealed that farmers in Africa had considerable knowledge of changes in rainfall, temperature and wind. These weather indicators help farmers to prepare and implement survival or coping strategies, especially with respect to crop production. This is why smallholder farmers are always conscious of the changing weather patterns and their impact on crop production, such as Bambara nuts (*Vigna subterranea*).

A Wheeler & Vo Braun (2013) study shows that climate change would increase susceptibility to food insecurity and malnutrition in developing countries. In 2010, the Department of Environmental Affairs of South Africa published a Green Paper detailing the various forms of climate change-related events that threatened accessibility to food. The events included water pollution, atrocious rainfall and soil erosion. Poor production of *V. subterranea* is also attributed to these events. Another study (Chang'a *et al.,* 2010) shows that scientists face difficulties in delivering precise and reliable seasonal forecasts as climate change worsens and extreme weather events occur. This leaves smallholder farmers with poor information on seasonal crop management forecasts, resulting in low resilience and thus perpetuates the challenges that local people face.

Identification of home-grown practices for adaptation of *V. subterranea* to climate variability may contribute to a broader understanding of this phenomenon. Jorgensen *et al*. (2010) assessed the effects of drought on *V. subterranea.* They found out that the crop tolerated harsh weather conditions compared to hazelnuts (*Corylus*) and beans (*Phaseolus vulgaris*). In addition, it was revealed that the indigenous knowledge that local people inherited from past generations enabled them to conserve the crop and adapt to famine situations. This is why the current study focused on *V. subterranea*, which smallholder farmers often produced in an attempt to counter the negative effects of climate change on food and nutrition security.

According to Jorgensen *et al*. (2010), *V. subterranea* is produced in South and Central America, South and East Asia, and Northern Australia. It originates from West Africa and has been cultivated in most African countries for decades (Hillocks *et al*., 2012). Africans incorporate nuts into their dietary regimes based on people's cultural preferences. For instance, Okonkwo & Opara (2010) report that in Nigeria and Ghana, people grind dried nuts into flour. South Africans and Zimbabweans boil fresh nuts and consume as snacks. The dried nuts are also cooked with samp. Samp is made of dried corn kernels that have been pounded.

A description of *Vigna subterranea* is included here because the crop is not adequately researched on. *Vigna subterranea* is the scientific name for Bambara nuts. Berchie *et al.* (2012) describe the crop as one of the seasonally grown African groundnuts. Anchirinah & Bennett-*Lartey* (2001) revealed that it contains 14–24% protein; 6-12%, and approximately 60% carbohydrates, the amino acids, methionine in the seed protein is greater than that contained in related legumes. Murevanhema & Jideani (2015) concur with the above descriptions that *V. subterranea* is the third most important legume is semi-arid Africa. It was found that the crop is nutritious, with the seed containing about 15-25 % protein, 5.2-6.4 % fibre, 49-63.5% carbohydrate and 4.5-7.4% fat. However, it was shown that *V. subterranea* is often overlooked due to the introduction and biased promotion of exotic crops. An experiment was conducted in Louis Tritchardt of Limpopo Province in South Africa (Murevanhema & Jideani, 2015) to determine the possibility of producing vegetable milk from *V. subterranea* experiment. It was observed that milk production and legume harvesting can improve food security and protein nutrition in rural populations.

The United Nations (2014) report highlights the need for promoting *V. subterranea* as a commercial crop. Also, the United Nations General Assembly released a report on 20 December 2013, which revealed that 2016 would be the "International Year of Pulses". The latter resolution was adopted to raise awareness of the health benefits associated with the underutilized pulses, including *V. subterranea*. Although *V. subterranea* is nutritious and tolerant to drought conditions, climate change exerts stress on its production, which relies mainly on indigenous knowledge of smallholder farmers. For example, there are traditional beliefs that justify delays in planting. However, there is inadequate research on this crop that builds a clear understanding of such practices. This was, partly, the origin of the current study that sought to explore the indigenous practices smallholder Bambara nut producers often considered in seasonal forecasting of rainfall.

1.2 Statement of the Research Problem

The worsening food and nutrition insecurity in most local communities, including those in South Africa demands that alternative crops such as *V. subterranea* be promoted. The fact that such pulse crops are cultivated mainly relying on indigenous knowledge to predict the onset and quality of rain dictates that studies be carried out to build a deeper understanding of what is involved. Smallholder farmers find it difficult to access seasonal forecast information they need to improve agricultural planning. Weather conditions are becoming increasingly unreliable, which worsens the vulnerability of local communities to climate variability and change. Even though smallholder farmers consistently grow *V. subterranea,* little is known about the effects of climate variability on the crop. Nor is there knowledge of how local people respond to the negative effects of the phenomenon. Two similar studies conducted in the past have shown that *V. subterranea* is grown for subsistence farming mainly and not for income-generation purposes. This is why the crop is labelled a "poor man's crop" (Jorgensen *et al*., 2010; Berchie *et al*., 2012).

Vigna subterranea does not seem popular in large-scale commercial farming systems, a reality that can be traced to little documentation on it within the context of indigenous knowledge systems. According to Ajani *et al*. (2013), climate studies pay little attention to the importance of indigenous knowledge in understanding climate change. The latter study revealed that researchers in development studies had always recognized its importance. Berchie *et al*. (2012) also point out that there is not much scientific research on *V. subterranea* production practices because the crop is not well recognised. Another study (Murevanhema & Jideani, 2015) notes that the introduction of exotic crops has influenced the underutilization of African legumes such as *V. subterranea.* Thus, this study was conducted in order to unravel the indigenous knowledge used in rainfall forecasting for adaptation of *V. subterranea* to climate variability and change.

1.3 Justification/Rationale of the study

Available scientific literature recognises *V. subterranea* as a drought-tolerant crop that can be produced to cope with climate variability and simultaneously enhance food security. However, the literature does not provide a clear link between seasonal forecasting and adaptation of *V. subterranea* production practices. For this reason, it was important to conduct a study that would help understand how selected communities were converting indigenous knowledge into actions that adapted the legume to climate variability. Therefore, the study should be viewed within the context of contributing to scientific methods that can be incorporated into seasonal forecasting so as to improve *V. subterranea* production.

The study also focused on rural development through linking between scientific literature and practical rural development work. The results can be used to implement policies to improve the use of seasonal forecasts in *V. subterranea*'s productivity. Moreover, this study contributed to professional development given that the relevant skills for rural development research and practices were obtained. Dissemination of knowledge about local protocols is likely to lead to a better understanding of what is involved in community engagement.

1.4 Context of the Study Area

Figure 1.1 shows the map of South Africa narrowed down to Limpopo Province and the specific study areas. The study was undertaken in Collins Chabane and Thulamela Local Municipalities of Vhembe District. Xigalo is located about 7.6 km to the north of Malamulele town, which is the central business area of Collins Chabane Local Municipality. The area falls under traditional authority. The inhabitants are mainly Va-Tsonga people. Both Christianity and African religions are practised. Grey sandy soils are common in the dry subtropical conditions of the Xigalo area. Warm to hot summers, and mild and cool winters characterise the area. The risk of flooding is high because it is located in a low-lying area in relation to the neighbouring Lambani community.

Lambani village is located in Thulamela Local Municipality, approximately 60 km to the northeast of Thohoyandou. Thulamela Local Municipality has its headquarters in Thohoyandou town. Local people practice Christianity and African religions just like those in Xigalo. However, the two ethnic groups have different cultural and traditional beliefs. Thohoyandou receives an annual rainfall of about 752 mm; the lowest rainfall is about 4 mm in winter, with most rains (154 mm) occurring in the middle of summer (Mzezewa *et al*. 2010).

1.5 Research Objectives and Related Questions

The main objective of the study was to identify and describe the indigenous approaches that smallholder farmers in some parts of Vhembe District used to forecast rainfall and adapt *V. subterranea* production practices. This was addressed by implementing activities linked to the specific objectives and associated questions presented below.

a) To clarify the indigenous methods used to forecast rainfall in Tsonga and Venda communities
    i. What indigenous methods are used to forecast rainfall?
    ii. How reliable is each forecasting method?
b) To identify indigenous practices smallholder farmers use to adapt *V. subterranea* production practices to climate variability
    i. What steps/ processes are involved in the production of *V. subterranea*?
    ii. How is indigenous knowledge used to inform decisions on *V. subterranea* production and adaptation practices?

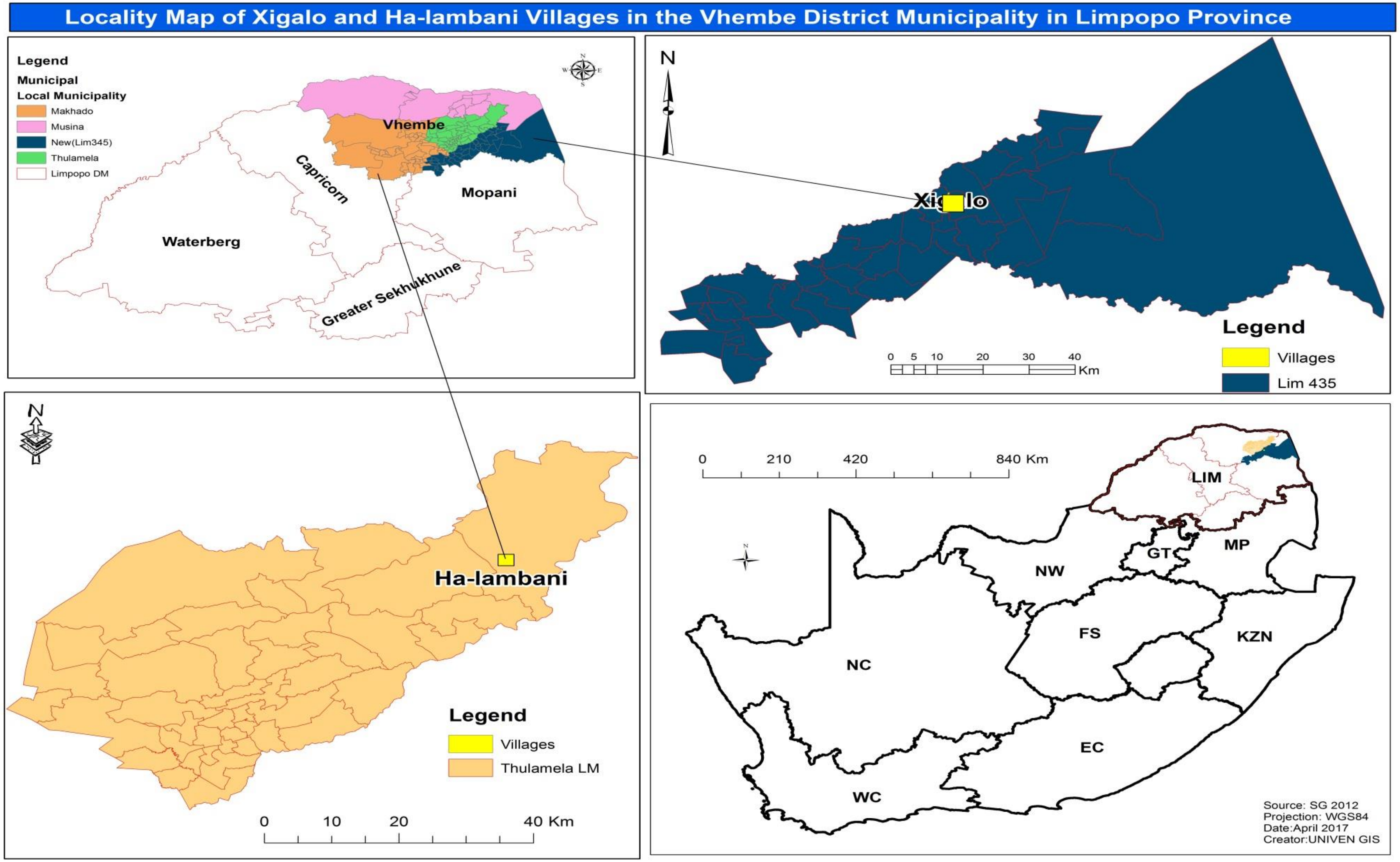

Figure 1.1 Map of Xigalo and Lambani village (UNIVEN GIS, 2017)

1.6 Theoretical Framework of the Study

The theoretical framework of Dekens (2007) was adopted for use in the current study. As shown in Figure 1.2, it clarifies the resilience of a community as a developmental process anchored on a relationship existing among indigenous knowledge, skills and adaptation. Community resilience is derived from the indigenous knowledge that local people rely on in response to a challenging environment, which in the current study is climate variability and change. It informs decision making on how to reduce vulnerability to climate change. One's understanding of how indigenous knowledge is used and the possibility of integrating it with scientific knowledge are enabled. Dekens (2007) developed the framework aiming to promote the community's resilience to environmental risks, taking into account local people's perspectives. The framework stresses the understanding of similarities and differences between indigenous and western scientific techniques. In doing so, the two approaches can complement each other. In Chapter 2, the similarities and differences are explored further as the merits and demerits of each approach are identified.

Dekens (2007) points out that researchers have begun to recognize the role of indigenous knowledge in local communities experiencing natural disasters. Some communities are located in remote areas where agencies that help manage disasters and provide relief when the need arises cannot reach. For example, local populations recommend plans before disaster management teams provide emergency assistance. In the current study, this framework was the first step towards building a better understanding of the community. It helped identify the techniques that could be integrated into a scientific investigation. Considering that traditional beliefs and religion are central to interpreting societal issues that often impede rural and sustainable development, they were taken into account.

1.7 Operational Definitions of Key Terms and Concepts

Dorner & Gorman (2011) define *indigenous knowledge* as the knowledge and capacity of local people that have existed for many years. It is influenced by traditional beliefs, culture and exposure to the real world. This study views indigenous knowledge as a hereditary education that plays an important role in guiding the behaviour or deeds of a particular community with a common background. The approaches have been shaped by people's experiences over time. This explains why dietary preferences and other activities vary from community to community.

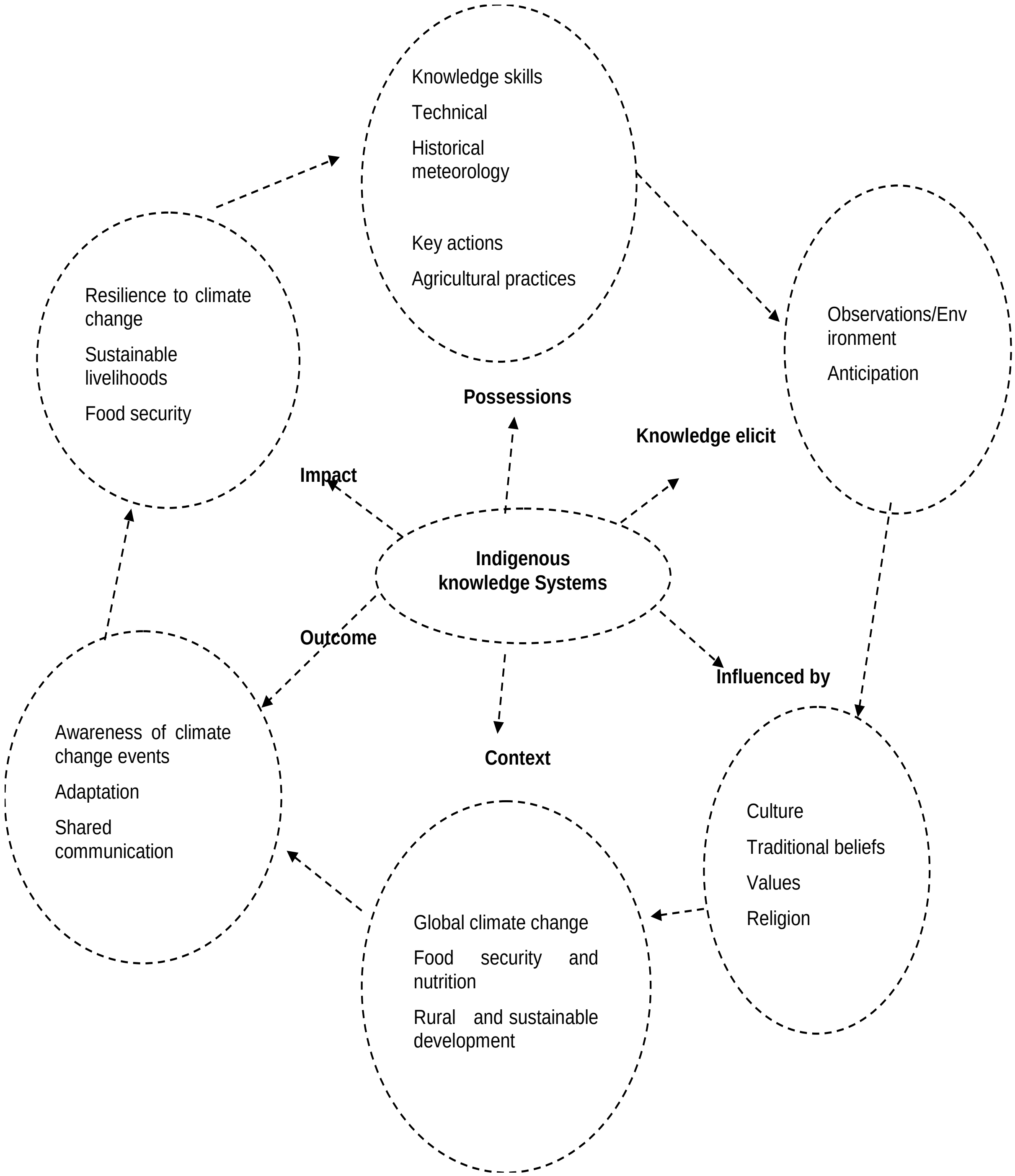

Figure 1.2 Indigenous knowledge on community resilience to climate change (Adapted from Dekens, 2007)

Adaptation refers to a degree of modification of normal processes in a favourable manner, increasing the efficiency of the phenomena (Berkel *et al*., 2011). Similarly, a definition of disaster risk 'preparedness' explained by Dekens (2007) clarifies the concept of adaptation used in this study context. Its definition of preparedness is a technique used to reduce the risk of vulnerability to disasters.

Climate is the average weather expected to occur in a particular location based on long-term averages. For example, climate forecasting information may indicate the expected weather event in a month or a year. Thus, Ramamasy & Baas (2007) state that climate variability refers to a climatic parameter that varies from its medium to long-term in a region. This may include year-to-year variability such as annual rainfall and temperature depending on their long-term average.

Climatic variability refers to the variation in seasonal weather conditions. This involves two commonly related words, weather and climate. Ramamasy & Baas (2007) define weather as a daily atmospheric condition that occurs in a given place. This may be observed in the open air and felt such as rainfall, temperature, humidity and wind. The period may be extended from a daily meteorological condition to a weekly weather condition.

Climate change is a concept derived from climate variability by the period (Dinse, 2009). It is the change in weather that lasts for long periods, decades to millennia, that occurs due to natural variability or human activities. However, it is important to note that this is mainly due to natural causes rather than human activities (Ramamasy & Baas, 2007).

The Yuan & Wood (2013) definition of *seasonal forecasting*, namely the processes of predicting weather based on the past and current climate observations, was adopted in the current study. Indigenous forecasts involve the use of abiotic and biotic indicators to predict rainfall and temperature. Lutgens & Tarbuck (2010) describe a modern forecasting method as the use of a scientific estimate of future climatic conditions, expressed in terms of temperature, precipitation and wind.

1.8 Organisation of the Dissertation

The dissertation is presented in five chapters. Chapter 1 provides an exordium and context on indigenous approaches to forecasting rainfall and how they relate to *V. subterranea* production. The context of the study area, the statement of the research problem, and the rationale for the study are presented in this chapter. In addition, research objectives and cognate questions are explained. The theoretical framework that supports this study is expounded. Moreover, an operational definition of terms is provided in order to ensure that any potential misinterpretations are eliminated. In Chapter 2, there is a literature review, which covers a significant portion of the research and identifies precedent studies plus pertinent scholarly material on the current study. Chapters 3 and 4 are presented as empirical research papers, that is containing a title, abstract, introduction, research methodology, results, discussion, conclusion and references. This is in line with the new trajectory of the Institute for Rural Development (IRD), which is designed to enhance the publishability of the outputs of postgraduate research. These chapters begin with a clarification of the social preparatory work and community entry approach followed. The research design, sampling procedures, data collection methods and analysis tools used are explained in detail. Moreover, the ethical considerations that have been applied are explained. Descriptions of results and the related discussion are presented. Chapter 5 is a synthesis of the entire study and encompasses conclusions and recommendations for further research and policy.

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CHAPTER 2 LITERATURE REVIEW

2.1 Abstract

Climate change and its effects on agricultural production are increasingly receiving attention from researchers, farmers and policy-makers. This concept is connected to many areas of research that should be considered to fortify the resilience of grassroots communities in enhancing food security. The purpose of this chapter was to review the literature on seasonal forecasts, climate variability and their relationship to *Vigna subterranea* production practices. This review is contextualised on the understanding of indigenous knowledge in forecasting rainfall and value attached to *V. subterranea* production practices. This was done in order to become familiar with previous studies related to the current study. Books and academic journals were mainly used as sources of the literature reviewed in this study. New contributions that can be made in the scientific literature have been identified, especially with respect to an extension of knowledge and new methodologies in the discipline. Although knowledge on the use of local knowledge in the production of *V. subterranea* is limited, some researchers have gained insights into the value of *V. subterranea* production practices. It was revealed that some smallholder farmers use seasonal forecast information that agricultural extension services provided. Despite this, indigenous knowledge of weather forecasts remains dominant as a convenient approach. In this review, the role of indigenous knowledge in rainfall forecasting was highlighted. Insights into studies of *V. subterranea* production practices were uncovered.

Key words: Adaptation, climate change, indigenous knowledge, rainfall, seasonal forecasting, scientific knowledge, *Vigna subterranea* and weather forecast

2.2 Introduction

In this chapter, previous research on indigenous knowledge relating to seasonal forecasting and *Vigna subterranea* production are reviewed. As this study explored *V. subterranea* adaptation practices in Xigalo and Lambani communities, literature was searched in books and academic journals using key words relevant to this focus. The review begins with an overview of studies on *V. subterranea* production practices in other parts of the world. It paved a way to a review of climate change and its effects on *V. subterranea,* given that it is an integral part of the context of this study. Thereafter, work on the role of indigenous knowledge and its challenges in rainfall forecasting are presented. Despite that the scope of the study focused on local prediction of rainfall, the themes used cover western scientific knowledge of seasonal forecasts. This was intended to emphasize the necessity of seasonal forecasts to improve the productivity of *V. subterranea*. Challenges related to the dissemination of seasonal forecasts are also included. In addition, a brief overview of the missing role of indigenous approaches in the adaptation of *V. subterranea* is discussed. An evaluation of the similarities and differences between scientific knowledge and indigenous knowledge of seasonal forecasts is provided. The last part of the chapter is a summary of the literature review.

2.3 Production of *Vigna subterranea*

In the 2030 Agenda for the Sustainable Development Goals (United Nations, 2015), the second goal set is to work towards zero hunger. The United Nations (2015) reports that the first Millennium Development Goals have led to rapid economic growth and increased agricultural productivity over the past two decades. The number of malnutrition has been reduced to almost half in many developing countries. As the Sustainable Development Goals target to eradicate hunger, smallholder farmers need more efforts that will help produce their preferred crops. Anchirinah & Bennett-*Lartey* (2001) used groundnut conservation, especially Bambara nut (*Vigna subterranea)*, to assess its vulnerability to the environment of north-western Ghana. The germplasm was collected as part of genetic susceptibility detection procedures to develop conservation strategies. *Vigna subterranea* has proven to be an essential legume in Africa, but there is little improvement in its production on a commercial scale. There is little research on understanding its production and nutritional value in local communities.

The study by Anchirinah & Bennett-*Lartey* (2001) shows that *V. subterranea* has a high market value in Ghana than in other parts of Africa because it is highly exploited there compared to other African countries. The market value of the crop shows the need for opportunities to improve crop productivity in some African countries where *V. subterranea* production is considerable. According to Makanda *et al.* (2009), early planting of *V. subterranea* is done to ensure that consumers get fresh to dry pods as it is preferable. In this way, the nutritious and fresh part of the crop lasts a long time. In light of these benefits, most farmers are encouraged to start planting early in the year.

Much remains to be done to promote food security and smallholder communities can improve the productivity of *V. subterranea* to counteract the effects of climate change on food availability. One of the key points to consider in improving the yield of *V. subterranea* germplasm is to understand the indigenous knowledge involved in the production practices of the legume. This indigenous knowledge contributes to the conservation and storage of germplasm for the future to promote sustainable production. Makanda *et al.* (2009) noted that many farmers normally store the grains in clay pots, built granaries and storage barns. It was also reported by Anchirinah & Bennett-*Lartey* (2001) that in Ghana, Bambara nuts and other groundnuts are common in Savannah regions and partly cultivated in forest regions. Additionally, the limitation with savannah soil is that it is difficult to manage during a dry season. On the other hand, forest regions had a yield reduction during the rainy seasons. Akuja *et al*. (2016) revealed that *V. subterranea* is intercropped with maize. However, local farmers usually plant major food and cash crops onset of first rains before they start growing Bambara nuts and other related legumes. Ho *et al.* (2017) indicate that this activity contributes to soil nitrogen.

2.4 Value of *Vigna subterranea*

According to the United Nations (2015) report, developing countries that are similar to Central Asia and East Asia are currently able to meet the nutritional needs of marginalised people since the inception of Millennium Development Goals. However, an estimated 795 million still suffer from chronic under-nutrition due to climate change and other factors that hamper food security. Anchirinah & Bennett-*Lartey* (2001) argue that many countries have not been able to take *V. subterranea* production to the commercial level due to lack of technical information. In addition, there are varieties of groundnuts, but limited studies are focused on the selection of groundnuts suitable for commercial production. Considering these remarks, the gap in contact between the commercial sector and local communities contributes to the problems associated with the selection of appropriate groundnuts. Rural communities are available to improve the production of healthy crops. Thus, this study recommends further scientific studies that will engage grassroots communities as they are subject to research and food security intervention.

Hillocks *et al*. (2012) noted that Bambara nuts are not produced for large-scale marketing because it cannot be easily harvested mechanically. This is why the crop is recommended for smallholder households. Hillocks *et al.* (2012) added that the value of Bambara nuts is related to nutrition rather than its commercial potential. Seeds are hardly purchased because women who produce them pass on the seeds to their children as the next generation. This statement suggests that seed conservation necessitate Bambara nuts as an important source of food in rural communities. In their study, Anchirinah & Bennett-*Lartey* (2001) found that Bambara nuts play a major African cultural role in Ghana, particularly for important cultural functions. It was revealed that it is used during funeral rites, for Moslem rites and rites associated with the birth of twins. Thirty-four percent of respondents used for rituals during the death of an adult man, 55*%* on the death of an adult woman, and 34*%* reported on Moslem rites and 41 *%* agreed on rites of twins and other rites.

2.5 Climate Change, Variability and Effects on *V. subterranea* Production

The impact of climate change remains a key issue that is a root cause of food insecurity and malnutrition in local communities. This prevents smallholder farmers from advancing their subsistence agriculture and increasing their local markets. That is why it is important to prepare in advance for climate change. Although *V. subterranea* grow in harsh conditions, Dube *et al*. (2008) affirm that agriculture is vulnerable to climate change as high temperatures reduce crop yields while rainfall variability decreases rain-fed crops. Khanal (2009) identified one of the effects of climate change such as drylands. This increased vulnerability as drylands is characterized by low amounts of seasonal rainfall and high variability of rainfall. It is clear that *V. subterranea* is affected by climate variability but its direct effect is absent in the literature. Makwara (2013) also noted observations that indicate an increase in climate variability in South Africa and most parts of Zimbabwe. The observed changes result from multiple and complex features that affect the spatial and temporal distribution of rainfall. Consequently, seasonal forecasts are erratic, which also disrupts scientists' efforts. Likewise, Ifejika (2010) agrees that sub-Saharan Africa has all the characteristics of a high rainfall variability such as floods and periods of drought. The national government is therefore aware of the conditions facing smallholder farmers and ensures the use of external assistance in case of emergency. However, emergency services are not convenient in remote areas.

Another study by Nkomwa *et al.* (2014) found that in Malawi, production from subsistence farming, which depends on rainfall, is affected by climate change and variability. This is becoming a global concern as agricultural production strengthens the economy of sub-Saharan Africa. After reviewing some studies on indigenous knowledge in Southern Africa, Jiri *et al.* (2016) found that there are challenges faced by societies causing vulnerability. It is a widespread phenomenon of poverty, recurring drought, inequitable distribution of land, excessive dependence on rain-fed agriculture. Jiri *et al.* (2016) argue that these challenges have made South Africa the most vulnerable region to global climate change. Moreover, Jiri *et al.* (2016) revealed that South Africa contain climate- and ecosystem-sensitive micro-crops, that crop yield decreases an average temperature rise of 4°C and rise in ambient temperature of 2°C. This is a clear indication from scholars that smallholder farmers have difficulty managing risks and adapting to change. To the extent that mitigation strategies are needed, it is necessary to explore the adaptation practices of *V. subterranea* to understand the relevant requirements for food security. Furthermore, South Africa is one of the countries committed to promoting the Sustainable Development Goals (SDGs) by acting against climate change and its impact. It is imperative that such difficulties be addressed as they also have an impact on *V. subterranea.*

2.6 Dissemination of Indigenous Knowledge on Weather Forecasts

Makwara (2013) reports that societies in Africa have historically used indigenous knowledge systems in response to many situations in their communities, and knowledge of past experiences is disseminated through oral tradition and passed on from generation to generation. In a nutshell, Makwara (2013) views the indigenous knowledge system as an approach to meeting the needs of society, using local knowledge to experiment with methods that are being implemented over time by local people. Indigenous knowledge is disseminated by different organizations within the community such as smallholder farmers, local social networks, rainmakers and community elders. Dissemination of indigenous knowledge informs decision-making. The Ilan (2012) perspective on the role of community elders in weather forecasts is to formulate hypotheses about seasonal precipitation based on the observation of natural phenomena. On the other hand, cultural and ritual specialists have their predictions that are deviated from dreams, visions and divination. Ilan (2012) also found that the rain-making spiritual ceremonies are performed at the request of the rainy seasons. Smallholder farmers are interested in the duration of seasons, which is regularly the duration of low temperatures, rainfall and wind characteristics. On this note, Goddard *et al.* (2010) suggest that smallholder farmers pay attention to good seasons rather than bad seasons when they can harvest more. This will enable them to prepare for a good harvest in the right seasons.

Risiro *et al.* (2012) pointed out that indigenous knowledge systems exist in more than one context but are generally used to help smallholder farmers with agriculture and resource management. Briggs & Moyo (2012) conducted their study in Malawi and report that indigenous knowledge in rainfall forecasting in rural communities is highly valued because it is obtained by the most respected elders. Elders are believed to have a lot of experience as they have lived in the area since time immemorial. Since IK originate from people's experiences, their effectiveness can improve over time depending on the events that occur. Decisions are regularly made based on past experiences; past events give people clues as to what to expect in similar situations that might occur in the present. Therefore, Shoko & Shoko (2013) suggest that research should be done from time to time to understand the changes that are occurring.

2.7 Use of Indigenous Knowledge in Rainfall Forecasting

Smallholder farmers still rely heavily on indigenous knowledge to understand climate patterns such as rainfall. It is clear from Roudier *et al.* (2014) that local people predict weather through observations and monitoring of the behaviour of animals, birds, plants, and insects. These are environmental and astronomical signs used to derive meanings on climate and weather. For example, Chang'a (2010) conducted a case study in Tanzania that found that communities normally observe the behaviour of certain animals and interpret from a climate viewpoint. Local indicators for seasonal rainfall forecasts that were identified include; moon, wind, sun, plant phenology, birds, insects and animals. The behaviour of the biotic or abiotic indicators is judged by the nature of their appearance and movements, including changes in vegetation. For instance, cloud and wind direction indicate a specific weather condition depending on the direction. In the case of Tanzania, the occurrence of strong winds is a sign of poor rainfall expected for the coming season. The appearance of large swarms of butterflies is an indication of early rainfall and the good season. On the other hand, when frogs start croaking, they are also associated with rainfall during the coming season. It is noteworthy that the interpretations of phenology vary across communities. This could be influenced by factors such as unrelated traditional beliefs, religion and the environmental setting.

It was important to document indigenous knowledge on rainfall prediction of *V. subterranea* adaptation practices of the Va-Tsonga and Vha-Venda populations. It contributes to the literature on indigenous knowledge-based forecasting that can be incorporated into the use of seasonal forecasts to develop resilience to climate change. Shoko & Shoko (2013) conducted a similar case study in two wards (12 and 13) in Mberengwa District of Zimbabwe. The objective was to identify a-biotic weather indicators and how they are used to plan agricultural activities. It was revealed that the community was using the combination of their developed indigenous weather forecasts and meteorological weather forecast in decision-making. Furthermore, most participants agreed that meteorological indicators are commonly used than celestial indicators. According to Ilan (2012), weather indicators such as rainfall, sunshine, thunderstorm help smallholder farmers prepare for future events. For example, the Shoko & Shoko (2013) study revealed that a visible ring around the sun known as "Halo" alerts people to the amount of rain expected for that season or day. In this way, a lot of rainfall is associated with the size of Halo. The amount of rain increases with its size.

Various studies reveal similar phenological indicators for rainfall forecasts. High production of mango trees has been found to signify rainfall. In addition, the appearance of termite, grasshoppers and scorpion swarms is associated with rainfall in some parts of Western and Eastern Africa. (Kijazi *et al*., 2013; Mahoo *et al*., 2015; Okonya *et al*., 2017). A related study found phenological cues used to forecast rainfall in the Delta state of Nigeria. Local people have been found to use the behaviour of flora and fauna to understand the rainfall variability. The following phenological cues are relied on; croaking sound of frogs, the emergence of millipedes, appearance of the fresh rubber tree and cassava leaves. These signs are associated with imminent rainfall. Elia *et al.* (2014) also identified similar local indicators. The scholar added that local farmers use the wind and dust direction as an indication of onset rainfall. Strong winds occurring in October and November signify a rainy season and a good year.

In sub-Saharan Africa, Gwenzi *et al*. (2016) noted that the tree or plant phenology was the most common rainfall sign. For example, Mafongoya (2017) indicates that flowering of trees including mango (*Mangiferia indica*), peach (Prunus persica), apricot (*Prunu armeniaca),* baobab (*Adansonia)* and Aloe forex signify the beginning of a rainy season. In addition, the moon phases and star constellation are the main rainfall indicators derived from sky observations. Sumi (2018), reports that mosquitos are active and bite more during hot periods and before the onset rainfall. The phenological indicators highlighted above show that indigenous-based rainfall forecasts are centred on environment observation. Nurturing the environment also contributes to the protection plants and animals used to predict rainfall in a community. According to Okonya & Kroschel (2013), observations on biotic indicators may vary across regions as they are specific to local areas. Many regions are more likely to share similar observations about the sky, sun, moon and weather conditions. However, interpretations may differ because predictions are centred on traditional beliefs, culture and religion.

2.8 The Role of Indigenous Knowledge in Adaptation to *Vigna subterranea*

It is evident that the 2015/16 drought in Southern Africa has highlighted the need to increase the production of drought-tolerant crops such as *V. subterranea* (Mabhaudhi *et al*., 2018). A study by Wilk *et al*. (2017) in Limpopo Province of South Africa noted that Lambani community plant mature, drought tolerant crops as a strategy for adapting to climate variability. This study considers adaptation as a means for local communities to reduce the risk of increased temperature and irregular rainfall on *V. subterranea*. Some scholars have discovered that *V. subterranea* is drought-tolerant (Jorgensen *et al.* 2010; Murevanhema & Jideani, 2015). However, local practices of adapting the crop to climate change are rarely found in the scientific literature. According to Ifejika (2010), adaptation involves a set of measures sufficient to adapt to climate change. In this case, adaptation practices for *V. subterranea* production are determined by indigenous knowledge. Crop's adaptation practices involve several variables that include water, soil, labour and capital. Ilan (2012) advocates that indigenous knowledge contributes more than is generally perceived in reducing vulnerability to climate change. However, the use of indigenous knowledge for climate adaptation tends to be concentrated in the event of a natural disaster when infrastructure and human life are threatened, irrespective of agricultural production.

Ibrahim *et al*. (2018) found farmers use recycled *V. subterranea* seeds that are stored in traditional storages such as granaries, jute bags and empty containers filled with sands that protect the seeds from weevils. The author revealed that *V. subterranea* with a cream colour are is most preferred seeds because they produce high yields. Monoculture is also used as the main cropping system. One of the objectives of this study was to understand how smallholder farmers deal with the impact of climate change, in situations that are not life-threatening but greatly affect *V. subterranea.* Apparently, the scientific literature has not documented local practices related to Bambara nuts but has focused on crops in general. Ilan (2012) stated that smallholder farmers use environmental indicators to plan a planting schedule, adjust the timing of planting when signs of rain begin to appear. It was found that traditional farm management methods such as crop protection, harvesting, preservation and storage are informed by indigenous knowledge. In terms of adaptation, Roudier *et al.* (2014) pointed out that original indigenous knowledge can change or improve when new information is received.

2.9 Challenges of Indigenous Rainfall Forecasting

Many smallholder communities may have relied on indigenous knowledge (IK) for rainfall prediction for many years. However, traditional approaches to rainfall forecasting are not much appreciated. Makwara (2013) and Kniveton *et al*. (2015) agree that the introduction of western or scientific knowledge dismissed local knowledge as being ineffective for development. Makwara, 2013 added that colonial systems in Africa have contributed greatly to the degradation of indigenous knowledge. It was revealed that colonialist ideology used to consider IK non-empirical and backward and that it was far from civilization. Briggs & Moyo (2012) also pointed out that negative perceptions of indigenous knowledge have spread around the world. This has led scholars to give little recognition to indigenous approaches and has prompted policy-makers to become sceptical about their use.

According to Kijazi *et al*., 2013, historically and to this day, local communities use indigenous knowledge, yet these are not well documented. Among the many challenges of IK-based rainfall forecasts, climate variability is the main obstacle that drives local farmers to lose confidence in their reliability (Kalanda-Joshua, 2011). A related study by Fitchett & Ebhuoma (2018) added that high rainfall variability could weaken rainfall forecasts based on IK. The timing of phenological indicators is also subjected to current rainfall regimes. Briggs & Moyo (2012) found that the indicators used to predict rain are disrupted by climatic erraticism. The loss of natural resources caused by climate change or human activities and the disappearance of rainfall indicators increase the inaccuracy of rainfall forecasts. Further research should focus on the challenges of native rainfall forecasting methods that can be addressed to increase the yield of *V. subterranea*.

Some studies noted that smallholder farmers receive information on rainfall forecasts from community elders, local social networks and rainmakers. It was revealed that local people prefer to use different indicators which show different forecasting information (Dutta, 2009; Frimpong, 2013). Other studies have shown that original local knowledge may be lost when older people die before being documented (Chang'a, 2010; Risiro *et al.*, 2012; Kolawole *et al.,* 2014). The arguments highlighted above emphasize the importance of documenting local rainfall forecasting approaches over time. In addition, the rainfall forecasts based on IK are known to be momentary because their predictions are focused on the immediate future. They are also interpreted differently for a given locality. Some scientific forecasts call it superstitious (Zuma-Netshiukwi, 2013). Some of these specific localities have increasingly gained religious liberty and some religions discourage the use of IK-based rainfall forecasts. Also, modern education influence people to abandon traditional beliefs associated with rainfall in some rural areas (Ayal *et al*., 2015).

2.10 Scientific Knowledge of Seasonal Forecasting Information

Apparently, the vulnerability to climate change requires scholars to conduct research on how to improve and disseminate seasonal forecasts. This is to help smallholder farmers adapt crops such as *V. subterranea*. It is, therefore, important to understand the scientific methods used for seasonal forecasts and how relevant information can be disseminated. Raymond *et al.* (2010) explain scientific knowledge in its broad sense that it is systematically documented. It was noted that scientific methods are guided by principles based on reliability and validity. Scientific knowledge is also classified as explicit or formal. Explicit knowledge exists in a written form and a categorized form that is widely accepted. Whereas, formal knowledge must adhere to the universal terms or rules to be applied. In addition, a study by Risiro *et al.* (2012) report that there are two types of modern methods used in weather forecasting. It is a subjective and numerical prediction. Subjective forecasting uses the details of daily and past observations of the atmosphere to understand future events. Numerical prediction is known as an objective method based on mathematical equations and physical principles to understand the atmosphere, predict weather conditions.

Furthermore, Risiro *et al.* (2012) noted that subjective methods are less expensive to apply in less developed countries. It can work with mediocre technology and an insufficient budget. The digital method requires advanced technologies such as satellites and radio detection and telemetry. Weather Service SA is responsible for appointing experts who apply high technology methods. According to Conway (2009), the effects of climate change seem to be misunderstood. In scientific terms, there are global climatic factors known as El Nino (Southern Oscillation movement), the intertropical coverage and the annual alteration of monsoons that interact with each other. Conway (2009) added that although it is not clear that global heat is the cause, trends are associated with global warming. This is more likely to be due to rising sea and land surface temperatures that result in extreme conditions such as food and drought.

2.11 Challenges in Dissemination of Seasonal Forecasting Information

Scientific knowledge is widely recognized and considered as global knowledge. However, Anchirinah & Bennett-Lartey (2001) report that local farmers face challenges when adopting new ways because traditional practices have become a habit. It was noted that farmers do not make sense of seasonal forecasts disseminated to them. This means that there is a need to capacitate farmers on the use of seasonal forecasts in *V. subterranea* production. Access to scientific weather information seems to be a challenge for rural farmers. In addition, Frimpong (2013) found that rural communities have difficulty accessing meteorological information and that, when they receive this information, it would be inaccurate. The remote areas tend to receive inaccurate information while central regions are exposed to accurate data. This could be influenced by the timing used to disseminate data in all areas. These findings are also supported by Chang'a (2010), who said inaccurate data with poor timing are presented in the electronic media. Apparently, the increase in climate variability, particularly unstable air movements is associated with an inaccuracy of seasonal forecasts.

Kalanda-Joshua (2011) reports that climate information is disseminated at the national level and loses its impact when it is transmitted to smallholder farmers. The author emphasizes the need to disseminate seasonal forecasts adapted to the specific local context. Other studies have shown that subsistence farmers are highly dependent on forecasts based on indigenous knowledge systems. For example; a study by Ebhuoma & Simatele (2017) reveals that farmers are wary of conventional forecasts shared through extension services. Their pessimistic views are influenced by inaccurate scientific predictions. Ochieng *et al*. (2017) identified lack of access to seasonal forecasts, illiteracy, culture and conflict as one of the barriers to using seasonal forecasts. It has been revealed that the level of illiteracy among community members, particularly the end-users of seasonal forecasting information, contributes to insufficient awareness and lack of access to information. As a result, local knowledge is used more than scientific information.

Aguado & Burt (2010) explained the challenges mentioned above arise in poor countries because forecasting equipment is available at a cost. The atmospheric processes that usually lead to weather forecasts are not well understood. Kniveton *et al*., 2015 affirmed that long-term climate information is difficult to use in decision making as it subject to changes. Seasonal forecasts normally provide information on total rainfall rather than the duration of the rainy seasons. This highlights the need to disseminate data that meets the needs of end-users. Wilk *et al*. (2017) conducted a study in Limpopo province on barriers that confine the dissemination of seasonal forecasts. The Limpopo Department of Agriculture and Rural Development (LDARD) emailing system limits seasonal forecasts in due time because of technical problems. Extension personnel do not give priority to the dissemination of seasonal forecasts because their tasks are not focused on disaster management. It has been revealed that seasonal forecast maps have a coarse spatial resolution and are not site specific. Some extension officers, therefore, have difficulty interpreting probabilistic information. In addition, the long hierarchy of communication channels delays the dissemination of seasonal forecasts.

According to Roudier *et al*. (2014) and Goddard *et al.* (2010), smallholder farmers are open to receiving seasonal forecasts to advance the productivity of their crops. However, their response to climate change depends on the ability to decipher the information presented. Local people find it difficult to interpret scientific data received from radio and television, which requires assistance from the agricultural extension services. The worst situation is when inaccurate information is also misinterpreted. The question is "what needs to be done to ensure that meteorological information benefits *V. subterranea* producers? Goddard *et al.* (2010) noted that there is little evidence that the seasonal forecast is used to improve crop production. It was shown that disaster forecasts are not digitized, they are disseminated as probabilities instead of extreme events. In addition, technical jargon or terminology is not well understood by people without background on scientific forecasts. Therefore, communication strategies need to be improved in simple terms applicable to users. Balaghi *et al*. (2010) support the idea of wide dissemination of seasonal forecasts as some smallholder farmers sell agricultural products to generate income and support their economic needs. However, Goddard *et al.* (2010) articulated that climate forecasts are available at a higher cost than indigenous knowledge since information is disseminated through various communication platforms.

2.12 Similarities and Differences between Indigenous Knowledge and Scientific Knowledge on Seasonal Forecasting

A comparison between indigenous knowledge in rainfall forecasting and scientific knowledge of seasonal forecasts helps to identify the links and gaps that can be infused to inform farming practices related to *V. subterranea*. This also helps how integration use of seasonal forecast can be pursued. Makwara (2013) and Hansen (2002) advocated an idea of the integration of IK and SK in strengthening the adaptive capacity of smallholder farmers. Briggs & Mayo (2012) conducted a study on seasonal forecasting techniques used by scientists and local communities. It was explained that indigenous knowledge on weather information is simple to understand and disseminated to community social networks through oral tradition. In contrast, access to seasonal forecasts is available at a cost. It has been observed that local populations access seasonal forecasts through radio and television, which requires formal training to interpret information. Moreover, weather forecasts are technical and indigenous knowledge is less technical and economical.

Another study by Kolawole *et al.* (2014) explained that indigenous knowledge is guided by a form of spirituality that is absent in the seasonal forecast, but it is possible to use both approaches. The methods used in indigenous knowledge forecasts and seasonal forecasts are based on observations, experiments and validation. According to Kniveton *et al*. (2015), the two sources of information on seasonal forecasts are not regularly accurate. In other words, rainfall forecasts are based on the probability of events that may occur in future.

According to Dash *et al*. (2018), scientific forecasts use historical data to predict future rainfall. Indigenous forecasts are not well documented, but experience and knowledge enable smallholder farmers to predict forthcoming rainfall. Rainfall forecasts based on IK observe short-term forecasts in relation to scientific seasonal information. For example; the appearance of dark clouds regarded a sign of good rainfall that can occur over a short period of a few hours to a few days (Zuma-Netshiukwi, 2013). Another study by Chagonda *et al*. (2014) on the comparisons of indigenous and scientific forecasts revealed that IK-based rainfall forecasts are normally downscaled to local areas while scientific forecasts provide static and general recommendations.

2.13 Summary of Literature Review

Various scholars and policy-makers tend to overlook the use of indigenous approaches in predicting onset and quality of rainfall to inform *V. subterranea* production practices. This may be deemed unimportant as *V. subterranea* has limited potential market value. However, its importance in dealing with food insecurity and malnutrition in rural communities throughout the world cannot be questioned. These issues triggered the current study. The review provided valuable information on how indigenous knowledge assisted smallholder farmers to plan agricultural activities related to *V. subterranea*. It was also noted that *V. subterranea* conservation lies within indigenous approaches. Indigenous-based forecasts are influenced by culture, traditions and religion of a specific locality. Smallholder farmers rely on phenological indicators to forecast rainfall including plant phenology, animal phenology and observations of the sky.

It was revealed that indigenous approaches to rainfall forecasting were no longer reliable because rainfall variability disrupted community-collected meteorological indicators. In most studies, scholars found that indigenous knowledge is exercised in response to climate risks or challenges that threatens smallholder food production. Seasonal forecasting approaches in farming practices are becoming more popular in scholarly research within the smallholder farming systems. This may be attributable to the marked effects of climate variability throughout the world. Increasingly, the value of integrating western seasonal forecasts and traditional forecasts is generally accepted to promote better farming practices. It has been revealed that smallholder farmers use more indigenous knowledge in rainfall forecasting than western meteorological information, mainly because the former is readily accessible to them.

Scientific forecasting information is not well disseminated as the terminologies used are poorly understood. This is attributed to the level of illiteracy in local communities and the inability of extension officers to interpret the seasonal information provided to smallholder farmers. Seasonal forecasts require technological innovation to improve the accuracy of information generated. It appears that seasonal forecasts are not currently used to adapt and mitigate the effects of climate variability on *V. subterranea.* This situation justifies on-going research on the use of indigenous knowledge in rainfall forecasts and smallholder agricultural practices of *V. subterranea.*

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CHAPTER 3 INDIGENOUS METHODS USED TO FORECAST RAINFALL IN SOME VILLAGES OF VHEMBE DISTRICT

3.1 Abstract

Throughout the world, indigenous knowledge in rainfall forecasts has raised the consciousness of climate change and variability among local people. For example, the productivity of Bambara nuts (*Vigna subterranea*) has always been correlated with traditional weather forecasting systems in some villages. Although scientific information on seasonal forecasts has lately been introduced to smallholder farmers through agricultural extension services, they are not yet widely used to expand the production of *V. subterranea.* This stems from the lack of knowledge about specific rainfall forecasts that need to be disseminated in local communities. A study was therefore conducted to identify the indigenous techniques that Tsonga and Venda communities used to predict rainfall and plan their agricultural practices related to *V. subterranea.* A representative of smallholder farmers, community elders and agricultural extension officers served as respondents. Participatory methods of data collection were used, namely key informant interviews, learning circles, narrative inquiry, photovoice and one-on-one interviews. Atlas.ti software was used to execute thematic content analysis of the predominantly qualitative data collected. Local people were observed to be predicting weather conditions by observing phenological indicators that existed in their immediate physical environment and atmosphere. The most commonly used phenological types for rainfall forecast were insects, celestial, lunar, birds and domestic animals. The cultivation periods of *V. subterranea* were reported to have now changed due to capricious weather patterns, which were revealed in the study. Drought, changes in rainfall patterns, deforestation, heavy rains, the altered seasonal cycle, scarcity of summer rains, and extreme temperatures were the climatic variability events highlighted in the study. Taking the results of the study into account, incipient policy interventions should consider the adoption of supplementary techniques to understand the need to improve seasonal forecasts in the smallholder farming sector.

Key words: Climate variability, forecast, indigenous knowledge, rainfall signs, *V. subterranea*, weather conditions

3.2 Introduction

Available literature from past studies indicates that smallholder farmers who have limited access to seasonal weather forecasts and thus, depend on local-based systems to plan agricultural activities to cultivate *V. subterranea*. This local knowledge is regarded as social capital for climate adaptation (Chang'a, 2010; Frimpong, 2013; Roudier, 2014). It is evident in the literature that farmers use environmental indicators such as fruit production, trees, wind distribution, bird and insect behaviour to predict the coming season (Makwara 2013; Kolawole *et al*., 2014; Konga *et al*., 2017). This study clarifies the signs of rainfall that are important for informing *V. subterranea* production in Xigalo and Lambani villages that represent the Tsonga and Venda communities in Limpopo Province. Although there is little knowledge on the impact of variable weather conditions on *V. subterranea*, it is likely to be influenced by climate change and this study identifies climatic events observed by study participants. This chapter begins by explaining the social preparations and community entry processes that were undertaken. In addition, the chapter discusses the research design, sampling procedures, data collection and analysis executed during the study. This includes ethical considerations that were adhered to throughout the research project. Furthermore, the results are presented and discussed based on each data collection technique, before conclusions are drawn.

3.3 Study Site

As reported in Chapter 1, the study was conducted in Xigalo and Lambani Tribal authority areas of Vhembe District. Both areas were purposively chosen to represent the Tsonga and Venda people who cultivated *V. subterranea* and other legumes commonly grown in African communities.

3.4 Training on Data Collection Tools

Data collection tools were developed to obtain data that met the objective and its associated questions. Recruitment of research assistants took place one week before the negotiation of community entry. Two research assistants were recruited and taken through an orientation session designed to help them get familiarized with the objectives and intentions of the study. They were chosen based on their ability to facilitate community engagements and to administer data collection tools using local languages. They were trained to administer data collection tools and ethical protocols. This included facilitating meetings, taking pictures and taking notes as well as the security of the data collected from the respondents. The training also provided knowledge on traditional protocols for community entry and data collection procedures. Furthermore, a translator was appointed to address language barriers between a researcher and respondents in the Lambani study area. The translator was identified in the local community and well connected with the respondents.

3.5 Community Entry

Permission to conduct the study was secured from the traditional authorities. This was done by following local protocols for consultation with the chief and headmen. Extension personnel helped organize meetings with traditional leaders and members of the community. The negotiation of entry commenced in Xigalo village. A letter for permission was sent to the tribal office before the community entry meeting. During the meeting, the study was presented to the leaders with the information sheet provided in support of the verbal explanation of the study. Approval to conduct the study was obtained after the meeting.

Chief Lambani was also visited by his royal family, requesting permission to conduct the study in the community with smallholder farmers. Through liaison with a member of the royal family and some members of the community, a meeting was held with the chief. Interacting with community members has provided lessons on traditional protocols that are respected during the chief's visit. Written information on the study was provided and a community meeting was successful. Further, the tribal authority was solicited with a token of gratitude as a means of respecting the royal family.

3.6 Research Design

A case study design was deemed appropriate to explore the current phenomenon in question. This is because the approach is open for an in-depth research strategy for a specific inquiry that emerges from a broader field of study. Various scholars noted that case studies are time-consuming and costly to implement but generate solid and reliable results. More importantly, results revealed from multiple perspectives can be used to inform an action or intervention (Baxter & Jack, 2008; Ritchie *et al*., 2013; Thomas, 2015). In the current context, a multi-case study was used to compare the indigenous rainfall forecasting system linked to *V. subterranea* across Xigalo and Lambani villages. An assortment of data collection methods was used to answer the research questions. The summary of the research methodology is presented in Table 3.1. Hussein (2015) calls this approach a triangulation of methods where different data sources are used to understand a phenomenon. This was done to ensure the validity and reliability of the insights collected on local rainfall forecasts used in Xigalo and Lambani communities.

Table 3.1 Summary of research methodology used to gain insights into indigenous approaches to rainfall forecasting in Xigalo and Lambani villages of Vhembe District

Research Questions	Sampling technique	Data sources	Data collection techniques and tools	Data analysis techniques and tools
a) What indigenous methods are used to forecast rainfall?	• Convenience sampling • Exponential non-discriminative snowball sampling	• 18 Community elderly in Xigalo Village • 2 Smallholder farmers in Xigalo village • 54 Smallholder farmers in Lambani village • 2 LDARD Extension Officers • 1 Retired Officer	• Key informant interviews • Learning circles • Narrative inquiry • Photovoice • One-On-One interviews • Structured interview guide • Camera, notebook, voice recorder	Thematic content analysis, Atlas.ti version 7.5.7 software
b) How reliable is each forecasting methods?	• Exponential non-discriminative snowball sampling	18 Community elderly in Xigalo village 50 Smallholder farmers in Lambani village	Narrative inquiry	Thematic content analysis, Atlas.ti version 7.5.7 software

3.7 Sampling Procedures and Study Respondents

Participation in this study was limited to the study population known as indigenous knowledge (IK) holders. IK holders were recognized in Xigalo and Lambani communities for their in-depth knowledge of local rainfall forecast and production practices of *V. subterranea.* Smallholder farmers and elderly people with more than 10 years of experience in the production of *V. subterranea* were considered to have more experience in indigenous-based rainfall forecasting. Most respondents were adults above over 40 years who had previously used indigenous-based rainfall forecasting to produce *V. subterranea*. In addition, they were chosen as they have resided in the community for more than ten years. During these years, local people produced *V. subterranea* and other crops following traditional procedures. Agricultural extension officers who provide extension services to the villages of Xigalo and Lambani were also assumed to have more experience with smallholder farmers and were therefore selected for the study.

The study respondents were mobilized using the exponential non-discriminative snowball sampling technique learned from Etikan *et al*. (2016). This technique was adapted to fit the current study. First respondents were mobilized through convenience sampling and expanded through referrals. Snowball sampling is normally recommended when the study population is not easily accessible. Therefore, the technique was considered suitable in this study because the total population to derive the sample was unknown.

The sampling process started with a convenience sample of extension officers who were initially identified in each study area. Extension officers were consulted first because they work closely with local farmers involved in *V. subterranea* production. A total of seventy-seven respondents participated in the current study. This comprises eighteen Xigalo community elderly, two Xigalo smallholder farmers, fifty-four Lambani smallholder farmers, two extension officers and one retired extension officer. Figure 3.1 shows the breakdown of the sampling process from one respondent to multiple respondents who participated in the study. In Xigalo case, an extension officer first identified in the study mobilized five key informants, two elderly women, one adult woman and two elderly men. Each key informant was asked to recruit other respondents and fifteen were invited. This were elderly women and men in the community, split into two groups by gender. As a result, the number of respondents was twenty.

A similar sampling approach was followed in Lambani where an extension officer mobilized four key informants, three women and one man. Through the networks of key informants and some smallholder farmers who arrived the first time, fifty smallholder farmers were invited. The total

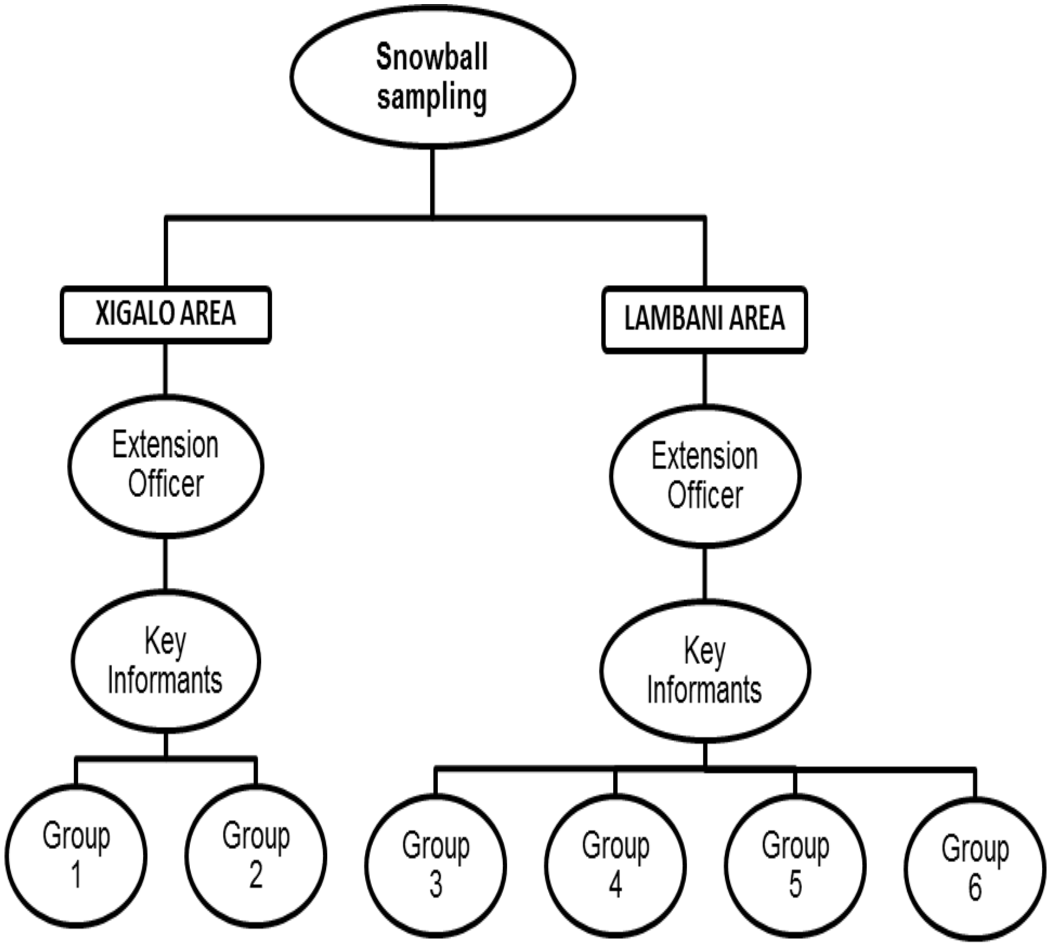

Figure 3.1 Snowball sampling process in Xigalo and Lambani communities

number of respondents was recorded using the attendance register used during the meetings. Respondent participation was not constant during data collection. Some respondents were absent on certain days. In addition, the sample size indicates that Tshivenda speaking respondents outnumber the Xitsonga speakers. This results from the recognition of limited access to smallholder farmers in Xigalo. There were no local farmers involved in a farming scheme. It emerged that most local farming schemes no longer existed and that local people generally grow *V. subterranea* in their home gardens. Despite this, data saturation was achieved as the data came from IK holders who participated in the study.

3.8 Data Collection Methods and Procedures

3.8.1 Key Informant Interviews

The data collection process began with key informant interviews (KII) in Xigalo and Lambani villages. Key informants are described as primary sources of information that know their community. In addition, they introduce researchers to community members and influence participants to participate in the study (Taylor *et al*., 2015). Referring to the above knowledge, nine key informant interviews were conducted. The initial plan was to interview ten key informants, but it turned out that one of the key informants was not available during the period KIIs. As a result, nine KIIs were conducted. The interviews were guided by a structured interview questionnaire. The research questions focused on indigenous techniques used for rainfall forecasting, respondent views and observations on climate variability events. Key informant interviews yielded findings validated by other data collection techniques such as learning circles and one-on-one interviews.

Respondents were identified as proficient people with considerable experience of more than ten years in the production of *V. subterranea*. Key informants also helped to recruit respondents who share similar characteristics to participate in the study. In other words, the approach contributed to the snowball sampling procedure employed to recruit participants. Of the five key informants in Xigalo, two elderly women and two elderly men were aged 60 to 65 years. One adult woman was in the age group of 50 years old. The interviews took place on a farm scheme while others were held at Xigalo retirement home centre. This is because respondents spent most of the days in the field during the summer period when data was collected. Voice recorders, notebooks and a camera were used to help with taking notes of the qualitative data and photographs.

3.8.2 Learning circles

The community elderly and smallholder farmers participated in learning circles. The study was presented to the management team of the Xigalo retirement home where the elderly spends their three days of the week. Fifteen respondents agreed to participate in the study. Two groups were formed consisting of ten elderly women and five men aged 60 years and over. The program was guided by the agenda, which was chaired by one of the staff members of the retirement home centre. Moreover, a staff member helped facilitate the meeting because the elderly respondents were able to express themselves freely in the presence of a familiar face. Staff members also have considerable experience in approaching and communicating with elderly people in Xigalo community.

A structured interview guide for learning circles was used during the discussions and respondents shared their responses in their respective groups. A voice recorder and notepad were used to take notes as respondents shared answers with the facilitator. Smallholder farmers in Lambani village also participated through the learning circles technique. The majority of smallholder farmers were above the age of 40 which most are still actively involved in farming. The data collection took place in a Lambani farming scheme for local farmers. A similar procedure was used in both the villages in terms of facilitating the gatherings. There was a great attendance because local farmers start to prepare the seeds and plough during the summer season since rainfall is expected. The meetings took place on different dates, which caused the respondents' participation in the study to fluctuate. As mentioned in the sampling procedure section, a total of fifty smallholder farmers participated in the learning circles. Four groups were formed, the groups were made up of five elderly men, women, and elderly women. Each group size ranged from 7 to 10 each day when the gathering was conducted.

3.8.3 Narrative Inquiry

A narrative inquiry was conducted to understand local people's experiences in rainfall forecasting for *V. subterranea*. This technique was used to solicit further information on stories related to the reliability of IK-based rainfall forecasting. Smallholder farmers and elderly people have observed many predictable and unpredictable climate patterns. The narratives were shared at a different date with the same respondents who participated in the learning circles. According to Clandinin (2016), a narrative inquiry is a method used in social science research to understand people's experiences through stories. It enables the inquirer to interpret the meanings associated with individual experiences. Kim (2015) referred to the method as “telling and knowing” because the stories are shared by participants with relevant experience in question.

Study respondents were asked prior to the narrative inquiry to prepare to share the historical events associated with rainfall predictions that informed *V. subterranea’s* production. Respondents were able to share home-grown practices that have worked for the community over the years through storytelling. Stories of past events have shown the reliability of rainfall forecasts from time to time. A total of six groups participated in the narrative inquiry for this study, in which two groups were involved in the Xigalo area and four groups in the Lambani area. Respondents in Lambani were between 40 and 80 years old. This included mostly smallholder farmers.

During the meeting, when a respondent shared a story, this prompted other respondents to share their stories. Moreover, respondents were cognisant that some discussions had been recorded and that photographs had been taken since they had given their consent when the researcher had asked sanction to do so. The attendance register circulated during the meeting. It was paramount to keep track of sample size and ratios.

3.8.4 Photovoice

The photovoice was last done because most of the photos were informed by discussions that took place during key informant interviews and learning circles. In other words, the photovoice technique was used to complement and validate field data. This helped to understand most of the oral descriptions provided by the respondents. Photovoice is considered a method used to present community experiences through photographs and videos (Taylor, 2015). The method is described by Delgado (2015) as a primarily applied visual search in social science studies that involve the use of photographs and other visual tools as research methods to conduct studies focused on major social change. The current study used pictures to support discussions of observed rainfall indicators that local people use to forecast rainfall.

Respondents were asked to take photographs that are evident to specified indicators. It emerged that respondents were struggling to capture some of the signs with a camera such as a moon and stars during the night. In addition, other rainfall signs could not be observed because the phenological indicators did not appear during the data collection period. Some photos were searched in the electronic media and were used during the meeting with respondents.

The same group of respondents who participated in the learning circles and the narrative inquiry were involved in the photovoice. Pictures were distributed during the meeting to each group where they were asked to describe the content that attracted them as smallholder farmers producing *V. subterranea.* The photovoice has raised scenarios that most respondents could relate to regarding climate variability, precipitation forecasting and *V. subterranea* production. Moreover, some of the questions previously explained were better clarified because the respondents used tangible illustrations.

3.8.5 One-on-One interviews

Three extension personnel were interviewed separately using a one-on-one approach. The nature of these interviews was different from that of the key informant interviews. The interviews were conducted to gather additional information on IK-based rainfall forecasting forecast known to extension officers. The aim was to validate information obtained from the community. This strengthened the results of the study. One woman interviewed was between 50 and 59 range years old and two men were interviewed at age 60 and older. Two interviews were conducted at the Limpopo Department of Agriculture and Rural Development (LDARD) offices while an interview for the retired officer was held at the respondent's home. All respondents received profile forms to complete and consent forms to sign after the explanation of the study. The same structured interview guide was used in a one-on-one interview. This was important because data collected from the extension officers gave an idea of how the community is perceived from different perspectives. Data collected from agricultural extension officers also verified some of the known information about the community because they worked with smallholder farmers for a while.

3.9 Data Analysis

Field notes and voice recordings helped capture verbatim responses and expressions from the study participants. The data was captured in Microsoft Excel spreadsheets prior to analysis. The thematic content analysis method learned from Creswell (2013) was used to analyse the data in this study. This approach has been considered open to any interpretation of the understanding acquired insights. It was explained that thematic analysis involves the organization of data into themes and the interpretation of results. Qualitative data is coded using table units to connect similar parts of data sets and linking the concepts to other parts of similar studies (Creswell, 2013). This was done using the Atlas.ti version 7.5.7 software. According to Given (2008), the software is recommended to manage data in the form of texts, graphics, audio and videos.

The data saved in Microsoft Excel was exported to Atlas.ti project. In Atlas.ti, data segments (Quotations) were selected and assigned to codes. It also involved writing memos and commenting on the data. Data was queried based on research questions utilising the following analytical tools: Cross-Primary Document Table, Query tool and Super codes. The Cross-Primary Document Table shows the frequency of the codes across datasets added to the Atlas.ti project. The frequency of quotations attached to codes across data collection techniques was revealed. Outputs were exported to Excel spreadsheets. Query tools presented verbatim quotes for specific research questions. In addition, the relationships between the codes were developed under the Network View Manager. The codes were imported as nodes to design a semantic network view. The nodes(codes) were linked with quotations or images. In addition, the codes Groundness (G) and Density (D) were presented. The Groundness indicates the frequency of the codes, while the Density referred to the number of links between codes. This enabled the presentation of links between codes, quotations and images attached to codes.

3.10 Ethical Considerations

Ritchie *et al*. (2013) highlighted the importance of ethical protocols in negotiating research relationships. It was shown that ethical considerations speak in volumes in qualitative studies, as unforeseen issues are likely to arise. Thus, in this study, ethical approval was sought from the University of Venda Research Ethics Committee. Prior data collection, the researcher asked the traditional authorities of Xigalo and Lambani villages for permission to conduct the study. The current study was presented to the traditional chiefs according to the local formalities. This aligned the community engagements with the chiefs and had an impact on the respondents' interest. For example, respondents expressed an interest in participating with confidence in the credibility of the study. As with any research study, an information sheet was used to inform participants of the intentions of the study and how the information will be used. They were informed that the information will be used primarily for academic purposes, which is documentation of the use of indigenous rainfall forecasts in farming activities of *V. subterranea*. Respondents were asked to give their consent to show their willingness to participate in the study.

Protocols related to culture, values and behaviour were observed during data collection. On this note, different perspectives shared during the meetings were acknowledged and valued. This enabled some of the respondents to participate freely. Respondents, as the custodians of indigenous knowledge, were given recognition in this study to ensure that the rights of sharing, access and use of knowledge remain with them. The results of the research were communicated back to the community in the form of community engagement meeting.

3.11 Description of Results

3.11.1 Events of climate change and variability observed in Xigalo and Lambani

Table 3. 2 shows a list of events that respondents perceived as evident to climate change. The list begins with the most popular of the least common events mentioned across key informants and learning circles. This reveals how much an event was discussed by study participants. As shown in Table 3.2, respondents observed 17 events of climate variability that influenced the yield of *Vigna subterranea*. The results obtained in Xigalo village are indicated by “X” while the Lambani area is abbreviated with “L”. Respondents noted that rainfall had become more capricious with climate change. The scarcity of summer rainfall was the most cited in all data sources. This indicated that the summer rainfall was important for local farmers as they were advised to start preparing *V. subterranea* seeds after the summer rain. The "seasonal cycle variations" issue was reported in all data sources except learning circles (X). It emerged that September was the period for early rainfall known to decompose dry meal stems before smallholder farmers began to sow. Rainfall shifted from September to November and December. Farmers adjusted their farming practices of *V. subterranea* to coincide with current rainfall change. Key informants and learning circles cited the issue of "extreme temperatures" ten times. In addition, heavy rainfall was mentioned as a common event, making it difficult for smallholder farmers to cultivate *V. subterranea*.

The results of key informants and Xigalo learning circles were consistent in showing that the *V. subterranea* ploughing season is delayed due to the scarcity of summer rainfall. Smallholder farmers were not able to make concrete plans for ploughing season. All interviews with key informants, particularly in Xigalo, highlighted that deforestation was the human activity that was influencing climate change. Key informant interviews and learning circles in Lambani showed that clouds used as signs of rainfall were rapidly disappearing due to climate change. The number of quotes shows that key informants discussed this more. It was the same with the events of "disappearing lunar signs". All key informants reported changes in rainfall patterns, which made it more difficult for indigenous knowledge holders to forecast rainfall. In addition, juvenile delinquents were associated with climate change, with the behaviour of local youth having evolved with the seasons over the years. Only the key informants of Xigalo mentioned drought as a recent climatic event. Water scarcity was also mentioned once by key informants from Xigalo

Table 3.2 List of climate variability events derived through key informant and learning circles

Climate variability events	Key Informant Interviews (X)	Key Informant Interviews (L)	Learning circle (X)	Learning circles (L)	Total
a) Scarcity of summer rain	5	4	2	4	15
b) Seasonal cycle variations	4	3	0	6	13
c) Extreme temperatures	5	1	2	2	10
d) Floods/heavy rains	3	3	0	4	10
e) Delayed ploughing period	7	0	2	0	9
f) Deforestation	4	2	2	0	8
g) Disappearance of lunar signs	2	3	0	3	8
h) Unusual summer trends	5	2	0	0	7
i) Rainfall patterns shift	2	4	0	0	6
j) Cloud signs quickly fades	0	3	0	3	6
k) Bad juvenile behaviour	3	0	2	0	5
l) Drought /Dry season	0	2	0	0	2
m) Land pollution	0	0	2	0	2
n) Funeral events	0	0	0	2	2
o) Social misbehaviour	0	0	2	0	2
p) Water scarcity	1	0	0	0	1
q) Leadership competition	0	0	1	0	1
TOTALS:	38	30	14	22	107

Key: X= Xigalo, L = Lambani

The results substantiate that Xigalo community faced the same challenges when the chances of rainfall were low. Four events were mentioned in Learning Circles (X) which include; leadership competition, social misconduct, funeral events, land pollution. These were the least popular among the data collection techniques associated with low rainfall. Some of the quotes linked to climate events are shown in Figure 3.2.

3.11.2 Observations on events related to climate variability derived from one-on-one interviews

The extension officers reported that they contributed to the introduction of scientific seasonal forecasts and modern techniques to enable smallholder farmers to improve decision-making. It was also pointed out that extension officers were infusing indigenous knowledge into their communication with smallholder farmers. Their observations were derived from both perspectives. Six climate events mentioned by the communities concurred with the results of one-on-one interviews with extension officers. This included; social misbehaviour, altered season cycle, water scarcity, delayed ploughing period, a disappearance of lunar signs and extreme temperatures. In addition, two extension officers expressed the following views:

> *"Things have changed, mango trees ripen early these days. Last year, we started eating mangoes in August when we had to wait until November".*

> *"It is too hot during the summer days and most seedlings burn when the temperature is still 38°C".*

> *"Since then, climate change has taken over, people in the community are also using modern knowledge of weather forecasts ... Sowing charts are no longer used."*

3.11.3 Signs used for indigenous-based rainfall forecasts

The native name for rain is *mpfula* in Xigalo community and it is called mvula in Lambani area. Study participants reported several signs of rainfall used prior to the production of *V. subterranea*

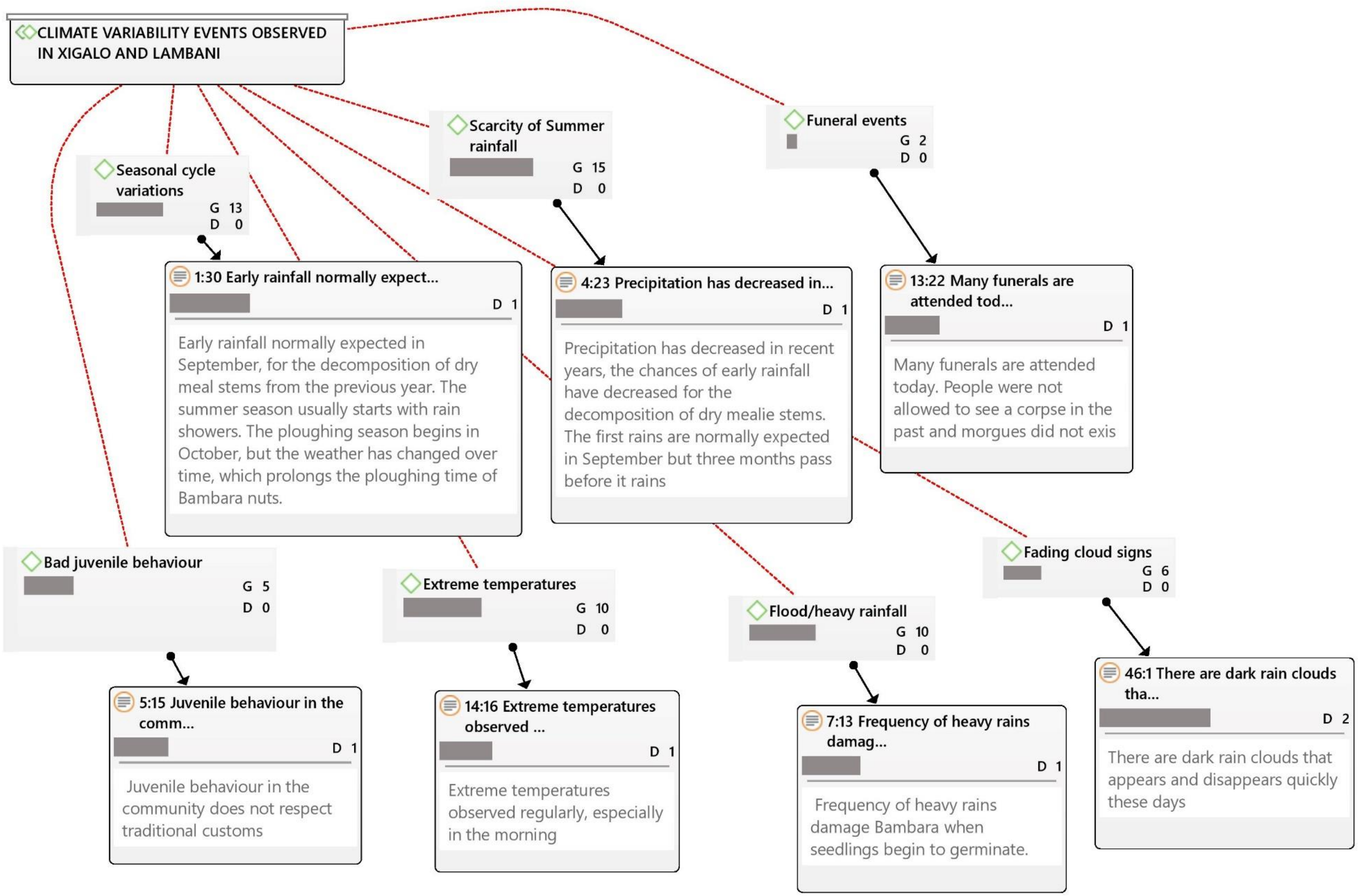

Figure 3.2 Quotations about climate variability events observed in Xigalo and Lambani villages of Vhembe District in Limpopo Province

Table 3.3 presents the signs of rain with their native names in parentheses. Figure 3.3 shows photovoice results with photographs that supported the descriptions of rainfall signs derived from phenological types. As illustrated in Table 3.3, 18 rainfall signs were revealed by key informants and learning circles in Xigalo and Lambani villages. These signs were categorized into phenological types. Celestial phenology was the most popular in the Xigalo area. Smallholder farmers and local people observed the sky more often throughout the year. Seven Tsonga-specific rainfall signs in Xigalo were the cumulonimbus clouds, morning star, evening star, mopane worms, wind gust, and perspiration and traditional copper bangle,

Findings from key informants and learning circles revealed that the morning star, known locally as *Mahlahle* and *Gongomelo,* the evening star emerge early in June, informing locals that it will rain during summer, Regarding the traditional copper bracelet, one respondent said;

> "*You see this bangle, it shines when the sun is hot and become darker when there are clouds".*

The traditional bangle was associated with rainfall and temperature. The image of the bracelet is displayed in the photovoice network of rainfall signs in Figure 3.3. Moreover, the image presented in P33 (Figure 3.3) shows the Mopane worms that were mentioned by Xigalo's key informants. It has been revealed that when there were plenty of Mopane worms, the chances of rain were very low. They were normally associated with dry seasons. In addition, cumulonimbus clouds in Figure 3.3 (P32) were associated with rainfall. In contrast, the wind gust was perceived as a weather condition that stopped the rain.

Perspiration was included as one of the signs of rain. It was indicated that some people felt sick and sweat all over the body when the rain clouds were about to appear. Furthermore, interviews with key informants and learning circles held in Lambani yielded six exclusive indicators for Venda people. These indicators were the ground hornbill, female calves, human female babies, fluffy white cumulus clouds, locusts and the sound of the Levubu River sound. A ground hornbill (*Dandila)* portrayed in Figure 3.3 (P35), is known as a rain bird for the community and considered a good sign of rain when it appeared.

Table 3.3 Consolidated rainfall signs and number of quotations in each data collection technique

Rainfall signs	Phenological type	XKII	LKII	XLC	LLC	Total
a) Milky Way Galaxy (*Xirimelo)*	Celestial	5	4	2	5	16
b) Fluffy white cumulus Clouds (*Makole*)	Celestial	0	2	0	4	6
c) Cumulonimbus clouds (*Mapapa*)	Celestial	3	0	2	0	5
d) Morning star (*Mahlahle)*	Celestial	2	0	2	0	4
e) Evening star (*Gongomelo*)	Celestial	2	0	2	0	4
f) Swallows (*Timbewulani*)	Birds	5	3	2	1	11
g) Ground Hornbill (*Dandila*)	Birds	0	2	0	3	5
h) Large swarms of Locusts (*dzi nzie*)	Insect	0	3	0	3	6
i) Mopane worms (*Matomani)*	Insect	2	0	0	0	2
j) Red circle moon shape (*Xidziva*)	Lunar	6	5	4	7	22
k) Blooming trees- Mango/ wild lyches (*Minsinya/Mirhi*)	Flowering plant	3	2	2	3	10
l) Frogs (*Machela/Zwidula*)	Amphibian	2	1	3	3	9
m) Human female babies (*musidzana*)	Human	0	3	0	6	9
n) Female calves	Domestic animals	0	2	0	6	8
o) Wind gust (*Xihuhuri*)	Atmospheric	5	0	2	0	7
p) Perspiration (*Nyuku*)	Human body Sensation	2	0	2	0	4
q) Levubu River sound	Natural stream Water	0	1	0	2	3
r) Traditional copper bangle (*Sindza*)	Personal ornaments	0	0	2	0	2
Total		33	27	23	42	133

Key: XKII= Xigalo Key Informant Interviews, LKII= Lambani Key Informant Interviews, XLC= Xigalo Learning Circles, LLC= Lambani Learning Circles

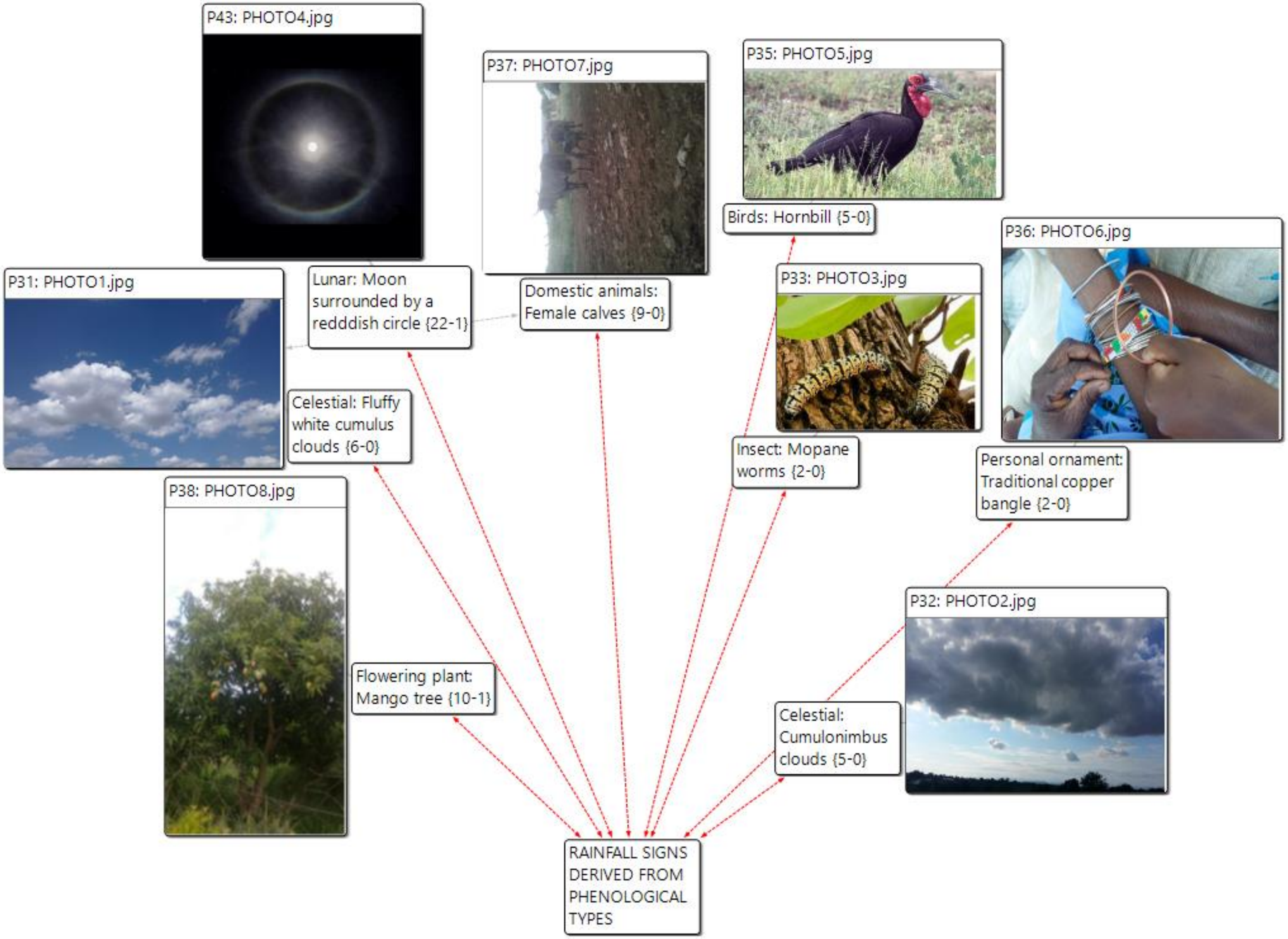

Figure 3.3 Photovoice of rainfall signs shared by Xigalo and Lambani communities

A pluvial season was expected when cattle raised many female calves. This withal applied to human baby girls, their increase in the birth rate was associated with rainfall season.
While the Tsonga people use Mopane worms as insect phenology for rainfall, Venda respondents pointed out that large swarms of locusts predicted good rainfall. An image of fluffy white cumulus clouds was taken in Lambani during data collection. The clouds form (P31) depicted precipitation. It was revealed that the Levubu River in Lambani village echoed a sound that contained a message about rainfall. On this note, a study participant replied the following:

> "*When the good season approaches, we used to hear a strange sound from the Levubu River and this sound is only heard by us in our community*".

Results of key informants and learning circles revealed five common signs of rain in Xigalo and Lambani areas. They were the Milky Way Galaxy, the red circle moon shape, swallow birds, frogs and blooming trees. Swallow birds were the most cited signs. According to study participants, Swallows made sounds like a musical composition that normally alerted local farmers about upcoming rains. Respondents described a Milky Way as a group of stars that appeared during the nights of a ploughing season which showed that it would rain during summer. Smallholder farmers were able to differentiate times through this sign and thus, prepared for the rainy season. One respondent shared the following sentiment about the red circle of the moon:

> "*Xidziva is a red circle around the moon that indicates that the moon is in deep water*".

Respondents referred to the deep waters mentioned above as rainfall. The appearance of large and small frogs predicted rain. The presence of frogs was generally heard through their musical compositions. The results also show that blooming of trees occurred at the beginning of the summer season. A high yield of wild lychee and mangoes was linked to a good season which meant rainfall. The current study also gave an idea of what the agricultural extension officers were exposed to. Results from one-on-one interviews with extension officers complemented most of the findings from key informant interviews and learning circles. Five signs of rain were confirmed, namely; the birth of female calves, bird indicators, moon shape, Milky Way Galaxy, swallow birds. Two respondents added that the communities were able to predict rain by observing the long-duration of wind, direction of rain and lightning. Hot temperatures were associated with lack of rainfall or drought.

3.11.4 Rainmaking ceremonies in Xigalo and Lambani villages

The results of the narrative inquiry revealed rainmaking ceremonies practised during the past years in the events of drought seasons. Community members participated in ceremonies when the rainy season did not result in a downpour. Two narratives stories that were shared through the narrative inquiry technique are presented in Figure 3.4. Respondents from Xigalo and Lambani unfolded how rain rituals were done during periods of drought. In the Tsonga community, the ritual is known as the *Nkelenkele ceremony.* Venda community called it the *Bandu*. The similarities that emerged from both stories are that the ceremonies were performed by elderly people and adults. In both communities, elderly people carried out their rituals in the savannah forest, far from households with children and youth. Rituals participants had to remove their clothes as a symbol of mourning for the rainfall. There were few visible cultural differences in rainmaking practices. Tsonga people reported that the participants in the ceremony cleaned up the community before performing the rituals besides the river. On the other hand, Venda people practised the *Bandu* in the morning and returned in the afternoon. Elderly people also consulted rainmakers without the knowledge of many community members who supported the process.

3.11.5 Reliability of indigenous knowledge forecasting

Respondents provided an overview of the reliability of the indigenous knowledge-based forecast through storytelling. On this note, two respondents in separate learning circles in Lambani narrated the story as follows:

> *"There is an abundance of Mopane worms this year, which is why the rain does not come. There are signs of rain, but showers stop before the ground gets wet".*
>
> *"We start ploughing Bambara nuts after the summer rains. The Milky Way Galaxy informs us about the ploughing time"*.

The Milky Way Galaxy sign mentioned above was used as a clock to help farmers differentiate between ploughing seasons. This sign only appeared during the ploughing season and was considered important because it could not be observed during other seasons. The narrative inquiry revealed stories of unpredicted floods and extreme weather that negatively affected smallholder farmers. Hurricane Katrina, which was expected to be normal rainfall in the year 2000 ended with heavy rainfall. A remarkable drought was also experienced between October 2014 and May 2015, which killed livestock owned by some members of the community. Figure 3.5 presents narratives on predictable and unpredictable events in Xigalo and Lambani.

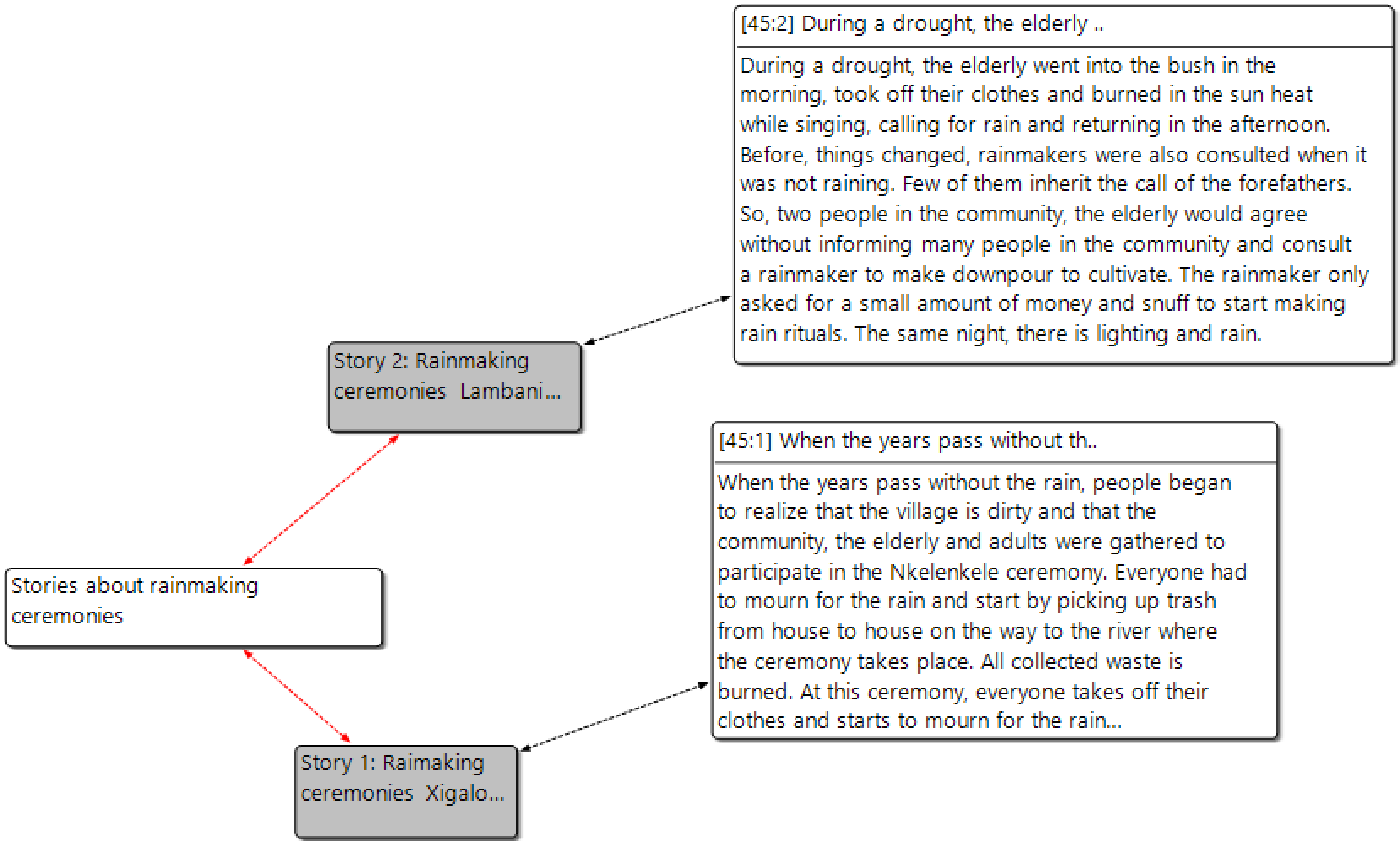

Figure 3.4 Narratives about rainmaking ceremonies practiced in Xigalo and Lambani communities

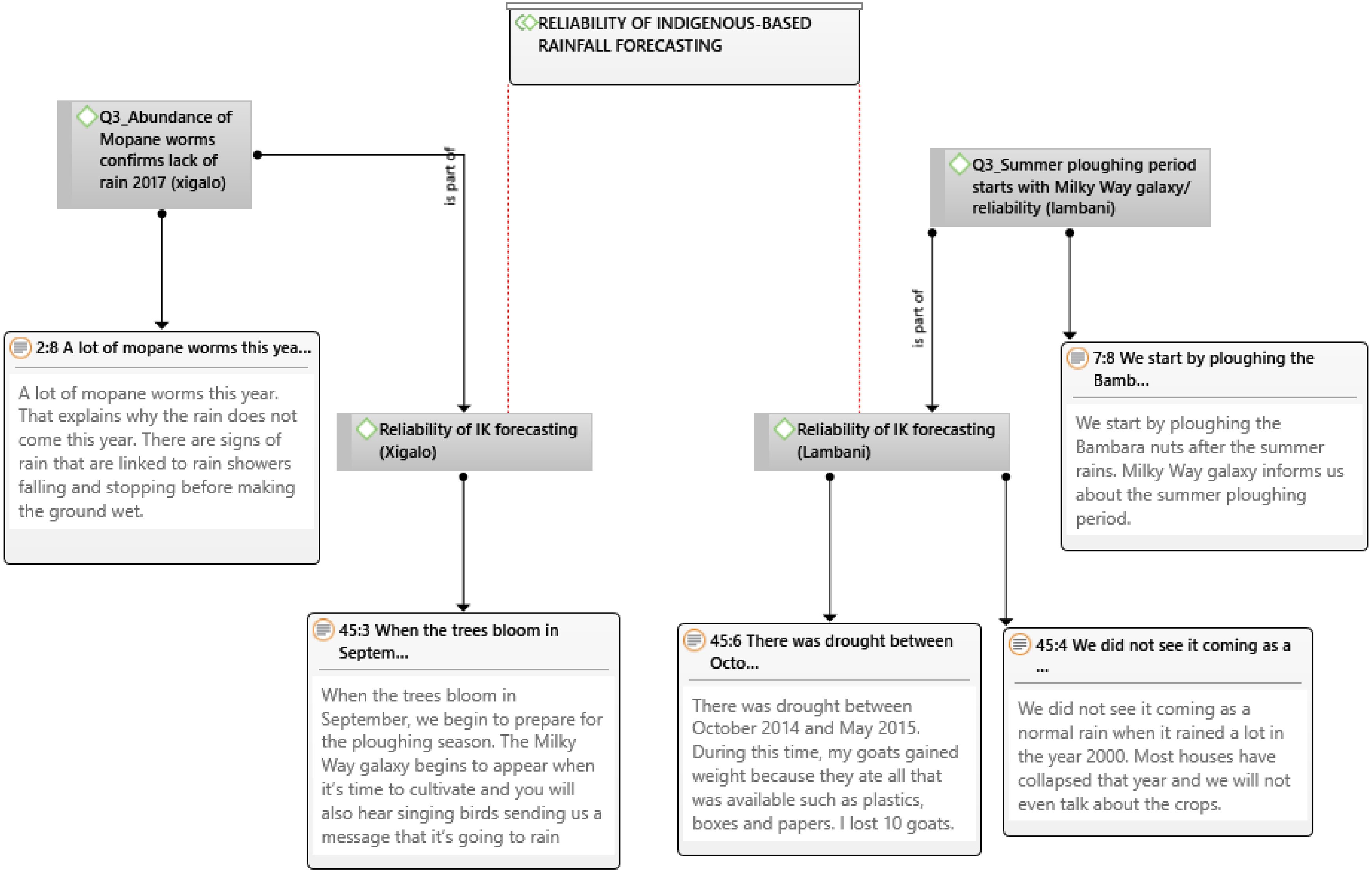

Figure 3.5 Narratives about the reliability of Indigenous weather forecasting

3.12 Discussion

The results on observed climate changes indicate that communities are vigilant about the varying climate conditions that effected on *Vigna subterranea*. A study by Kalanda-Joshua (2011) documented the inventory of climatic patterns observed by local people in Nessa village, Southern Malawi. It was revealed that phenomena such as El-Nino (heavy rainfall and strong winds), prolonged drought, and flash flood were confirmed by conventional forecasts. Most reported changes in this study, such as dry seasons, floods or heavy rainfall and extreme temperatures are similar to those in the broader literature (Dube *et al*., 2008; Khanal, 2009; Ifejika, 2010; Nkomwa *et al*., 2014). This also explains the reason for a few producers of *V. subterranea*. This study revealed that most climate weather forecasts in the smallholder farming sector are devoted to rainfall forecasts than temperature and wind. Although most smallholder farmers depend on rain to grow staple crops, early summer rainfall is mainly needed to prepare for *V. subterranea* production.

Youth behaviour and social misconduct were mentioned as climatic variability events that relate to climate changes over time. The results of one-on-one interviews with extension personnel only confirmed six climate variability events reported by key informants and learning circles. These are some of the similarities that validate the findings, while the differences show the importance of using different data collection techniques to answer an objective. This is what Hussein (2015) called the use of method triangulation to obtain the depth of data that improves the reliability and validity of the study.

The concept of forecasting precipitation is complex because it triggers many discussions that trace climate change, human behaviour and consciousness, knowledge dissemination, and forecasting techniques. These concepts relate to those of the theoretical framework used in this study (Dekens, 2007). Concepts such as observations and anticipation explain how the Xigalo and Lambani communities derive meaning from rainfall signs and use this knowledge to adapt to climate change. Despite the fact *V. subterranea* is prone to climate risk, climate variability has a ripple effect on rainfall forecasts based on local knowledge. The study discovered that some of the early rainfall signs could not be observed because they were extinct. This is supported by Briggs & Moyo (2012) study which found that climate variability had led to the disappearance of indigenous signs of rainfall. The extinction of some phenological indicators prevents local people from predicting rainfall. Thus, there is a need to conserve the environment and nurture phenological signs that exist in local contexts.

The findings show that indigenous signs of rainfall used to predict rainfall were the behaviour of birds, insects, croaking frogs and domestic animals, the flowering of trees, appearance of clouds, stars and moon shapes. These results are consistent with other studies (Changa *et al*., 2010; Mahoo *et al*., 2015; Gwenzi *et al*., 2016; Kagunyu *et al.,* 2016; Okonya *et al*., 2017; Fitchett & Ebhuoma, 2018). However, the mopane worms and traditional bangle are some of the indicators that differ from those documented in the broader literature cited above. Eighteen rainfall signs emerged from both study villages. Seven rainfall signs are unique to Tsonga people and six indicators are used by Venda people. The two communities share five common signs used to forecast rainfall. The rainfall signs may be common because the study villages are in the same geographical region.

In the current study, the sprouting of trees such as mangoes (*Mangifera indica)* and lychees (*Litchi chinensis*) was used as a sign of rainfall. Trees among other plants are mainly used as part of plant phenology. A study by Elia *et al*. (2014) also found that plum fingerleaf (*Vitex ferruginea*), baobab (*Adansonia digitata*) were associated with rainfall in Tanzania. The observation that different plants are used to predict rainfall may be explained by cultural differences. The observations of the local people are guided by culture and tradition that exists within a community. The use of different trees to predict rainfall can be attributed to ecological differences. Therefore, rainfall signs are locally based. Rankoana (2016) added that edible insects signify rainfall. In the Lambani area, swarms of locusts were mentioned as insect signs for forecasting rainfall. In contrast, mopane worms are used to signify the dry seasons in Xigalo village. Various insects are valued as rainfall indicators in each local community.

The photovoice results presented photos of a fluffy white cumulus and cumulonimbus cloud formations interpreted as rainfall indicators in Xigalo and Lambani areas. Other studies in Uganda and other parts of Africa have reported the appearance of dark clouds, light red clouds and rapid cloud movements indicating heavy rainfall and rainstorms (Okonya and Kroschel 2013; Mwanahija, 2016). The strength of the current study lies in the photographs attached to the descriptions of cloud formation and other signs of rainfall presented. The images provide evidence to the forecasting techniques that currently exists in both study villages.

Besides the results were similar as in literature, the findings on the reliability of IK-based forecasts show that rainfall signs keep smallholder farmers on alert, but certain climatic conditions are not predictable. This can be attributed to seasonal cycle variations and rainfall patterns shift. There is a need to improve the use of seasonal forecast to combat the adverse effects of climate change and promote the sustainability of *V. subterranea*. The results on rainmaking ceremonies reveal that the cultural practices between Tsonga and Venda people are similar, as the rainmaking is undertaken in the same way. Through narrative inquiry, it became clear that elderly people performed rainmaking ceremonies during prolonged droughts. In addition, respondents reflected on their past experiences with accurate and inaccurate prediction. The use of narrative inquiry as a data collection technique revealed adaptation measures that are put into practice to adapt to some of the climate variability events mentioned by key informants and learning circles. As a result, the results obtained through the use of a narrative inquiry supplemented the results of the key informants.

The rainmaking practices revealed in the study showed an element of adaptation to the drought seasons. Kagunyu *et al*. (2016) noted that village elders are responsible for disseminating warnings and signs such as heavy rainfall and droughts. This was the case in Xigalo and Lambani villages, with the elderly people participating in rainmaking ceremonies held on behalf of the community. These ceremonies are likely to become less significant soon as they are no longer performed. More importantly, some of the climate action for sustainable *V. subterranea* ought to study past activities to understand the shift and make a way forward. The results also revealed that rainmaking rituals were practised in savannah forests as sacred events. This refers to what Guthiga & Newsham (2011) called the rainmakers “custodians of sacred knowledge.

The accuracy and reliability of seasonal forecasts is still an issue, especially now that climate change is underway. Indigenous rainfall forecasts have their strengths and weaknesses like any other forecasting method. The strengths of IK forecasts presented were identified on the presence of rainfall signs that gave smallholder farmers the assurance that it would rain. Weaknesses were noted in the inability of IK's forecasts to determine the amount of rainfall expected. Signs of rainfall could serve as a warning of heavy rain or normal rainfall. The stories were appropriate for studying the relationship between local rainfall forecasts and the real events that occurred. A study by Chengula & Nyambo (2016) used a household survey to determine the reliability of specific rainfall signs. Reliability results were based on respondents’ perceptions.

3.13 Conclusion

Native approaches to rainfall forecasts to inform *V. subterranea* have been clarified and documented in this chapter. The results indicate that smallholder farmers and community elderly anticipate rainfall conditions through observations of environment indicators that are available within their space. This enabled them to prepare the tillage period for *Vigna subterranea.* The rainfall signs revealed were clustered into the phenological types that included; celestial, birds, personal ornaments, amphibians, lunar, insects and flowering plants. However, the accuracy of indigenous approaches is no longer reliable as climate changes become unpredictable under normal and extreme conditions. Consequently, the signs of precipitation that are used to predict weather appear and disappear quickly. The local communities have resorted to rainmaking practices during dry periods in the past, but the rituals have lost their meaning for the new generations. There is a need to improve the use of seasonal forecast in the production of *V. subterranea* production practices.

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CHAPTER 4 INDIGENOUS PRACTICES SMALLHOLDER FARMERS USE TO ADAPT *VIGNA SUBTERRANEA* PRODUCTION PRACTICES TO CLIMATE VARIABILITY

4.1 Abstract

There is an increasing awareness that climate variability events are the prevalent challenges in most smallholder farming systems. Events observed by local people are composed of; heavy rains, unpredictable rain, wind gusts, extreme temperatures, deforestation and social misconduct. Although there is no clear effect of meteorological variations on *V. subterranea* as it is considered drought-tolerant, its low production aspect is cognate to heavy rainfall and drought seasons. The indigenous methods are overlooked by scholars and pertinent policy-makers. It is difficult for local farmers to thrive and become secure for food and nutrition. This is attributed to the underutilization of *V. subterranea.* However, indigenous knowledge, as the main source of mitigation strategies, empowers smallholder farmers to produce the legume. The main inquiry was based on the identification of indigenous practices that the Xigalo and Lambani communities are executing to adapt *V. subterranea* to the global changing climate. Key informant interviews, learnings circles and one-on-one interviews were data collection techniques used to understand this phenomenon. Respondents from both communities were invited through exponential non-discriminative snowball sampling method. Five key informants were involved in Xigalo village. In addition, respondents were grouped by gender and two groups of elderly women and men partook in learning circles. In the case of Lambani area, four key informants were interviewed and six groups comprising one group of elderly men and three groups of women participated. Two extension officers and one retired officer recruited by convenience sampling also took part. Thematic content data analysis was adopted using Atlas.ti version 7.5.7 software to analyse qualitative data. The results of the study showed that V. subterranea grown under conditions of high rainfall and prolonged drought produced lower yields. The ploughing period of the legume is influenced by the changing climate and is justified by culture and traditional beliefs of Tsonga and Venda people. Adaptation strategies are part of the conservation of *V. subterranea*. The following conservations are used to protect the legume from damage caused by climate change and human behaviour. Hilling V. subterranea plant, weeding, traditional storage, planning hedgehog skin, soaking seeds before planting time. Further studies should focus on participatory modelling to improve climate adaptation and food security.

Key words: Adaptation, climate variability, conservation, legumes, production practices *Vigna subterranea*

4.2 Introduction

It is evident that food security and nutrition is a global challenge, especially in most smallholder communities situated in semi-arid areas (Wheeler & Braun, 2013; FAO, 2014; Minkoff-Zern, 2014; Cheeseman, 2016). Given that smallholder farmers are susceptible to climate change, lower yields of *Vigna subterranea* are also traced from climate variability events (Jiri *et al*., 2017). Smallholder agriculture sector has limited access to seasonal forecasts and local people still use most indigenous knowledge to cultivate *Vigna subterranea* (Frimpong, 2013). The phenomenon of climate change has so far attracted too much attention from scholars while *V. subterranea* production and adaptation practices remain under-explored. *V. subterranea* is normally produced in semi-arid savannah regions where its production is derived from indigenous knowledge. *V. subterranea* crop is known for its sources of nutrition and its tolerance to poor soils and drought conditions. It is also considered a climate-smart crop (Unigwe *et al*., 2016; Ho *et al*., 2017; Jiri *et al*., 2017). The current study stems from issues referred above. This being the case, it was important to understand how climate variability affected *V. subterranea*. The purpose of this study was to identify how smallholder communities produce and conserve *V. subterranea* to the constant variability of climate conditions. The previous chapter dealt with local observations on climate variability and early rainfall signs used to plan the production of *V. subterranea*. Existing home-grown practices that smallholder farmers or community elderly adopt are incorporated in this chapter. The resilience of the local communities is more reflected in the conservation practices and at the same time call for more adaptation strategies to improve *V. subterranea* production. A triangulation of data sources appraised the results of this study which are presented and discussed in more detail. This chapter is presented in the same outlines used in chapter 3.

4.3 Study Area

The present study on the local approaches of the Tsonga and Venda people to the adaptation of *V. subterranea* was conducted in the Xigalo and Lambani tribal areas alluded to in chapter 1. The participation in this study mainly concerned the elderly people of Xigalo villages and smallholder farmers in the Lambani area.

4.4 Training in Use of Data Collection Tools

Two research assistants recruited during the first study became familiar with the current one and were still involved in the current one. They were trained on the data collection tools that were used to serve the study purpose. The tools covered were key informant interviews and learning circles guided by a structured interview guide. The responsibilities expected of the research assistant include keeping the study documents safe. Other roles are mentioned in chapter 3. The structured questionnaire guide, study information sheets, consent forms, attendance register, field notes were the documents used in the data collection process.

4.5 Community Entry

Community entry was negotiated once for the two empirical studies presented in chapter 3 and chapter 4. Obtaining data for the first inquiry laid the basis for this study.

4.6 Research Design

This study was guided by a case study used in the previous study presented in Chapter 3. The design was deemed relevant for this study because it aimed to provide a thorough understanding of what is currently involved in the adaptation *of V. subterranea* to climate variability. In addition, the design was flexible for the triangulation of data sources and methods such as key informant interviews, learning circles, and one-on-one interviews. The thematic content analysis used to analyse the qualitative data obtained through these methods revealed the results that exposed the significance of different data sources. This is attributed to the case study plan used in this study.

4.7 Sampling Procedures and Study Respondents

The same group of respondents who were invited for the first inquiry participated in this study. Respondents were recruited using the exponential non-discriminative snowball sampling technique of Etikan *et al*. (2016). As it was mentioned in Chapter 3 that the sampling approach focused on the current study, the procedure is illustrated in Figure 3.1. Extension officers, as a convenient sample, provided a reference to the first 4 key informants interviewed. The officers work in the Limpopo Department of Agriculture and Rural Development (LDARD) which cooperates with the University of Venda and the local communities. It was noted that respondent mobilization continued during data collection.

4.8 Data Collection Methods and Procedures

This study collected secondary data for the literature review provided in Chapter 2. The primary data was collected through nine key informant interviews, eight learning circles, and three one-on-one interviews. These data collection techniques were performed in the same way as described in Chapter 3 with the same respondents who participated in the first study. These techniques were performed with a structured interview guide tool. Key informants were first interviewed because they are an influencing group in the community or in the study population. They are likely to know more about the subject under study. Respondents were asked and responded in dialogue form. This created a scene for the other respondents who participated in learning circles. The learning circles first discussed ideas in the groups and presented their views to all participants. Discussions took place using Xitsonga and Tshivenda which are the local languages. This provided a comfortable environment for the respondents, as they were free to express their knowledge in their home language.

A local interpreter was asked to interpret some of the terminologies that were not clearly understood by the study participants. One-on-one interviews were conducted with extension officers. The main purpose was to validate the information shared by the community. More importantly, the intention was to understand what is currently known about the communities of Xigalo and Lambani. Notepads, voice recorders and a camera were the tools used to capture information shared by respondents during data collection. It should be noted that different data sources from both techniques and respondents were used, which is concurs with Hussein's (2015) methodological triangulation explained in Chapter 3.

4.9 Data Analysis

This study collected qualitative data that was analysed through thematic content analysis learned from Creswell (2013). Atlas.ti version 7.5.7 software was used to analyse data collected through key informant interviews, learning circles and one-on-one interviews. The software was chosen because it is an appropriate tool for manipulating rich qualitative data. Field notes and voice recorders were used to capture data into Microsoft Excel spreadsheet imported into Atlas.ti, as a project. The data segments were highlighted and assigned to codes and sub-codes which were categorised into themes. The codes were used to run the full analysis in Atlas.ti, where the frequency of quotations was identified across data collection techniques. This was done using codes-primary document tables. The tables also revealed the number of quotes linked to individual codes. Further, nodes were imported into the Network View Manager to show links between codes and data segments.

4.10 Ethical Considerations

The ethical protocols of Ritchie *et al*. (2013) discussed in Chapter 3 have been followed in this study. Respondents gave their consent to participate voluntarily. They were informed of their rights, and their honour and integrity were respected when collecting the data. It was made clear that the information provided will be used mainly for academic purposes such as publication in accredited journals and presentation of results in conferences.

4.11 Description of Results

4.11.1 Observed effects of climate variability on *V. subterranea*

The results presented in Table 4.1 show the observed effects of climate variability on *V. subterranea.* The following effects of climate variability emerged as popular events in the previous chapter; heavy rainfall, scarcity of summer rain, seasonal cycle variations. These events were said to influence the production of V. subterranea. Four key informants pointed out that climate variability was characterized by heavy rains that led to moist soils. The Va-Tsonga people name *V. subterranea* as *tindluwa* and Va-Venda people call the legume *phonda*. It was revealed that *tindluwa*/*phonda* did not grow well under heavy rainfall conditions as the plant absorbed a lot of water. The results of the two learning circles in Xigalo and two learning circles from Lambani area confirmed the issue of heavy rainfall. In addition, one key informant mentioned that the legume is irrigated by other canals due to lack of rain. Three key informants in Xigalo and two key informants in Lambani mentioned the scarcity of summer rain as a factor delaying the production of *V. subterranea*. This was affirmed by one learning circle from Xigalo village. The normal summer rain expected between December and January no longer occurred on time.

The results in Table 4.1 show that the planting time for *V. subterranea* was adjusted to February and March due to lack of rain. Three groups in Lambani agree with results of three key informants from Xigalo.

4.11.2 The planting time of *Vigna subterranea* in Xigalo and Lambani communities

Table 4.2 shows perceived varieties of Vigna subterranea grown in Xigalo and Lambani villages. This table shows the results obtained through key informant interviews and learning circles. Five groups and six key informants agreed that the varieties of *V. subterranea* were visually differentiated into four colours; white, red, black and speckled brown. Three groups and four key informants mentioned that these varieties were visible in sizes including large and small. Some legumes multiplied into three and four and they are known as female legumes while the legume that germinated separately are called male legumes. Notably, six groups and nine groups agreed that *V. subterranea* varieties were normally planted in January each year.

Table 4.1 Effects of climate variability on *Vigna subterranea* perceived by respondents in Xigalo and Lambani villages

Effects of climate variability on Bambara legumes	Key Informants X	Key Informants L	Learning Circles (X	Learning circles (L)	Total
Heavy rain: moist soil *V. subterranea* (tindluwa/phonda) do not grow well under moist soil after a heavy downpour. This results in lower yields	4	1	2	2	9
Water scarcity: *V. subterranea* grow under high temperatures without irrigation water	1	0	0	0	1
Lack of Summer rain: Changes in planting dates Tindluwa/phonda are now planted between February March. It takes four to five months to grown Bambara nuts.	3	2	1	3	9

Table 4.2 The planting time of *Vigna subterranea* varieties

Perceived varieties of Bambara legumes	Learning circles (L)	Learning circles (X)	Key Informants L	Key Informants X	Total
Variety of colours *Four varieties in colours such white, red, speckled brown and black* *Dark brown legume is used a cure to kidney failure*	3	2	4	2	11
Variety of sizes *V. subterranea germinate in small and large sizes* *There are female tindluwa/phonda that multiplies in three or four, the male seeds germinate separately*	3	0	3	4	10
Planting period *January is the first month to plant tindluwa/phonda after the early summer rain* *V. subterranea seeds stops rain if planted before it rains*	4	2	4	5	15

The planting date was set based on the traditional beliefs that *V. subterranea* were exceptionally planted after the early summer rain because they affected rainfall. In addition, early rainfall was used to inform the seed preparation of *V. subterranea*. Smallholder farmers waited for rain in December and January to start planting before February. However, respondents observed seasonal cycle variations and thus adjusted planting times to correspond with the current rainfall regimes.

On the above note, the results showed that the local tradition was respected during the production of *V. subterranea.* The following are some of the sentiments shared by respondents:

> "*Bambara nuts are not supposed to be planted before the early summer rain. If you are caught planting before time, the chief used to order people who go to the households to uproot it. While in some cases, people uproot only a sample of seedlings and throw them into the river to compensate for the misdeeds. Then it's going to rain again*

4.11.3 Production and conservation of *V. subterranea*

Vigna subterranea was grown and conserved against damage caused by climate variability and human behaviour. Some smallholder farmers planted *V. subterranea* seeds separately while others intercropped them with maize after two to three months of planting maize. The production practices of *V. subterranea* had elements of conservation embedded. As presented in Figure 4.1, key informants and groups showed that smallholder farmers weeded and covered (earthed up) plant bases with soil when the flowers began to germinate. This was the most frequently cited strategy because failure to maintain the plant at flowering stage affected yields. It was also reported that the seeds had to be soaked in water to plant them before planting time. The seeds were usually soaked when smallholders opposed the traditional planting procedure before the rainfall. This strategy was used to adjust the planting time affected by climate change. It was also highlighted the soaked seeds ripened early and produced higher yields.

Some aspects of *V. subterranea* conservation focused on correcting traditional procedures that were not followed from planting to plant maturity. In the case of Xigalo, smallholder farmers planted hedgehog skin in farmland with *V. subterranea* to protect the plants from any damage or loss. In other words, hedgehog skin was considered a tool for protecting *V. subterranea* yields.

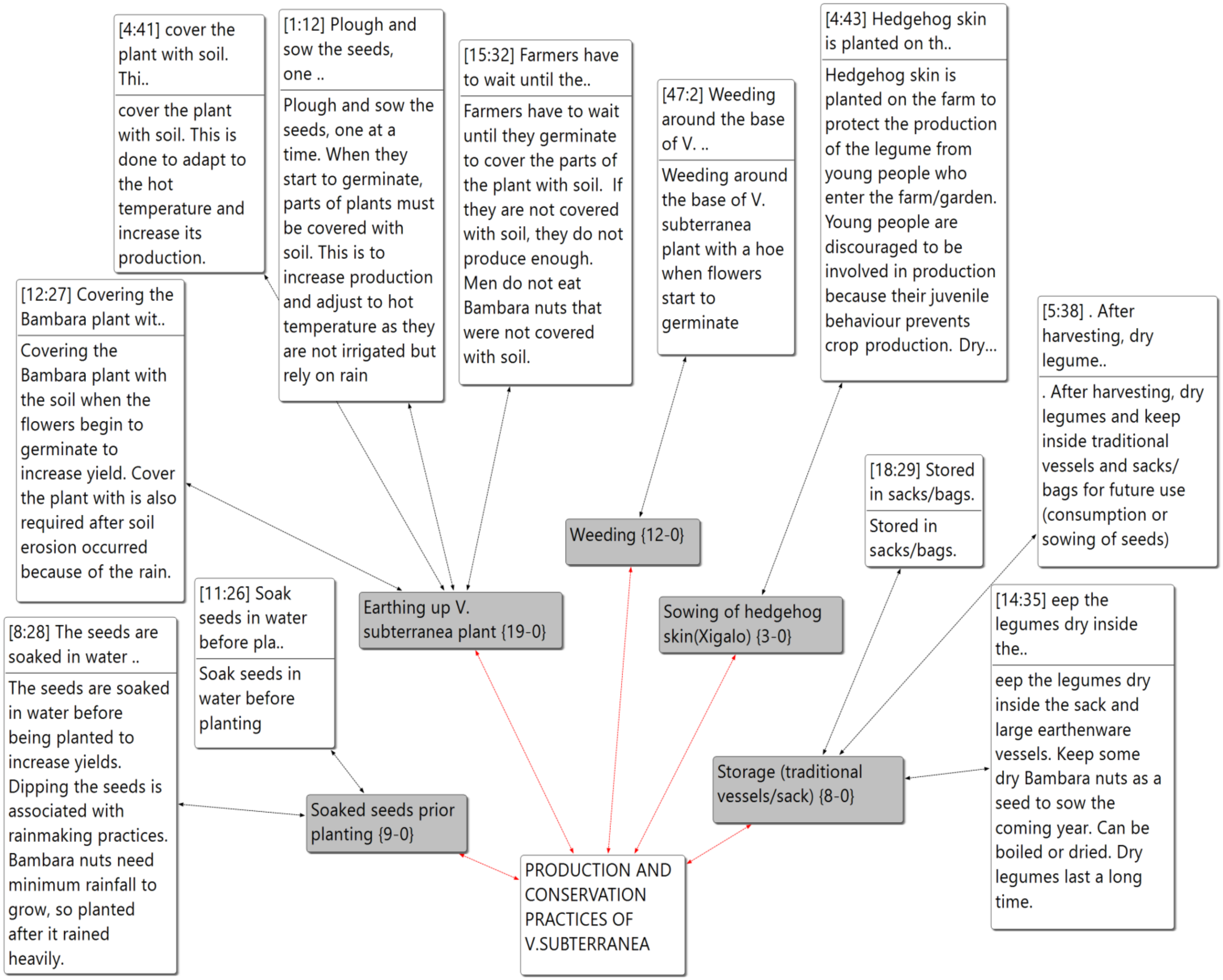

Figure 4.1 Production and conservation practices of *V. subterranea*

Women were mainly involved in the production, but pregnant women were not permitted to enter a farm or garden where *V. subterranea* was planted. One respondent explained the issue using the following expressions:

> *"Pregnant women were also not allowed to enter the farmland where Bambara nuts are planted because they affect the yield of crops, but in case they entered, they were supposed to pick up leaves and sit on them then layout soil on their way out".*

Traditional vessels and sacks were used to store *V. subterranea* for up to eight months. Community elderly pointed out that the rondavel thatched house was used as storage for *V. subterranea.* A hole dug in a dwelling and plastered with cow dung was used as a basin for storing the legumes.

4.12 Discussion

The studies conducted by Rankoana (2016) and Fitchett & Ebhuoma (2018) confirm the findings of this study that the characteristics of climate events are manifested through changes in rainfall, temperature patterns, dry summer, wet winter and extreme heat. The scholars revealed that rainfall recently shifted from September to October, November and the following year. In the case studies of Xigalo and Lambani, it was found that the delay of ploughing period was influenced by the rainfall shift from November and December to January and February. The current study found that planting dates of *V. subterranea* were modified to coincide with the current rainfall patterns. This is what Rankoana (2016) has called "farming adjustments" influenced by rainfall variability.

Interestingly the results of the study confirmed the findings of Unigwe *et al*. (2016) that Vigna subterranea is tolerant to harsh conditions such as drought. Mabhaudhi & Modi (2013) and Kagunyu *et al*. (2016), however, it was discovered that *V. subterranea* grown under prolonged drought produced lower yields. The findings of the study showed that some elements of scientific knowledge and indigenous knowledge are similar but explained in different terms. For example; the current study found that *V. subterranea* is planted after rainfall and that respondents believe that it stops the rain and contributes to long periods of drought. Other studies tested the landraces of *V. subterranea* that have proven to be a drought-tolerant crop (Jorgensen *et al*., 2010; Murevanhema & Jideani, 2015; Unigwe *et al.*, 2016). This confirms the results revealing that the lack of rainfall in summer delays the planting times.

The findings of this study showed that *V. subterranea* does not require much water/rain to grow. Heavy rainfall that leads to moist soils and water scarcity have been mentioned as conditions that affect the yield of legumes. Chibarabada *et al*. (2015) who compared the yield of irrigated and rain-fed *V. subterranea* discussed similar results in scientific terms. Their study found that the plant is sensitive to water stress. Rain-fed legumes have poor viability and vigour, while irrigated crops produce more yield. This study suggests further experiments to be carried out in other local contexts where *V. subterranea* is planted under drought, rain-fed and irrigated conditions to test its yield. Studies on food security and climate change will guide relevant adaptation strategies. The results of this study revealed components that are reflected in the theoretical framework of Dekens (2007). The awareness of climate change events contributes to adaptation that promotes food security and sustainable livelihoods.

According to Makwara (2013) and Kolawole *et al.* (2014), it is important to study the weaknesses and strengths of scientific and indigenous methods to forecast before the implementation of the integration of the two approaches. This study has so far highlighted the indigenous practices concerned in adapting *V. subterranea* to climate change. No evidence was found that the integration of scientific seasonal forecasts and indigenous forecast made it possible to adapt or produce *V. subterranea.* This study is of a view that scientific information and indigenous knowledge have a role to play in enhancing food security and can be used to figure out how the two approaches can work together. Smallholder farmers can continue to focus on monitoring climate changes and work with climate scientists who use technology advances to understand the challenges they face. Further research should focus on developing a model for integrating climate-related monitoring and risk-reduction approaches in rural communities.

In the current study, respondents expressed that varieties comprise white, red, black and speckled brown and climate variability affects all the varieties in the same way. It was alluded that the varieties are visually identified by sizes as there are seeds that grow and multiply into pairs. Chibarabada *et al.* (2015) found similar results except for the speckled brown which was stronger than white and red landraces. The above is related to what respondents meant when they mentioned that black coloured nut treats kidney failure. Ho *et al*. 2017 support this finding by articulating that the crop is a protein source and has essential nutrients for human consumption. The planting month seems to have shifted from January to February and March due to lack of rainfall. Such a change affects smallholder farmers considering that *V. subterranea* take about four months to grow. This means that the harvest will serve less purpose on subsistence farming that it is expected. Thus, the production practices of *V. subterranea* should be promoted to enhance food and nutritional security in smallholder farming livelihoods.

The main findings regarding the conservation of *V. subterranea* have been revealed through key informant interviews and learning circles. Some conservation methods such as weed hoeing may be related to scientific knowledge. The same method is disseminated in the Bambara groundnut Production Guideline published in 2011 by the Department of Agriculture, Forestry and Fisheries (DAFF). It is known as weed control in which weeding is done during the flowering stage to maintain the growth of *V. subterranea*. Traditional storage methods shown in this study are similar to other areas. In some semi-arid regions of Nigeria storage such as granaries, bags and containers are used (Aviara *et al*., 2013). The granaries appear similar to rondavel dwelling that was used in Xigalo area of this study. In addition, *V. subterranea* is mainly cultivated by women in Xigalo and Lambani areas. This confirms the findings of Hillocks (2012), Aviara *et al*. (2013) Boureima *et al*. (2015), which describes *V. subterranea* as an indigenous crop grown mainly by women to ensure household food security. The issue of pregnant women can be related to a social protection mechanism that protects pregnant women from labour-intensive activities.

4.13 Conclusion

Key informants, learning circles and one-on-one interviews appraised the results on the planting, conservation and traditional storage for *Vigna subterranea*. It was noted in this study that crop is faced with climate change, especially heavy rains and floods which exert water stress on these plants. However, the results presented in this chapter have shown that smallholder farmers produce and conserve *V. subterranea*. Adaptation strategies revealed are conservation based on the timing of planting, flowering stage and harvest period. More so, *V. subterranea* seeds are customarily planted during wet periods after a summer rainfall. Further research and experiments can be done to test yields under irrigated, rain-fed and dry conditions.

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CHAPTER 5 SYNTHESIS OF INDIGENOUS APPROACHES USED TO FORECAST RAINFALL FOR ADAPTATION OF *VIGNA SUBTERRANEA* IN XIGALO AND LAMBANI VILLAGES, LIMPOPO PROVINCE

5.1 Introduction

The recognition that climate change influenced smallholder farmer decision making most (FAO, 2014) influenced the current study. They used indigenous approaches to predict rainfall and adapt *Vigna subterranea's* production practices. Climate action strategies are increasingly focused on the integration of scientific forecasts and local forecasts (Dekens 2007, Makwara 2013, Kolawole *et al*., 2014). However, there is little knowledge of the native approaches involved in rainfall forecasting for *V. subterranea* adaptation. As alluded to earlier, *V. subterranea* is a climate-smart crop that tolerates drought and poor soils. The legume is known for its ability to promote food security and nutrition in sub-Saharan Africa, but scholars have paid little attention to this crop (Jiri *et al*., 2017). The following two objectives were therefore achieved in this study to understand the indigenous approaches used by smallholder farmers in Xigalo and Lambani villages of Vhembe district to predict rainfall and inform *V. subterranea* production practices: (1) To clarify the indigenous methods used to forecast rainfall in Tsonga and Venda communities; and (2) To identify indigenous practices smallholder farmers used to adapt *V. subterranea* production practices to climate variability. This has led to a better understanding of the role of indigenous knowledge in smallholder farming practice. An in-depth study of the phenomenon under study is of utmost importance as the need to increase food and nutrition security becomes deeper. In this chapter, the methodological imperatives related to the objectives are raised. This is followed by the major issues that emerged from the study. The contribution of the study to the body of knowledge is discussed. The recommendations cover three areas, namely policy interventions, rural development practices and further research. Finally, a conclusion and a summary of the key issues in the study are presented.

5.2 Methodological Imperatives

Convenience and exponential non-discriminative snowball sampling methods were used to mobilize relevant respondents. Sampling procedures were informed by Etikan *et al.* (2016) and adapted to fit into the current study. This study initially targeted a significant number of smallholder farmers in both villages but, it emerged that the Lambani's sample size was greater than that of Xigalo because community farming schemes no longer existed. As a result, eighteen community elderly participated in Xigalo while Lambani had fifty-four smallholder farmers. In addition, the initial plan was to add rainmakers to the study, but they were not available in both communities. The understanding is that the rainmakers use their own practices that might have provided the study with new information on rainmaking practices. Further, smallholder farmers and community elderly were invited to this study because they had more experience producing *V. subterranea* and were familiar with the traditional erudition of forecasting rainfall. Their age groups were over 40 years old, anchoring the type of data collected in this study.

The case study research design was adopted to explore the native approaches used to predict rainfall in order to adapt *V. subterranea* in the Xigalo and Lambani villages. The case study is supported by Ritchie *et al*. (2013) and Thomas (2015) who stated that design is flexible and uses different perspectives to understand a phenomenon. In this case, the triangulation of data collection methods, data sources and sampling was adapted to the current study and employed. This is supported by the literature, which shows that the use of triangulation leads to data saturation (Hussein, 2015, Fusch & Ness 2015). The authors further stated that "one size does not fit all". In other words, multiple perspectives contribute to the depth of the data and increase the reliability and validity of the research.

Key informant interviews, learning circles, narrative inquiry and photovoice have proved to be appropriate for collecting rich data. The Atlas.ti analysis software was appropriate for performing a thematic content analysis of the data collected in this study. The tool was chosen because it is useful for processing rich qualitative data. Results were revealed based on each data collection technique used to achieve the study objectives. The use of multiple techniques contributed to the validity of this study as information was collected from different sources. Some responses obtained through key informants were corroborated by learning circles and one-on-one interviews with government extension officers. Additional information was withal obtained through photovoice, narrative inquiry and one-on-one interviews.

5.3 Major Issues Emerging from the Study

The current study has established a link between indigenous rainfall forecasts and the production of *V. subterranea* which is rarely found in the literature. Currently, most studies have focused on indigenous precipitation forecasts and *Vigna subterranea* production as general and distinct topics (Berchie *et al*., 2012; Soropa *et al*., 2015). This study focused on the production and adaptation of *V. subterranea* based on local rainfall forecasts. Rainfall signs used by Tsonga and Venda people to forecast forthcoming seasons were found in this study. It has now become clear that indigenous knowledge and approaches still constitute social capital for observing climate changes and countering deficits (Ajani *et al*., 2013).

Xigalo and Lambani villages of Vhembe District were the contexts of the study. The findings were subjected to culture, traditional beliefs and the local environment in which the study was conducted. Therefore, a similar study may yield different results if conducted in another part of the world. It is noteworthy that extension officers are infusing indigenous knowledge in their communication with smallholder farmers. This development is reinforced by scholars such as Dekens (2007), Kolawole *et al*. (2014) and Makwara (2014). Such an initiative is beneficial for climate change action measures as they are exposed to some of the local terminologies that are explained differently scientifically. An extension can bring together smallholder communities and relevant stakeholders to foster resilience to climate change. It will also encourage smallholder farmers to adopt new strategies to improve the use of seasonal forecasts in an adaptation of *V. subterranea* production practices.

As already mentioned, knowledge of *V. subterranea* production practices is limited (Murevanhema & Jideani, 2015). Respondents were found to have participated in a number of research studies, yet most of these studies focused on other crops such as maize and vegetables. In this study, it emerged that local rainfall forecasts and scientific forecasts share similarities in their climate observations such as clouds and weather conditions but different approaches and explanations. This finding is corroborated by (Briggs & Moyo, 2012; Roudier *et al*., 2014). More so, it has been revealed that *V. subterranea* needs minimum rainfall to grow as water stress decreases its yield (Chibarabada *et al*., 2015). However, this study revealed that smallholder farmers expect rainfall primarily because legumes should be planted after rainfall according to the local principle. The summary of the major issues emerging from the study is shown in Table 5.1.

5.4 Contribution of the Study to Literature on Rural Development

It was revealed in earlier parts of the dissertation that little was known about indigenous rainfall forecasts and how *Vigna subterranea* producers use it to inform farming practices. The nature of the current study was based on the characteristic of the context of the study area. This study helped to understand the dimensions of a theoretical framework developed by Dekens (2007). The native rainfall forecasting approaches of Tsonga and Venda people were revealed. It contributes to the literature on indigenous approaches to rainfall forecasting and climate change adaptation practices. Since *V. subterranea* production practices are not popular, it was important to learn traditional procedures involved in the production of the crop.

This study adopted the collection of participatory data collection techniques for each objective. The photovoice technique normally uses interviews and group discussions to attain more in-depth information that may be missed during the discussions. This technique has become increasingly popular in qualitative data collection but is rarely used by studies in smallholder communities (Cooper & Yarbrough, 2010).

Table 5.1 Summary of major issues emerging from the study

Objectives	Methodology	Major Findings	Implications
1. To clarify the indigenous methods used to forecast rainfall in Tsonga and Venda communities	a) Two case studies used convenience and exponential non- discriminative snowball sampling to select respondents b) 18 community elderly, 56 smallholder farmers, 2 extension officers, 1 retired officer participated through key informant interviews, learning circles, narrative inquiry, photovoice and a one-on-one interview. c) Thematic content analysis used to analyse qualitative data	a) Xigalo and Lambani communities are aware of climate variability events that reduce the yield of *Vigna subterranea* b) 18 signs of rain were revealed, of which 7 were found among the Tsonga people and 6 revealed by Venda people. Both communities had 5 common rainfall signs used to predict forthcoming seasons c) Most common rainfall signs are derived from phenological types such as celestial, domestic animals, insect, flowering plant, birds and lunar	a) Indigenous rainfall forecasts may be incorporated with a scientifically proven information to combat the negative effects of climate variability on *V. subterranea* b) Phenological signs may be nurtured for future observations
2. To identify indigenous practices smallholder farmers use to mitigate the effects of climate variability on *V. subterranea.*	a) 5 Key informants in Xigalo Village and 4 of them in Lambani. 2 learning circles were conducted in Xigalo and 6 were carried out in Lambani. 3 One-on-one interviews. b) Thematic content analysis using Atlas.ti version 7.5.7 software	a) The three most considerable effects of climate variability on three varieties of *V. subterranea* were found. This includes; heavy rainfall, water scarcity, lack of summer rain. Consequently, *V. subterranea's* planting dates are changing over time and heavy rainfall is associated with water stress which results in lower yields b) Indigenous approaches have long-standing adaptation strategies integrated into the conservation of *V. subterranea.* Weeding control, earthing up V. subterranea plant, hedgehog skin, soaked seeds and traditional storage were used to protect *V. subterranea* plants and yields. c) The dates of ploughing *V. subterranea* are influenced and justified by the culture and tradition of the Tsonga and Venda communities	a) Awareness raising of African nutritional legumes that can improve food security b) Developing effective strategies that can be adopted to enhance the sustainability of *V. subterranea*

According to Guell & Ogilvie (2015), photovoice is a method for picturing the community. Thus, this study used key informant interviews, narrative inquiry, learning circles and photovoice enabling readers to imagine how smallholder farmers derive a sense of rainfall signs for *V. subterranea* production. The adopted methods can be used to solve future research problems similar to current research. The sampling procedures operated well in this study because they were based on the actual context in which the sample size was not anticipated. These constraints may emerge in similar empirical studies on rural development.

The current study considers rural development as an approach to understanding the multidisciplinary issues that affect the quality of life people (Dixon, 2015). This primary study remains relevant because it was conducted to understand how smallholder farmers adapt *V. subterranea* in response to climate change to improve household food security. Moreover, this study is a product of the insights shared by respondents. In other words, the elderly, smallholder farmers and extension officers participated in the scientific study that identified their own strengths (resilience). This implies that the community members can deliberate on the issues that concern them and initiate or seek solutions that are appropriate to their situation.

5.5 Conclusion

It has become clear that from this study that indigenous approaches to rainfall prediction enable smallholder farmers and elderly people to become aware of climate variability events affecting *V. subterranea* production. Indigenous precipitation forecasts are based on observations that are of interest to scientific predictions. Scientific seasonal information has not been widely used by smallholder farmers to improve the production of *V. subterranea*. The conservation of *V. subterranea* is embedded with adaptation to variable weather conditions, especially heavy rainfall. The study set the scene for future studies and intervention related to seasonal forecasts and climate change adaptation.

5.6 Recommendations

5.6.1 Recommendations to policy interventions

a) Zero Hunger is the second of the 17 Sustainable Development Goals (SDGs) established by the United Nations (2015) to improve food security and nutrition to improve sustainable agriculture by 2030. It is recommended that hunger-fighting efforts focus on extension services that can be induced by indigenous knowledge holders to effect the yield of *Vigna subterranea*.

b) The climate action effort, which is the 13th of the 17 SDGs, should promote community resilience to climate change by using adaptation strategies that are adapted to the local context.

c) There is a need to improve the accuracy of seasonal forecasts in rural communities. Interventions should be embedded with educational programmes on climate terminologies to improve the dissemination of seasonal forecast information.

5.6.2 Recommendations for Rural Development Practice

a) Engage relevant community members to develop a framework that improves the use of seasonal forecast in the smallholder farming sector

b) Fostering smallholder communities to engage in dialogues will help identify needs to enhance the sustainability of V. subterranea in the changing climate

c) There is a need to deliberate on strategies to nurture some of the phenological signs of rainfall to open up research and interventions opportunities

5.6.3 Recommendations for further research

a) How can indigenous practices be infused with scientific practice to improve the accuracy of seasonal forecasts?

b) Develop participatory modelling approaches for improved climate adaptation and food security

c) Determine effective strategies that can be adopted to enhance the use of seasonal forecasts and the sustainability of *V. subterranea* production practices

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LIST OF APPENDICES

Appendix 1: Ethical Clearance Certificate

RESEARCH AND INNOVATION
OFFICE OF THE DIRECTOR

NAME OF RESEARCHER/INVESTIGATOR:
Ms AE Hlaiseka

Student No:
16016738

PROJECT TITLE: **Indigenous approaches to forecasting rainfall for adaptation of Bambara Nuts (VIGNA SUBTERRANEA) production practices in selected villages of Vhembe District.**

PROJECT NO: **SARDF/17/IRD/07/1008**

SUPERVISORS/ CO-RESEARCHERS/ CO-INVESTIGATORS

NAME	INSTITUTION & DEPARTMENT	ROLE
Prof J Francis	University of Venda	Supervisor
Mrs MA Mathaulula	University of Venda	Co- Supervisor
Ms AE Hlaiseka	University of Venda	Investigator – Student

ISSUED BY:
UNIVERSITY OF VENDA, RESEARCH ETHICS COMMITTEE

Date Considered: August 2017
Decision by Ethical Clearance Committee Granted
Signature of Chairperson of the Committee: ....
Name of the Chairperson of the Committee: Prof. G.E. Ekosse

UNIVERSITY OF VENDA
DIRECTOR
RESEARCH AND INNOVATION
2017 -08- 29
Private Bag X5050
Thohoyandou 0950

University of Venda
PRIVATE BAG X5050, THOHOYANDOU 0950, LIMPOPO PROVINCE, SOUTH AFRICA
TELEPHONE (015) 962 8504/8313 FAX (015) 962 9060
"A quality driven financially sustainable, rural-based Comprehensive University"

Appendix 2: Letter for Permission

University of Venda

X5050 Thohoyandou

Limpopo, South Africa

Xigalo Tribal Office

Malamulele, Limpopo

0982

13 October 2017

Dear Chief

RE: REQUEST FOR PERMISSION TO CONDUCT A STUDY IN XIGALO VILLAGE

My name is Amukelani Hlaiseka, a student from the University of Venda currently enrolled in a Master's degree in Rural Development.

I wish to conduct a research study for my Master's dissertation, which aims to better understand the *indigenous knowledge used predict rainfall for adaptation of Bambara nuts (Vigna subterranea).* This study is conducted under the supervision of Prof. J. Francis and approved by the University of Venda Higher degrees committee and by the Ethics committee.

I hereby request your permission to enter your community to present the study and approach a group of smallholder farmers, community elderly and rainmakers who can contribute with the rich indigenous knowledge to the study. In addition, I will liaise with extension officers from the Limpopo Department of Agriculture and Rural Development who are currently working closely with the farmers in your area.

I will appreciate your permission to conduct the study.

Yours Sincerely,

Amukelani Hlaiseka

____

Appendix 3: Letter of Consent

Dear Selected Participant

My name is Amukelani Hlaiseka. I would like to invite you to a study I am currently conducting as a prerequisite for the Master's dissertation in Rural Development at the University of Venda. This study focuses on indigenous approaches to forecasting rainfall for adaptation of Bambara nuts (*Vigna subterranea*) production practices in Xigalo and Lambani villages of Vhembe District.

The current study seeks to discover the indigenous knowledge that smallholder farmers, community elderly use to predict forthcoming seasons. This study seeks to learn how smallholder farmers cope with hot temperatures and variability of rainfall when growing Bambara nuts (*Vigna subterranea*).

You are asked to participate in this study, hoping that I will learn more about your home-grown techniques for predicting seasonal rainfall in the production of Bambara nuts.

Please note that there are no rewards in the participation, but the study will help to understand multiple factors that are like a heritage of the Tsonga and Venda communities.

Process

If you choose to participate, you will be invited to join the learning circles where you and other participants will share information relating to this study. I will visit your community many times because the nature of this study seeks to learn more about this community, but that does not mean you are forced to participate. Please understand that you participating voluntarily and feel free to withdraw at any stage of the study.

I would also like to ask permission to use a recording device that will help me make notes

Information Use

Note that the information collected from you will be kept secure and accessed by me, the University, and disseminated in academic journals, as it will be used for academic purposes.

Questions about research

If you have any concerns about this research, do not hesitate to contact my supervisor, Prof. J. Francis at 015 962 8804/ joseph.francis@univen.ac.za and if you feel that you have been unfairly treated, you can contact the University of Venda Research Ethics Committee.

Informed Consent

I understand the procedure of this study, to which I participate voluntarily. ☐

I am aware that this study is for an academic purpose that I will not receive any reward thereafter ☐

The information collected from me will help to better understand my community ☐

I understand that I am not at risk by being a research participant ☐

I can choose whether to be in this study or not and I can withdraw at any time without consequences ☐

I asked questions and I am satisfied with the answers explained by a researcher

I agree to participate in the study ☐

Signature of participant ____________________ Date __________________________

Appendix 4: Participant Register

Indigenous approaches to forecasting rainfall for adaptation of Bambara nuts (*Vigna subterranea*) production practices in Xigalo and Lambani villages of Vhembe District

Date: ____________________ Place: ______________________

Surname and Initials	Male or Female	Community elderly or Smallholder farmer	Phone numbers	Email	Signature
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					
9.					
10.					
11.					

Appendix 5: Data Collection Guide

Step by step guide to data collection

1. Community entry

a) Secure permission of the traditional leaders to conduct the study

Resource: letter addressed to the Chiefs of Lambani and Xigalo areas

2. Selection of respondents

a) Identify and select key informants (e.g. community elderly, smallholder farmers, rainmakers and extension officers)

3. Structured interview guide of each objective

Objectives/ Questions	"How" to answer the questions of each objective		
	Phase 1	**Phase 2**	**Phase 3**
Objective 1: To clarify the indigenous methods used to forecast rainfall in Tsonga and Venda communities	Key Informant Interviews (KII)	Narrative inquiry	Photovoice workshop
1) What changes have you observed over the years which confirm that climate change is taking place? 2) How do you predict the quality of the seasons ahead? (example; rainfall, temperature and wind) 3) How reliable are the indigenous methods you use to predict the quality of season ahead? (Share with me any stories that support this)	Learning circles (LC)		

Objectives/ Questions	"How" to answer the questions of each objective		
	Phase 1	**Phase 2**	**Phase 3**
Objective 2: To identify indigenous practices that *V. subterranea* producers use to mitigate the effects of variations in temperature and rainfall. 1) How has climate variability affected the production of Bambara nuts over the years? 2) What varieties of Bambara nuts are grown here? When are they normally grown? Why are they grown in this particular period? 3) Which varieties of Bambara nuts are most affected by Climate Variability? 4) How do you grow and conserve Bambara nuts in response to Climate Variability? 5) How effective are the mitigation strategies you use? (share related stories)	Key Informant Interviews Learning circles		Photovoice workshop