

Indigenous Knowledge Systems cues essential in agricultural management and tracking seasonality in KwaZulu-Natal and Eastern Cape, South Africa



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Declaration

I declare that this my work, unless otherwise acknowledged. This research is submitted in fulfilment of a Master's Degree in the school of Geography Archeology and Environmental Studies at the University of the Witwatersrand. This work has not been submitted in fulfilment of any Degree qualification before.

A handwritten signature in black ink, appearing to read 'Sinoxolo Magaya', with a stylized, cursive script.

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Date: 17 February 2021

ABSTRACT

More than 10% of the South African rural population practice subsistence farming to supplement food sources and secure livelihoods. Therefore, subsistence farming is critical for food security, particularly for rural communities in KwaZulu-Natal and the Eastern Cape Provinces in South Africa. Community members in the rural areas within these provinces, including Umzimkulu and Lusikisiki, produce various crops to ensure food availability accessibility for their households. Climate change stressors undermine the efforts to produce food in most rural areas across the globe, more so in rural subsistence farming. However, community members in these areas are not passive actors. They develop and employ pragmatic adaptive strategies using several environmental variables to infer weather forecasts and facilitate adaptation methods. The indigenous knowledge systems (IKS) cues are based on observing the sequence of recurring, and mostly seasonal plant or animal life events. Therefore, species phenology is a significant part of traditional weather forecasting. The study used interviews to investigate the use of IKS cues important in agricultural management in Umzimkulu, KwaZulu-Natal and Lusikisiki, Eastern Cape, South Africa. The results indicates that community members in Umzimkulu and Lusikisiki use several phenological, meteorological and astronomical cues that are essential in short to medium-term weather forecasting. These include peach tree flowering to indicate spring onset, moon with a hollow to indicate windy conditions on a certain day and croaking of frogs to signal oncoming rainfall. People in these communities also note that the reliability and abundance of indicator species are decreasing. This indicates that IKS cues based in phenology are threatened. Meanwhile, the reliability of meteorology based indicators has not changed but is less significant for agricultural activities. Meteorology indicators are mostly used for short-term (hourly-daily) weather forecasting, thus do not afford farmers enough time to implement significant adaptation methods or exploit the oncoming weather conditions. Therefore, these indicators are less relevant

for the growing season preparedness. Changes in the reliability of IKS cues can have detrimental impacts on food production in rural areas.

Keywords: Indigenous Knowledge Systems, Phenological indicators, Subsistence farming, Umzimkulu, Lusikisiki, South Africa.

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List of Acronyms

GCM: Global Circulation Model

GDP: Gross Domestic Product

IK: Indigenous Knowledge

IKS: Indigenous Knowledge Systems

IPCC: Intergovernmental Panel for Climate Change

m.asl: meters above sea level

SAWS: South African Weather Services

SRZ: Summer Rainfall Zone

STATSSA: Statistics South Africa

TEK: Traditional Ecological Knowledge

TPK: Traditional Phenological Knowledge

TRACOR: Transkei Agriculture Corporation

WRZ: Winter Rainfall Zone

YRZ: Year-round Rainfall Zone

1. Introduction

Subsistence farming is significant part for food availability across South African rural households, these households practice farming mainly to ensure food availability for their families (Kisaka-Lwayo and Obi, 2012; Kibirige and Obi, 2015; Garutsa and Nekhwevha, 2018). In 2017, 15.6% of South African households were involved in agriculture, mainly subsistence farming (STATSSA, 2017). Subsistence agriculture refers to farmers that cultivate food primarily for themselves and their families, typically, in developing countries, it is without financial gain (Gill, 1991; Baiphethi and Jacobs, 2009; Seoraj-Pillai, 2011; Yusuf *et al.*, 2014). Although some studies suggest that there has been an increasing dependence on commercial market food supplies (cf. Gbetibouo *et al.*, 2010; Ngcoya and Kumarakulasingam, 2017), rural settlements are still largely dependent on their backyard gardens for their food production (Seoraj-Pillai, 2011; Sibhatu and Qaim, 2017). Studies conducted to ascertain the contribution of subsistence farming to food security in South Africa have indicated that it can effectively alleviate poverty and food insecurity (Modi *et al.*, 2006; Aliber and Hart, 2009; Mkhodo, 2017). This is because, in most rural areas, it has relatively low input requirements which accommodate the socio-economic conditions of most households (Yusuf *et al.*, 2014; Bakre and Dorosamy, 2015). Food security exists when people have socio-economic and physical access to nutritious and preferred food that satisfy their dietary needs for a healthy lifestyle (Peng and Berry, 2019). Subsistence farming is one of the three main food sources, including markets, and transfers from public programmes or other households (Baiphethi and Jacobs, 2009). According to the STATSSA (2017) report, households that are involved in agriculture are predominantly found in KwaZulu-Natal, Eastern Cape and Limpopo. STATSSA (2013) highlighted that a majority of agriculture practicing households are in rural, marginalised communities that have no income and often have limited access to basic services

such as electricity, water and sanitation. These communities commonly have low salary-based income in households, and mainly depend on state claims, wage earnings and petty trade (Averbeke and Khosa, 2007; STATSSA, 2017). Therefore, the majority of the households use subsistence farming to supplement food sources (Meyiwa *et al.*, 2013; STATSSA, 2017). Apart from being cost-effective, subsistence farming also ensures food sovereignty and security, which is the most important component to some for the elderly population in rural areas (Ngcoya and Kumarakulasingam, 2017). Subsistence farming is argued to not ensure complete food and nutritional security because most farmers focus on foods that grow well in their areas regardless of nutritional value (D'Haese *et al.*, 2013; Maseko *et al.*, 2017; Peng and Berry, 2018). However, it is still a major contributor to two components of food security; food availability and accessibility (Kisaka-Lwayo and Obi, 2012; Sibhatu and Qaim, 2017).

In South Africa, agriculture, particularly subsistence farming, is mainly determined by rainfall patterns and thus, it is one sector that is mostly undermined by the effects of climate change (Apraku *et al.*, 2018). Climate directly influences crop production, from short term decisions regarding choice of crops to grow, sowing and harvest dates, to long term investment choices (Cairns *et al.*, 2013; Shoko *et al.*, 2019). Subsistence farmers predominantly rely on natural environment viability for productivity because they are less mechanised and mostly lack the necessary resources to promote optimal productivity (Kisaka-Lwayo and Obi, 2012; Rukema and Umubyeyi, 2019). Therefore, they are uniquely vulnerable to the effects of environmental change, including changes in seasonality and rainfall patterns, soil fertility and photoperiod (Santhia *et al.*, 2018). Changes in these variables can be a determining factor for food availability in South African rural areas because seasonality influences a wide range of activities in agriculture (Serdeczny *et al.*, 2017; Apraku *et al.*, 2018; Roffe *et al.*, 2020b). Not only is the agricultural

sector notably vulnerable to climate change because of increased exposure due to the geographic location of South Africa (Roffe, 2019), but considerably low adaptive capacity renders this region more likely to experience increased food insecurity because of anthropogenic climate change-related stressors (Bakre and Dorosamy, 2015). Accordingly, climate change introduces extra challenges to the existing agricultural management and development constraints that hamper food security and livelihoods in sub-Saharan Africa, such as increased pest infestations and spread of diseases such as malaria to new regions due to species range shifts (Mapfumo *et al.*, 2016; Santhia *et al.*, 2018). Therefore, extensive understanding of species response to climate change will reduce the vulnerability of these regions to climate change, limit severe financial and agricultural losses, and promote quality of life of the residents (Alexander *et al.*, 2015; Serdeczny *et al.*, 2017). Nonetheless, rural communities have displayed an ability to adapt to environmental changes through a store of locally developed methods and strategies that stem from their close relationship and dependence on the natural environment (Ebhuoma and Fitchett, 2018; Rukema and Umubyeyi, 2019).

For generations, subsistence farmers have adapted to environmental risks using Indigenous Knowledge Systems (IKS) (Chand *et al.*, 2014; Altieri and Nicholls, 2017; Fitchett and Ebhuoma, 2018). In Msinga, a village in the North of KwaZulu-Natal, Rukema and Umubyeyi (2019) found that droughts are pervasive in the area and as a result, drought management methods and seasonal adjustments are inherent to the community members to ensure adequate agricultural yields and maintain livelihoods. Community members in this area use indicators such as livestock behavior, return and behavior of summer birds and ancestor's revelations to forecast and mitigate drought impacts on farming activities (Rukema and Umubyeyi, 2019). Furthermore, they believe praying to ancestors through performing rituals can abate droughts and promote agricultural productivity.

In line with climate variability and uncertainties, rural communities have devised several strategies to address these changes, including planting winter resilient crops to avoid frost damage and limit losses in case of extremely delayed spring rainfall onset (Cartea *et al.*, 2010; Simon *et al.*, 2014; Rukema and Umubyeyi, 2019). Furthermore, rural communities have various, mostly phenological based indicators for daily and seasonal weather forecasting (Eakin, 1999; Chambers *et al.*, 2013; Bagchi, 2015; Ebhuoma and Simatele, 2017; Fitchett and Ebhuoma, 2018).

African countries have extensive Indigenous Knowledge (IK) that stem from the intimate understanding of the terrain and seasonal patterns, borne from dependence on natural resources for basic survival (Ebhuoma and Simatele, 2017). IK is defined as community-based knowledge that is distinct to a particular culture or community (Orlove *et al.*, 2010; Ajani *et al.*, 2013; Chambers *et al.*, 2017; Ebhuoma and Simatele, 2019). IK is informed by observations, experimental activities, and beliefs and in some instances reinforced by inaccessibility to modern science meteorological services (Orlove *et al.*, 2009, Ebhuoma and Simatele, 2019). IK is unorthodox to western science because it is considered more subjective, it is often not documented and its application is informed by immediate observed data because of the direct relationship between its users and the environment (Chambers *et al.*, 2017; Fitchett and Ebhuoma, 2018). Available studies indicate that IK has always formed a crucial and effective role in understanding changes and reducing vulnerabilities of the changes in the natural environment (Orlove *et al.*, 2010; Mwinga *et al.*, 2019). However, more research in various locations is still needed to understand the effectiveness of IKS in climate change adaptation and the limits to IK methods that may arise due to climate change scenarios (Orlove *et al.*, 2010). The reliability of IK based indicators is being questioned because of the effects of climate change on flora and fauna seasonal

cycles which form bases for most traditional weather forecasts (Chambers *et al.*, 2017; Fitchett and Ebhuoma, 2018).

Adapting to climate change requires accurate predictions of future climate scenarios to regulate responses for the agricultural sector and adaptation priorities (Dawson *et al.*, 2011; Cairns *et al.*, 2013; Descheemaeker *et al.*, 2016; Altieri and Nicholls, 2017). Phenology is argued to be one of the most accurate and climate-sensitive biological responses to depict the extent of climate stressors, variability, and change because both flora and fauna species are tuned to seasonality and climate of their habitat (Cleland *et al.*, 2007; Fitchett and Ebhuoma, 2018; Rezaei *et al.*, 2017). It is therefore arguably a reliable indicator to be used in IKS and believed to be more accurate than the meteorological seasonal forecasts in some rural areas (Fitchett and Ebhuoma, 2018). For example, in the Delta state of Nigeria, farmers still believe phenological IK to be more reliable in forecasting the climate for the following growing season, particularly because of the inaccurate forecasts that were provided by meteorology services in the past that led to significant agricultural losses (Ebhuoma, 2017). Subsistence farmers have used the knowledge accumulated through observing the natural environment to inform pivotal decision making in the agriculture practices for generations (Altieri and Nicholls, 2017). However, there have been observed species and location-specific phenological mismatches and range shifts attributed to anthropogenic climate change (Chambers *et al.*, 2017). These shifts on the onset and duration of phenological events may hamper the effectiveness of IKS in tracking climate variability and change (Cleland *et al.*, 2007; Chambers *et al.*, 2017). Therefore, in addition to the direct impacts of climate change on rural livelihoods, due to high exposure to stressors, climate change also threaten the means to adapt to the effects through possibly reducing reliability and success of IK methods and strategies (Chambers *et al.*, 2017). Changes in the timing of phenological events will pose challenges to

subsistence farmers who rely on IKS to inform pivotal decisions in their farming practices (Chand *et al.*, 2014, Chambers *et al.*, 2017). An increase in average air temperatures results in changes on the onset and duration of phenophases causing early springtime events and range shifts (Fitchett and Ebhuoma, 2018).

KwaZulu-Natal and Eastern Cape have distinct cultural diversity, which is characteristic of South Africa (Tayob, 1998; Kent, 1996; Meier and Hartell, 2009; Apraku *et al.*, 2018). IKS is culturally rooted and phenological cues that are used for seasonal forecasting in different regions vary and are interpreted differently by different cultural groups (Chambers *et al.*, 2017; Ajani *et al.*, 2013). Therefore, cultural differences between communities may translate to varying interpretations of the phenological indicators regarded in traditional seasonal forecasting. For instance, for farmers in Tlaxcala, Mexico, ants' fleeing their underground habitat is the indicator for dry conditions (Ebhuoma and Simatele, 2019) However, in Chagaka village in Southern Malawi and, Nagpur and Chagaka villages in India, ants migrating from their colony is considered an indicator for oncoming rainfall (Pareek and Trivedi, 2011; Nkomwa *et al.*, 2014; Bagchi, 2015; Ebhuoma and Simatele, 2019). Furthermore, the ways in which communities perceive and interpret phenological and astronomical cues are influenced by the relatively natural state of their environment (Gadzirayi *et al.*, 2006; Ebhuoma and Simatele, 2019). This study will investigate various indigenous knowledge systems and oral histories that are used by the subsistence farmers of Umzimkulu and Lusikisiki to inform pivotal decision making in farming. The research will further explore the differences between the used phenological cues in the two communities.

1.1 Rationale

Significant changes in mean seasonality and rainfall patterns have already been noted in KwaZulu-Natal and the Eastern Cape Province (Savo *et al.*, 2016; Roffe *et al.*, 2020a). This will illuminate a plethora of social, economic, and environmental challenges in the provinces because rural areas within these provinces largely depend on environmental viability for livelihoods (Meyiwa *et al.*, 2013). However, these areas have potential to combat or reduce these effects through tapping into under-utilised knowledge system and include it in development and adaptation policy plans (Goduka 2012; Garutsa and Nekhwevha, 2018; Rukema and Umubyeyi, 2019). Therefore, more research is still required in different communities within the provinces to inform environmental and community development legislation and ensure the efficiency of the strategies (Santhia *et al.*, 2018). Furthermore, this will increase the involvement of communities in the development of strategies that are applicable and relevant to their agricultural needs while increasing trust between government avenues and subsistence farmers, thus ensuring joint efforts in climate change adaptation, reducing vulnerability and ensuring food availability (Apraku *et al.*, 2018). This will also ensure that research is tied to contextual priorities (Parsons *et al.*, 2016). Understanding IK conforms to South Africa's wide reconstruction and development of strategies to ensure sustainability and growth (Rukema and Umubyeyi, 2019). To effectively integrate IK into broad provincial and national climate change adaptation, it is paramount to understand what community members have been doing to facilitate productivity, and in-depth studies in these rural areas offer a useful view to study and understand community members and their culture which is the foundation for IK (Garutsa and Nekhwevha, 2018). This study will contribute to understanding the importance of IKS in agricultural management and highlight some of the challenges that are posed by climate change and development on the conservation of this

knowledge system. It will also contribute to the field of phenological input in IKS and climate change adaptation in the context of South Africa.

1.2 Study Aims and Objectives

The main aim of this study is to investigate various phenological cues intrinsic in Indigenous Knowledge Systems for agricultural management in Lusikisiki in the Eastern Cape and Umzimkulu in KwaZulu-Natal, South Africa. It is also to investigate the effectiveness of IKS in facilitating adaptation to climate change.

The aim will be achieved through the following objectives:

To determine the indicators used for timing tilling, sowing, and harvesting dates in Umzimkulu, KwaZulu-Natal and Lusikiki, in the Eastern Cape Province.

- a. Relating to observed weather.
- b. Relating to observed phenology.

To explore the perceived reliability of the indicators for sowing dates in each town.

- a. Are these indicators reliable?
- b. Do they prefer these IK methods to the national meteorology forecast?

1.3 Structure of the dissertation

This dissertation is made up of seven chapters:

Chapter 2 present arguments regarding the use of phenology in IKS and effects of climate change on these factors for agricultural management and climate change adaptation. The sections detail the effects of climate stressors on poor rural populations and the vulnerability of subsistence farming activities (Section 2.1-2.2). The effects of climate change on phenophases and the

influence these changes may have on ecological functions and agricultural productivity (Section 2.3). Finally, the chapter presents the discussions regarding IKS, its importance to rural communities and the suggested integration of knowledge systems (Section 2.4-2.6).

Chapter 3 presents the geographic description of Umzimkulu and Lusikisiki within KwaZulu-Natal and the Eastern Cape Provinces. This chapter describes physical characteristics; climate and the topography in these areas, it also outlines the agricultural activities and the relevance of IKS. This chapter also highlights the socio-economic conditions of these areas, which has a significant influence on practicing subsistence farming in rural communities.

Chapter 4 is the methodology chapter. It describes the research design adopted to achieve the objectives of this study. This chapter firstly addresses researcher's positionality (Section 4.1). The recruitment of participant, data collection and analysis processes are also explained (Section 4.2). This chapter specifically highlights the data collection and analysis methods and the justification for using the chosen methodologies (Section 4.3-4.5). Lastly, ethical considerations are presented (Section 4.6).

Chapter 5 illustrates the results of the study on climate perceptions, IK indicators for tilling, sowing and harvest dates. Firstly, the description of respondents that contributed to the results is provided and the description of terms that are used by participants is detailed. The chapter then presents the results that demonstrate the perceived reliability of IK strategies in weather forecasting in Umzimkulu and Lusikisiki. It also highlights discuss the preferred weather forecasting methods in the study areas.

Chapter 6 is the discussion chapter, this chapter is dedicated to interpreting the results within the context of literature in phenology, IK and farmers' responses to climate change to address the research objectives.

Chapter 7 is the conclusion. This chapter has reflections on the extent to which the objectives of the research were completed. It also considers possible future research avenues for the topic areas.

2. Literature Review

This study is situated within and aims to contribute to the recent discussion in academia about the value of community-based knowledge for climate change adaptation. This chapter outlines the theoretical background of the study. It introduces key arguments and theories in the literature concerning the use phenology in tracking seasonality and climate change in rural areas. Broad climate change impacts on subsistence farming and rural livelihoods are discussed (Section 2.1-2.2). It then views the interconnection between IKS and phenology in rural areas (Section 2.3). Then discusses changes in phenology and perceived threats on IKS reliability (Section 2.3-2.4). The chapter concludes by presenting important work on traditional knowledge production, conservation and integration of knowledge systems (Section 2.5-2.6).

2.1 Climate Stressors

Climate change presents complex challenges for current and future livelihoods in both developed and developing countries, through increased frequency and magnitude of climate extremes (McCarty, 2001; Parry *et al.*, 2007; Blanc, 2012; Sun *et al.*, 2016). Anthropogenic climate change causes and intensifies the magnitude and frequency several global challenges associated with hydrological and meteorological disasters, including droughts, floods, hurricanes and tropical cyclones (Bryan *et al.*, 2009; Birkmann and Teichman, 2010; Jones *et al.*, 2012; Lynn, 2018). Changes are mostly nonlinear and present new, and predominantly irreversible thresholds that sometimes surpass the estimation of general circulation models (GCM) (Rosenzweig *et al.*, 2008; Jones *et al.*, 2012; Lynn, 2018). Bryan *et al.* (2009) highlight that GCMs projected that climate change will lead to increased rainfall intensity and frequency in East Africa. However, recent research indicates that local circulation effects will lead to substantially decreased rainfall (Howden, 2007; Blanc, 2012; Serdeczny *et al.*, 2017; Radeny *et al.*, 2019). The inconsistencies

are partly attributed to the coarse spatial resolution of the models, which requires downscaling from broad global data probabilities to infer various localities (Bauner, 2013; Wang *et al.*, 2016; Akinsanola *et al.*, 2018). Moreover, the rapid rate of climate change coupled with complex input variables affect the predictive value of the GCMs (Aparna and Trivedi, 2011; Savo *et al.*, 2016). The resolution of new GCMs is increasing because of new technology inventions (Akinsola *et al.*, 2018). However, there is still a myriad of local and regional environmental uncertainties regarding the impacts of climate change that influence reliability and agency of the information provided (Savo *et al.*, 2016; Akinsanola *et al.*, 2018). These complexities hinder adaptation efforts of nationalities through limiting the availability of timely and reliable weather forecast information (Jiri *et al.*, 2016; Savo *et al.*, 2018). The agriculture sector in developing countries is argued to be the most vulnerable sector to the impacts of climate change (Edgar *et al.*, 2003; Kotir, 2010; Seaman *et al.*, 2014; Ebhuoma, 2017). This is because subsistence farmers often lack adequate resources required to limit excessive damage or adapt to the changes caused by climate stressors (Shisanya and Mafongoya, 2016; Ebhuoma, 2017). Climate change impacts influence the agricultural sector in several explicit and implicit ways that hinder productivity (Kitor, 2010; Gonzalez-Sanchez *et al.*, 2019). High frequency of climate extremes can limit crop growth and increase livestock mortality through water or moisture shortages, flooding, heat stress, and limited agricultural management strategies as a result of limited resources available to farmers (Shisanya and Mafongoya, 2016; Gonzalez-Sanchez *et al.*, 2019). These components can directly translate to food shortages and reduced food accessibility in most rural areas in developing countries, including South Africa (Calzadilla *et al.*, 2014; Abdu-Razak and Kruse, 2017; White *et al.*, 2018). Climate variables define potential and limits for every aspect of agriculture (Inouye, 2008; Fitchett *et al.*, 2015; White *et al.*, 2018). This is because environmental changes that arise because of

climate change have a ubiquitous influence on ecological efficiency and structure of the biosphere (Peñuelas *et al.*, 2004; Cleland *et al.*, 2012; Liu *et al.*, 2018). Anthropogenic climate change affects ecosystems through altered mean climatic conditions coupled with significant complex changes in marine and atmospheric greenhouse concentrations (McCarty, 2001; Thomas *et al.*, 2007; Savo *et al.*, 2016). It is changing the biophysical environment within which plants grow and the type of responses to essential factors such as temperature, precipitation, soil moisture and CO₂ fertilisation (Laux *et al.*, 2010). These changes have led to altered crop vegetative and reproductive growth periods, which directly affects plant productivity (Peñuelas *et al.*, 2004; Liu *et al.*, 2018). Furthermore, changes in climate variability, particularly through altered rainfall patterns and mean seasonality changes also directly affect temporal limits for plant productivity (Souza *et al.*, 2016; Ma *et al.*, 2017). This has far-reaching consequences especially in food availability and accessibility (Baiphethi and Jacobs, 2009; Blanc, 2012; White *et al.*, 2018). In addition to reducing moisture availability, potentially destroying vulnerable flora, droughts can significantly alter carbon balances by changing crop yields, altering agricultural schedules and can also lead to diseases and insect infestation (Xu *et al.*, 2015; Sun *et al.*, 2016).

While climatic factors are projected to have severe impacts on agriculture, some research studies have pointed out that agricultural management strategies, such as sowing dates, cultivar selection and fertiliser choice can have a significant influence on plant phenology and productivity for both commercial and subsistence farmers (Blanc, 2012; Rezaei *et al.*, 2016). Therefore, agricultural management decisions can offer adaptive strategies to address the effects of climate change on agricultural productivity (Rezaei *et al.*, 2017). For example, He *et al.* (2015) found that the use of late-maturing cultivars reduced the negative impacts of increased mean temperatures on wheat yield in China. Additionally, Nagaran *et al.* (2010) argue that shorter-duration cultivars are an

effective adaptation measure because they promote early anthesis thus limiting crop exposure to heat stress during this stage. Cultivars have been successfully used in the production of cereal crops, including maize and oats in different countries (Rezaei *et al.*, 2018). This demonstrates the potential for successful food production in the future by employing extrinsic and intrinsic effective agricultural management strategies (Chmielewski, 2003; Mwongera *et al.*, 2017). It also challenges the view that observed changes in crop phenology are exclusively caused by climate change. Therefore, comprehensive research considering all components of agricultural management needs to be conducted to understand the extent to which management strategies can reduce vulnerability (Jones *et al.*, 2012; Rezaei *et al.*, 2017; Renner and Zonher, 2018). There is a paucity of studies about the use of diverse cultivars for agricultural adaptation in an African context. However, several other studies detail different forms of agricultural management as a viable tool to adapt, mostly involving the use of IKS (Gadzirayi, 2006; Mafongoya and Ajani, 2009; Orlove *et al.*, 2010; Kalanda-Joshua *et al.*, 2011; Kijazi *et al.*, 2013).

Overwhelming dependence on the natural environment has equipped the farmers in the region with local and context-specific adaptation alternatives (Orlove *et al.*, 2010; Jiri *et al.*, 2016). IKS are argued to promote holistic ecosystem conservation and economically sustainable climate change adaptation strategies, particularly to areas that are more vulnerable to climate change stressors (Orlove *et al.*, 2010; Jones *et al.*, 2012; Ebhuoma, 2017; Chambers *et al.*, 2019). For example, Ebhuoma, (2017) found that rural farmers in Nigeria use phenological indicators to adjust sowing and harvesting dates to ensure maximum yield. Similarly, in Malawi weather conditions at the beginning of spring and phenological activity inform agricultural decision making for the growing season (Nkomwa *et al.*, 2014).

Various approaches have been implemented globally to mitigate and adapt to the effects of the changing natural environment (Parry *et al.*, 2007; Cr  tat *et al.*, 2012). They are grouped into three main categories: engineering, scientific, and traditional approaches, or IKS (Fabiya and Oloukui, 2013; Boucher *et al.*, 2014). However, there is a consensus that comprehensive, efficient and ecosystem-based climate change adaptation measures must be developed and implemented to ensure environmental management and food production success (Jones *et al.*, 2012; Altieri and Nicholls, 2017; Chambers *et al.*, 2017). Traditional ecological knowledge (TEK) offers locally developed, affordable strategies that are mostly based on plant and animal species behaviour to address challenges of specific communities (Jones *et al.*, 2012; Adger *et al.*, 2013; Armatas *et al.*, 2016). Drawing from this knowledge system to develop adaptive strategies is a suggested solution for climate change adaptation (Mafongoya and Ajayi, 2009; Zuma *et al.*, 2013; Radeny *et al.*, 2019). Traditional knowledge relies on predictable environmental sequences such as the response of plants and animals to climate variables and intra-seasonal variability (Zuma-Netshiukhwi *et al.*, 2013; Armatas *et al.*, 2016; Fitchett and Ebhuoma, 2018).

There is no evidence suggesting that agriculture management strategies affect phenophases and adaptive capacity of wild flora and fauna (Clealand *et al.*, 2012; Scraton and Amarasekare, 2017; Liu *et al.*, 2018). Therefore, disruption of wild flora and fauna seasonal cycles will disturb ecological functions and relationships that inform IKS based cues intrinsic in weather forecasting (Fitchett and Ebhuoma, 2018). This may lead to the misguidance of subsistence farmers who depend on IKS informed weather forecasts, further limiting adaptive capacity and increasing their vulnerability to climate change stressors (Altieri and Nicholls, 2013; Fitchett and Ebhuoma, 2018; Chambers *et al.*, 2019). In view of this, several studies in climate change adaptation echo the need for integrated farm-level adaptation strategies that consider the value of both IK and western

systems to ensure that communities can take advantage of all available solutions and reduce their vulnerability to anthropogenic climate change (Nyong *et al.*, 2007; Jones *et al.*, 2012; Ajani *et al.*, 2013; Chambers *et al.*, 2019).

Vulnerability to climate variability and change is determined by exposure to climate stressors, resilience to the impacts and socio-economic capabilities of communities to adapt to the changes that might arise (Thorlakson and Neufeldt, 2012; Serdeczny *et al.*, 2017). Accordingly, Roudier *et al.* (2011) state that regions that are highly sensitive and vulnerable to climate change are mostly developing countries with poor people, because of their geographical location which mostly exposes them to frequent and high magnitude climatic stressors, and a myriad of factors contributing to their low adaptive capacity. The impacts of climate change lead to significant ecological losses and exacerbate the socio-economic conditions of these regions because, for the most part, people in these locations depend on environmental viability for livelihoods and food production (Blanc, 2012; Williams *et al.*, 2020). Developing nations are reportedly disproportionately affected by climate change-related stressors given their perceived insignificant contribution to anthropogenic greenhouse emissions (Aparna and Trivedi, 2011; Bauer, 2013; Fernández Llamazares Onrubia, 2015). This vulnerability is attributed to extreme poverty, corruption and misguided ideologies that associate climate change with religious beliefs thus limiting the potential for the development of pragmatic adaptation strategies in these areas (Gill, 1991; White *et al.*, 2018; Ebhuoma and Simatele, 2019). Fredriksson and Neumayer (2016) state that a country's corruption level influences environmental policy development and implementation, thus affects climate change adaptation efforts.

It is noteworthy that the observed impacts of corruption on climate change adaptation are mostly a result of decisions that were taken decades ago, therefore are highly influenced by the history

of the developing nations (Fredriksson and Neumater, 2016; Araos *et al.*, 2017). Marginalisation and historical exclusion have a role in high vulnerability and limited adaptive capacity (Fredriksson and Neumater, 2016). However, the exceedingly hampered food production and development in developing nations are mostly attributed to the dependence on primary resource-based sectors for economic growth and rain-fed agriculture for food production (Ziervogel and Opere, 2010; White *et al.*, 2018). These components demonstrate interacting factors that contribute to Africa's vulnerability to environmental change (Davis, 2011; Seaman *et al.*, 2014). Furthermore, the economic development in the region is mostly comprised of climate-sensitive sectors such as agriculture and mining, therefore climate change has a profound impact on national economies (Laux *et al.*, 2010; Williams *et al.*, 2020). One of the most prominent effects of global climate change is prolonged dry spells, droughts, and increased temperatures, which are exacerbated by pronounced spatial and temporal variations in rainfall distribution (Crétat *et al.*, 2012; Roffe, 2019).

Rainfall patterns are the most important climatic variable in food production and livelihoods and are greatly affected by climate change (Peñuelas *et al.*, 2004; Jones *et al.*, 2012; Roffe *et al.*, 2020b). Relatively modest changes in rainfall distribution and frequency have the potential to adversely hamper agricultural productivity and consequently cause food insecurity in southern Africa (Baipethi and Jacobs; 2009; Blanc, 2012; Tibesigwa *et al.*, 2017). This is because agriculture is mainly rain-fed in this region and there are limited resources to address the impacts of extreme weather events, especially to subsistence farmers who depend on environmental viability for household food availability and sovereignty (Gadziray *et al.*, 2006; Nelson *et al.*, 2014; Serdeczny *et al.*, 2017). Furthermore, Calzadilla *et al.* (2014) point out that there are indications that intense climate change may lead to ~8% agricultural yield reduction in Africa by

2050 (Mapfumo *et al.*, 2016; Sultan *et al.*, 2019). This will accentuate the negative socio-economic impacts that anthropogenic climate change has in Sub-Saharan Africa (Serdeczny *et al.*, 2017). Agricultural losses will be mainly be caused by increases in mean temperature and significant changes in rainfall patterns, which will result to altered regional water endowments between countries and decreased soil moisture (Parry *et al.*, 2007; Davis *et al.*, 2011; Calzadilla *et al.*, 2013; Mapfumo *et al.*, 2016). Temperature increases have complex impacts on biodiversity and ecology, including altering organisms' morphology, influence species abundance and changing the timing of life-history events (Cleland *et al.*, 2012; Fitchett *et al.*, 2015; Doi *et al.*, 2017; CaraDonna *et al.*, 2018). All these changes can have a negative influence on species conservation and food production (Dio *et al.*, 2017; Rezaei *et al.*, 2018). In commercial agriculture, phenophases influence economic elements, such as harvesting and marketing thus control the timing of income influx (Ncube *et al.*, 2010; Rezaei *et al.*, 2018). Delay in phenophases or co-occurrence with extreme climate events affect the maturing time and productivity of crops and can result to significant economic losses (Calzadilla *et al.*, 2013; Chen *et al.*, 2016). The effects of climate change on subsistence farming may lead to short-term impacts such as food inflation and shortage of grain, to soil erosion and infertility which are more lasting (Bauer, 2013; Dasgupta *et al.*, 2014; Serdeczny *et al.*, 2017). Agricultural activities are mostly geographically constrained and therefore requires effective adaptation measures to assure productivity over a long period (Ziervogel *et al.*, 2014). Given this, Jones *et al.* (2012) points out that the development of integrated affordable farm level adaptation measures will ensure productivity and reduce vulnerability.

2.1.1 Climate Change and the Rural Poor

Approximately half (47.4%) of global populations reside in rural areas and 90% of those people are in developing countries (Dasgupta *et al.*, 2014; Magni, 2017; Kassam *et al.*, 2017). There is no universally recognised definition of rural that adequately represents the theoretical construct (Hawley *et al.*, 2016). This study adopts Dasgupta *et al.*'s (2014) definition of rural areas. Dasgupta *et al.* (2014) describe rural areas as areas with a high prevalence of poverty, marginalized, receive poor services from governments, and predominantly neglected by policymakers. Rural communities are also reported to house the majority of subsistence farmers, which are dependent on the natural environment for livelihoods, food security, and sovereignty (Ngcoya and Kumarakulasingam, 2017; Kassam *et al.*, 2017). In most rural areas, agricultural activities are the backbone of food security, and some subsistence farmers within rural areas contribute to the Gross Domestic Product (GDP) in various developing countries (Ziervogel *et al.*, 2014). Rural areas are essential for food production and are reservoirs of renewable and non-renewable natural resources (Mashamaite, 2014; Kassam *et al.*, 2017). Reports state that there is a decline in extreme poverty rates globally but this is not evident in Sub-Saharan Africa because poverty rates are rising (Mafongoya and Ajani, 2009; Dasgupta *et al.*, 2014; Radeny *et al.*, 2019).

The rural poor populations are one of the most vulnerable group to the effects of environmental and development change (Blanc, 2012; Mashamaite, 2014; Serdeczny *et al.*, 2016; Ebhuoma, 2017). This is, in part, attributed to poor service delivery, geographic location and their dependence on natural resources for livelihood (Eakin, 1999; Nyong *et al.*, 2007; Davis, 2011; Vermeulen *et al.*, 2011). However, several studies (Gadzirayi, 2006; Nyong *et al.*, 2007; Orlove *et al.*, 2010; Kijazi *et al.*, 2013; Chand *et al.*, 2014; Ebhuoma, 2017; Ebhuoma and Simatele, 2017) have demonstrated the rural poor communities are not passive actors. These communities

have knowledge systems that are important in ensuring that they are prepared and can respond to ecological and challenges over time. Subsistence farmers in rural areas employ pragmatic mitigation and adaptation measures to reduce vulnerability to climate change (Gadzirayi *et al.*, 2006; Ajani *et al.*, 2013; Ebhuoma, 2017; Chambers *et al.*, 2017, 2019; Benyei *et al.*, 2020). Mitigation measures include actions that are aimed at preventing, controlling and reducing environmental impacts that exacerbate climate change while adaptation measures include reducing the vulnerability to the effects of climate change (Davis, 2011; Hao *et al.*, 2014). IK is used in many rural areas by subsistence farmers to mitigate and adapt to the environmental changes that arise as a result of climate change, to ensure continued food security (Acharya, 2011; Fabiyi, 2013; Ebhuoma and Simatele, 2017). In many African countries, IK is used to forecast and prepare for precipitation or drought because agriculture is dominantly rain-fed (Nkomwa *et al.*, 2013; Fitchett and Ebhuoma, 2018). Subsistence farmers in rural areas use phenological and meteorological indicators to forecast daily and seasonal weather conditions (Chambers *et al.*, 2017). Therefore, the projected shifts in phenology as a result of climate change will have a sequence of detrimental impacts on the socio-economic security of these areas (Chambers *et al.*, 2013d; Calzadilla *et al.*, 2014; Sibhatu and Qaim, 2017).

2.2 The Contribution of Subsistence Farming to Food Production

Globally, 10% of terrestrial land is used for subsistence farming and is responsible for food production for more than half of the world population (Ambagna *et al.*, 2012). Food and Agriculture Organisation (FAO) argues that subsistence agriculture is the best option to ensure food security in developing nations, mostly due to low input requirements of this type of farming (Ambagna *et al.*, 2012). It is one of the three main food sources; markets, subsistence production

and transfers from public programmes or other households (Baiphethi and Jacobs, 2009). Subsistence agriculture is defined as the type of farming where farmers cultivate food and tend to livestock primarily for themselves and their families, typically, in developing countries, it is without financial gain (Gill, 1991; Baiphethi and Jacobs, 2009; Seoraj-Pillai, 2011). Therefore, subsistence farming productivity directly and significantly affects household nutrition (Dweba and Mearns, 2011; Altieri and Nicholls, 2013). Favourable weather conditions can result in a surplus that farmers can sell and buy types of food they cannot grow (vegetable oil and/or salt), thus improving welfare and reducing the effects of inflation (Blanc, 2012). However, some subsistence farmers are forced to sell crops to meet their financial commitments despite not having a surplus, which limits farming contribution to household dietary needs (Baiphethi and Jacobs, 2009; Blanc, 2012). By contrast, ‘smallholder’ is used to characterise farmers from rural areas, particularly in developing countries that, similarly to subsistence farming mainly rely on family labour for farming activities but the profits from the farming products are the main source of the family’s income (Baiphethi and Jacobs, 2009; Ngcoya and Kumarakulasingam, 2015). The distinctions between the two types of farming are growing obscure, there is peculiar lack of updated scholarly definitions for subsistence farming given the two types of farming’s mounting overlapping properties due to socio-economic development across the globe (Thorlakson and Neufeldt, 2012; Vermeulen *et al.*, 2012).

Rural communities across developing countries still produce most of their food (Baiphethi and Jacobs, 2009; Magni, 2017). Peng and Berry (2019) state that the ability of subsistence farmers to produce their food does not account for food security. Food security is achieved when all people have economic and physical access to sufficient nutritious food for a healthy lifestyle (Aliber and Hart, 2009; Vermeulen *et al.*, 2012). Nonetheless, subsistence farmers have been remarkably

successful in ensuring food production for their growing population and changing the environment for generations (Gill, 1991; Ebhuoma and Simatele, 2019; Fitchett and Ebhuoma, 2018). Subsistence farming remains the dominant food source in rural areas although there is a substantial increase in market dependence; 60-80% expenditures (Baiphethi and Jacobs, 2009; Peng and Berry, 2019). However, it must be taken into account that the recorded increases are a gross approximation of the rural food patterns (Ngcoya and Kumarakulasingam, 2015; Sibhatu and Qaim, 2017). Subsistence farming strongly encompasses three of the four FAO food security dimensions; food accessibility, availability and the stability of the two components (Napoli *et al.*, 2011; Peng and Berry, 2018). Therefore, it is crucial to ensure that food production is maintained or improved through reducing the vulnerabilities of subsistence farming to extreme climate conditions (Morton, 2007).

2.2.2 Subsistence Farming in South Africa

In South Africa, 2.9 million (20%) households are involved in agriculture, mainly subsistence farming (STATSSA, 2017). Some of the households practice smallholder farming (Aliber and Hart, 2009; Provincial Budget Review, 2017). Subsistence farming is the main source of food for most rural families (Altieri and Nicholls, 2013; Ebhuoma, 2017). According to STATSSA (2017), households that are involved in agriculture are mostly found in KwaZulu-Natal, Eastern Cape and Limpopo. STATSSA (2017) states that these households are in rural, marginalised communities, often have low or no income and mostly have limited access to basic services such as electricity and clean water. This suggests that these households are immensely dependent on subsistence farming. Chapman and Tripp (2004) argue that the extent to which people depend on subsistence farming is determined by the quality of outside income. Therefore, although there are arguments

that there has been an increasing dependence on commercial market food supplies (Gbetibouo *et al.*, 2010; Ngcoya and Kumarakulasingam, 2015), rural settlements are still largely dependent on their backyard gardens for food production because of accessibility and the backdrop of food price inflation and the exponential increase of cash needs (Baiphethi and Jacobs, 2009; Seoraj-Pillai, 2011; Fitchett and Ebhuoma, 2018). Apart from being cost-effective, depending on subsistence farming for food production ensures food accessibility and sovereignty, which is very important especially to the older population in rural provinces and is a more stable food source (Gbetibouo *et al.*, 2010; Ngcoya and Kumarakulasingam, 2015). It is crucial to understand the ways in which rural communities manage their agricultural activities because they demonstrate their capability to adapt to climate change and that information is significant in adaptation policy developments (Bryan *et al.*, 2009; Kassam *et al.*, 2017).

KwaZulu-Natal and Eastern Cape are two of the rural provinces in South Africa (STATSSA, 2013), these areas are the high summer rainfall areas, receiving approximately 550-950mm of rainfall annually (Ashton, 2008). It is projected that as a result of climate change this region will experience an increase in rainfall intensity (Meissner and Funke, 2014; Roffe *et al.*, 2020b). The projected changes in rainfall will affect plant life cycles and potentially IK phenological cues used in the areas (Olsen and Olsen, 1989; Peñuelas *et al.*, 2004; Dawson *et al.*, 2011; Zuma-Netshiukhwi *et al.*, 2013; Donnelly and Yu, 2017). This will have decisive impacts on farming activities of the community members that rely on IKS for important decision making (Ebhuoma, 2017; Chambers *et al.*, 2017,2019).

2.3 Species Seasonal Cycles

Climate conditions are an important abiotic influence on species, they govern intrinsic biochemical processes that are essential in fitness and productivity (Parmesan and Yohe, 2003; Mittler, 2006; Fitchett *et al.*, 2015). Therefore, changes in air temperatures have considerable effects on the operating environment, they have resulted in changes in the distribution, intensity, and frequency of climate extremes (Rosenzweig *et al.*, 2008; Davis, 2011; Hughes *et al.*, 2019). As a result plant and animal seasonal cycles are considered a fundamental component in determining climate change footprint because changes in climate result in significant alterations in species behaviour (Arakawa, 1956; Frank *et al.*, 2001; Dreyer *et al.*, 2006; Körner and Basler, 2010; Cleland *et al.*, 2012). Gibbs and Beich (2001) found that a 10-13 day advance in frog calling phenology in Ithaca coincide with a 1-2.3°C increase in temperature during critical months. Similarly, Dreyer *et al.* (2006) found that the flowering of South African Oxalis indicates the drop in mean daily temperature and rainfall onset in the Cape region. Species interaction and responses to the natural environment are understood through a growing body of literature in biology, dedicated to assimilating flora and fauna recurring events such as the timing of leaf budding, flowering, and migration; phenology (Chmielewski and Rötzer, 2001; Cleland *et al.*, 2007; Dawson *et al.*, 2011; Rafferty *et al.*, 2014; Fitchett *et al.*, 2015). Phenology is significant in ecology, from individuals to an entire ecosystem, it dictates fitness, distribution, and survival of species (Parmesan and Yohe, 2003; Doi *et al.*, 2017).

Northern Hemisphere countries have records spanning centuries that demonstrate the relationship between various phenophases and their abiotic settings, such as the first croak of the generally known frog, unfolding of oak leaves or the arrival of swallows (Arakawa, 1956; Lieth, 1974; Chmielewski and Rötzer, 2001; Chambers *et al.*, 2013d). This is part of the reason why phenology

is considered the oldest documented biological record and a tool to determine impacts of climate change on ecosystems (Collinson and Sparks, 2008; Donnelly and Yu, 2017). Research demonstrates that flowering days and animal migration dates are synced to seasonality (Arakawa, 1956; Cleland *et al.*, 2007; Chambers *et al.*, 2013d; Fitchett *et al.*, 2015). Factors that limit or maximise species fitness, abundance and distribution are correlated to the onset and duration of their phenophases, which are determined by climate conditions (Burrows *et al.*, 2014; CaraDonna *et al.*, 2018). For instance, the temporal variation between vegetative and reproductive phases that take place in concert with flowering is important to optimal seed set thus fruit yield (Tooke *et al.*, 2010; Rezaei *et al.*, 2018). Olsen and Olsen (1989) found that rainfall frequency and intensity, directly and indirectly, influence the breeding of Falcons (*falco peregrinus*). High rainfall frequency before the laying season may reduce hunting efficiency and result in low energy stores and affect the timing and success of breeding (Olsen and Olsen, 1989; Chambers *et al.*, 2013d). High rainfall intensity on the other hand shortens laying days through flooding nests (Olsen and Olsen, 1989), either way, climate variables influence the success of the breeding season and subsequently species abundance. There is a gap in the literature for African studies that record phenology and its changes dating more than five decades, but there has a notable increase in published peer-reviewed research on the topic (i.e. Dreyer *et al.*, 2006; Hart *et al.*, 2013; Bussière *et al.*, 2015; Pretorius *et al.*, 2020). This suggests that phenological responses to climate and environmental change still need to be more investigated in the context on South Africa, particularly because climate variability and change impacts vary broadly between different regions within the country (Landman *et al.*, 2017; Roffe *et al.*, 2020a). This suggests that species responses to changing climatic factors may also mirror the complex effects of climate change.

As a result of changes in climate patterns, species cues that are critical for tracking the timing of life-history events have become maladaptive causing significant changes in the onset and duration of phenological events (Chuine, 2010; Cleland *et al.*, 2012; Chambers *et al.*, 2013; Rafferty *et al.*, 2015). The onset and duration of phenophases also affect carbon dioxide uptake and albedo effects thus affecting temperatures (Yang *et al.*, 2010; Moyo, 2018). For example, water scarcity induces low vegetation productivity and reduction leading to significantly lowers terrestrial net primary productivity which results in carbon imbalance in the atmosphere (Sun *et al.*, 2016). The timing of reproductive seasonal events is considered the most reliable adaptive trait in species because it is sensitive to environmental change, immediate and the phenological event's (e.g leaf budding and flowering) responses are easily observed (Peñuelas *et al.*, 2004; Fitchett and Ebhuoma, 2018). Accordingly, Lieth (1974) defines phenology as a skill to notice plant and animal life cycles in their temporal occurrence all year round. It is an important determining factor for population dynamics, species interactions, animal movement and evolution of life histories (Van der Putte, 2012; Alexander *et al.*, 2015). because for example, blooming time has a strong effect on the success of fruit maturation and progeny quality, pollination success and level of herbivory (Chuine, 2010; Tooke *et al.*, 2010; Archaya 2011; Bussière *et al.*, 2015). Alterations in the timing of phenological events can be beneficial to species abundance especially primary consumers (Moyo, 2018). For instance, early green-up of trees in the Savanna forests as a result of warm temperatures accelerating budburst, enable the trees to access to nutrients without the grass competitor. (Moyo, 2018). Meanwhile, Visser and Both (2005) state that delayed leaf budding is detrimental to the survival and distribution of herbivores in the arctic. Majority of studies in climate change and biology discourse are based on recording or providing evidence and causes of phenological shifts in insects, vertebrates and plants species (Hughes, 2000; Parmesan

and Yohe, 2003; Burrows *et al.*, 2011; Cleland *et al.*, 2012; Doi *et al.*, 2017). This is partly because shifts in phenology have several complex consequences on ecological functions and species communities, i.e. phenological mismatches and species distribution range shifts (Bullock *et al.*, 2017).

2.3.1 Sensitivity to the Changing Environment

Species reactivity to climate change is determined by the sensitivity of flora/fauna to certain climatic stressors, therefore it is notably spatial and species-specific (Cleland *et al.*, 2012; CaraDonna *et al.*, 2018). Cleland *et al.* (2012), defines species sensitivity as the phenological shift per temperature change, it displays the ability of species to track climate change. Brandley *et al.*, (1999) argue that the sensitivity of species to environmental changes determines species adaptive capacity. This is supported by Willis *et al.* (2008), who state that plant species that do not have advancement in flowering dates (or unresponsive to change) decreased in abundance compared to species that flower or bud burst early as a result of an increase in average air temperatures. Additionally, Møller *et al.* (2014) found that birds with migration advancements had more stable populations while birds with no advancement were declining in abundance. It is acknowledged that the timing of seasonal events is crucial for sustaining the coexistence of multiple species in diverse communities, and sustain mutualistic relationships (Yang *et al.*, 2010; Wann *et al.*, 2019). For instance, the plant-pollinator interactions depend on flowering of plants and timely migration or peak hatching of required insects (Nicole *et al.*, 2014). As a result, differences in sensitivity to climate changes threaten synchronies between ecological interactions (Thackeray *et al.*, 2016). This can have adverse impacts on plant or animal survival, fitness and distribution (Cleland *et al.*, 2007; Rafferty *et al.*, 2015). In addition to biotic phenological shifts, changes in local climate

have caused a rapid change in species geographic distribution range (Doi *et al.*, 2017; CaraDonna *et al.*, 2018). Species geographic range shifts are reported to be increasing and can lead to declines in partner densities further causing mismatches (Burrows *et al.*, 2014). This suggests that species that do not phenologically track climate or have notable phenological shifts are more vulnerable to the effects of change. Furthermore, this shows that sensitivity of phenology to changing physical environment is an important indicator for their fitness, future abundance, and distribution. Species that can track climate and respond through advancing phenological events are argued to be more adaptable than species that are unresponsive or have delayed phenology (Cleland *et al.*, 2007; Chuine, 2010; Wann *et al.*, 2019). However, Menzel (2006) points out that delayed phenology can be advantageous to species that become active towards the end of the season. Moreover, delayed phenophases can prevent weaker species from being easy prey or limit herbivore damage on plants (Whitecross, 2017). Phenology and climate change impacts on species phenological events and interaction is broad and complex. As a result, Hughes (2000) state that it is essential to understand spatial and species-specific variability in plant or animal responses to climate change (Burrows *et al.*, 2011; Cleland *et al.*, 2012). More in-depth research in various locations around the globe is needed to ensure that ecosystems vulnerability to climate change are well understood and pragmatic adaptation measures are established (Chambers *et al.*, 2013d). This is important to achieve effective species conservation, tracking mutually beneficial interactions between various species and comprehending the changes that will arise from future climate change (Cleland *et al.*, 2007; CaraDonna *et al.*, 2018). Moreover, understanding vulnerabilities will promote modelling of range shifts trajectory and infer species geographic limits thus indicating climatic niches for species, and predict possibly mismatches (Parmesan and Yohe, 2003; Burrows *et al.*, 2014; Alexander *et al.*, 2015).

2.3.2 Phenological Mismatches

All ecological functions have a significant temporal component that its processes (McCarty, 2001; Parmesan, 2006; Cleland *et al.*, 2007; Miller-Rushing *et al.*, 2010; CaraDonna *et al.*, 2018). When the timing of seasonal recurring events is altered at different rates to its interacting species it will lead to phenological mismatches (Inouye, 2008; Renner and Zohner, 2018). An unambiguous relationship between increases in average air temperature and changes in the biology of flora and fauna is well established in climate change adaptation, agricultural management and biology research (Arakawa, 1956; Dreyer *et al.*, 2006; Memmot *et al.*, 2007; Doi *et al.*, 2017). Species differ in evolutionary traits, dispersal abilities and physiological tolerance to altered climate variables, therefore their responses to climate change a considerably complex (Parmesan and Yohe, 2003; CaraDonna *et al.*, 2018). Therefore, advances and delays in phenology may disrupt temporal and spatial overlap between species with mutual and/or antagonistic relationships such as plant-pollinator, parasitoids-host interactions (Memmot *et al.*, 2007; Rafferty *et al.*, 2015; Linden, 2018). Although some species can accurately track phenological shifts of their host species, a majority of advances in phenology result in asynchrony between interacting species (Parmesan, 2006; Doi *et al.*, 2017).

Mutualists phenological mismatches cannot be easily attributed to rapid climate change because of their co-adapted phenological strategies (Parmesan, 2006; Renner and Zohner, 2018). In antagonistic relationships, mismatches are likely to have positive fitness consequences on the producer species and reduced fitness and abundance on the prey (Post and Forchhammer, 2008; Damien and Tougeron, 2019). For instance, Linden (2018) demonstrated that phenological synchrony is a strong determining factor for parasitoid population size and fitness while it is insignificant on host populations through nine years longitudinal study between *Cotesia*

melitaerum parasite and the *Melitaea cinxia* host. As a result, predator-prey and parasitoid-host mismatches can be easily attributed to climate change because of their micro evolutionary nature (Renner and Zohner, 2018; Damien and Tougeron, 2019). Species responses to climatic factors are determined by their phenotypic plasticity and evolutionary changes (Bradley *et al.*, 1999; Parmesan, 2006; Cleland *et al.*, 2012; Damien and Tougeron, 2019). Therefore, there are considerable differences in the rate and nature of species responses to abiotic changes (Beaubien and Hamann, 2011; Linden, 2018). These variations must be considered in the development of simulation models for climate change adaptation required by land managers to model flora-fauna responses to environmental change (Cleland *et al.*, 2012). This will increase the accuracy of models, assist farmers in selecting provenance with best adaptable climate conditions and facilitate better understating of population dynamics and species interactions (Bradley *et al.*, 1999; Cleland *et al.*, 2012; Scraton and Amarasekare, 2017). In addition to varying species sensitivities to climate factors, different phenophases also have varying degrees of sensitivity to the climatic factors (Beaubien and Hamann, 2011; Liu *et al.*, 2018). Bertin (2008) found that there was a 4-5 days/°C increase advance in plants flowering activity while later phenological stages' response to temperature increase is more diverse. These advances in phenological events also vary extensively between the Northern and Southern Hemisphere due to different climate drivers in the regions (Lantz and Turner, 2003; Chambers *et al.*, 2013d). For example, Chambers *et al.* (2003d) state that the in southern Hemisphere the phenology generally advanced by 4.2-6.0 days/decade, which is higher than then projected 2.86-0.35 days/decade advancement for terrestrial species in the northern hemisphere. Furthermore, drivers of phenological change are different between regions, because in most temperate regions phenology events are mainly governed by changes in temperature (Lantz and Turner, 2003). Meanwhile, in most tropical

regions phenology events depend on rainfall (Larsen *et al.*, 2011; Chambers *et al.*, 2013d). This underscore, the complexities in species climate tracking (Chuine, 2010; Cleland *et al.*, 2012; Scraton and Amarasekare, 2017).

Phenological characteristics display a notable degree of genetic difference within populations in plants and animals (Dreyer *et al.*, 2006; Chuine, 2010; Burrows *et al.*, 2014). Therefore, the observed patterns are progressive results of generations of natural selection acting on individual organisms (Dreyer *et al.*, 2006; Clements *et al.*, 2010). This indicates a unique ability to rapidly evolve given strong selection gradients, but most of the noted phenotypic changes in at least the last two decades are mainly environmentally induced (Bradshaw and Holzapfe, 2001; Clements *et al.*, 2010; Chuine, 2010; Hoffmann and Sgro, 2011). Therefore, close monitoring of seasonal events provides an opportunity to understand and track the effects of climate change on intrinsic biotic components which can offer means to quantify climate change footprint (Lefale, 2010; Alexander *et al.*, 2015). Climate change-induced genetic evolution of traits that are essential in adaptation such as insect dispersion is already observed (Thomas *et al.*, 2001; Chuine, 2010; Hoffmann and Sgro, 2011). Adaptation of phenophases to various conditions throughout ranges requires that species exhibit phenotypic plasticity to environmental cues such as photoperiod and temperature, coupled with genetic differentiation (Chuine, 2010; Ryan *et al.*, 2010; Van der Putten, 2012). Therefore, phenology is an essential adaptive trait for species, it defines species relationships within a habitat, and shapes the geographic distribution of flora and fauna, thus governing community structures and functions (Bradshaw *et al.*, 2007; Doi *et al.*, 2017). However, the mechanisms and environmental factors that determine range boundaries are obscure, which is mainly due to the stochastic nature of natural phenomenon (Miller-Rushing *et al.*, 2010; Denny *et al.*, 2014; Malsale *et al.*, 2018). Therefore, ecosystem resilience is argued to

perhaps be the most important component in sustainability of the natural environment given the complexities involved in climate change-related scenarios (Elmqvist *et al.*, 2003; Miller-Rushing *et al.*, 2010; Bullock *et al.*, 2017). The resilience to environmental change is determined by the magnitude of change an ecosystem can sustain and still remain a domain of attraction, it includes the rate at which an ecosystem can adapt to changes without great ecological losses (Elmqvist *et al.*, 2003; Bijlsma and Loeschke, 2011). Many ecosystems have been affected and adapted to climate change-induced alterations but some changes have led to micro-macro species extinctions while others resulted in increased fitness, depending on species sensitivity to environmental change (Yang *et al.*, 2010; Rafferty *et al.*, 2015). The resilience of ecosystems to climate change impacts is predominantly contingent on species biological diversity and sensitivity variations within the ecosystem (Elmqvist *et al.*, 2003; Corlett and Westcott, 2013; Bullock *et al.*, 2017).

2.3.3 Range Shifts

Species geographical ranges are mostly determined by several environmental components, including soil moisture, precipitation and species interactions within a habitat (Parmesan, 2006; Thomson *et al.*, 2010; Burrows *et al.*, 2014). Therefore, species are often distributed within a certain range that is predominantly conducive for its survival and fitness (Van der Putten, 2012; Searcy and Shaffer, 2016). As a result of climate change species are expanding and contracting ranges to more adaptable environments (Parmesan and Yohe, 2003; Chen *et al.*, 2011; Van der Putten, 2012; Denny *et al.*, 2014; Alexander *et al.*, 2015). Geographic range shifting is one of the most effective adaptation mechanisms for species and is an important mechanism of escaping the effects of climate change and maintaining or enhancing productivity, fitness and survival of flora and fauna (Burrows *et al.*, 2011, 2014; Renner and Zonher, 2018; CaraDonna *et al.*, 2018).

Species range shifts are argued to be more pronounced in high altitudes because climate change induces steeper temperature changes in the region (Post and Forchhammer, 2008; Regehr *et al.*, 2009; Burrows *et al.*, 2014). Therefore, more research has focused in studying and documenting the distribution dynamics in the polar areas (Root *et al.*, 2003; Regehr *et al.*, 2009; Burrows *et al.*, 2014). Range shifts are contingent on complex species biological traits and spatial specific environmental attributes that plants and animals are exposed to (Parmesan, 2006; Van der Putten, 2012; Alexander *et al.*, 2015). Therefore, there is no collective generic data exhibiting changes for whole species populations that can be extrapolated for broad conservation measures (Collert and Westcott, 2013). In view of this, Larsen *et al.* (2011) point out that more extensive research is required to understand the behaviours and responses of tropical species because these species are adapted to narrow meteorological conditions, therefore, they are more susceptible to extinction due to climate change. This is because tropical ecosystems have limited latitudinal range so species may not effectively adapt to new gradients (Eguiguren-Velepucha *et al.*, 2016). Furthermore, drivers for species distribution and phenology change vary between tropical and temperate regions due to different seasonality characteristics (Chambers *et al.*, 2013d). Therefore, simulations that are mainly informed by higher altitude species dynamics will not be useful in projecting future habitat availability, ecosystem protection and restoration for tropical species (Chambers *et al.*, 2013d; Platts *et al.*, 2019).

Organisms are also responsive to other climate variables, but thermal controls are the most important studied environmental variable that governs species productivity and growth (McCarty, 2001; Chuine, 2010; Chambers *et al.*, 2013d; Alexander *et al.*, 2019). Change in average temperature is the most prominent climatic variable to prompt range shifts (Kelly and Goulden, 2008; Burrows *et al.*, 2011; CaraDonna *et al.*, 2018). This is because increases in average air

temperatures, exceeding species thermal thresholds are detrimental to the fitness and survival of flora and fauna (Burrows *et al.*, 2014). Furthermore, there is greater confidence in the trajectory of future temperature changes, than there are for precipitation (Parry *et al.*, 2007; Chambers *et al.*, 2013d). Shifting distribution ranges is facilitated by the ability of organisms track environmental change and the rate of response to sustain their thermal niches (Kelly and Goulden, 2008; Alexander *et al.*, 2015). Therefore, it is contingent on species sensitivity to climatic stressors (Van der Putten, 2012).

Biogeographic range shifts directly influence the abundance of species in a habit, and alters community structure and ecosystem functioning, through the disappearance of habituated species and introduction of new ones (Thomson *et al.*, 2010; Peter, 2014; Alexander *et al.*, 2015). The alterations in species composition can have detrimental impacts on agricultural productivity (Thomson *et al.*, 2010). For instance, introduction of new species has significant implications for agricultural productivity because it favours the introduction of new weeds and pests, and a temporal mismatch with natural enemies thus reducing biocontrol efficiency (Gutierrez *et al.*, 2008a; Peter, 2014). For example, Thomson *et al.* (2010) state that changes in the distribution of natural enemies has led to spatial and temporal mismatches with herbivore insects resulting in more crop damage and reduced agriculture yields. Changes in species distribution ranges may lead to the introduction of new diseases and pests to new ranges, which could lead to agriculture failures and human mortality (White *et al.*, 2018; Ryan *et al.*, 2020). For example, malaria vectors are projected to expand ranges in southern Africa due to increasing mean temperatures (Davis, 2011; Ryan *et al.*, 2020; Swatton and Fitchett, 2020). This will lead to malaria outbreaks to new locations, thus exacerbating multiple socio-economic stressors and further deteriorating food security in the region (Calzadilla *et al.*, 2013; Ryan *et al.*, 2020). However, range shifts can also

lead to the disappearance of some pathogen vectors, thus decreasing insect-transmitted disease on crops and promoting agricultural success (Eigenbrode *et al.*, 2018). Phenological traits must, therefore, be considered in species distribution-based models to accurately understand and project species distribution globally (Malsale *et al.*, 2018). People from rural areas offer primary based monitoring because of their dependence on the natural environment and their ability to adapt to the changing climate (Chambers *et al.*, 2013d; Armatas *et al.*, 2016). This is because phenology is an important component for comprehending climate variability in change in rural areas, particularly by subsistence farmers (Archaya *et al.*, 2011; Armatas *et al.*, 2016; Fitchett and Ebhuoma, 2018). Therefore, it is imperative to include IKS in climate change and phenology studies to inform climate change adaptative strategies for both agriculture and environmental conservation purposes.

2.4 Indigenous Knowledge

IK defined as community-based knowledge that is distinct to a particular culture, or community (Orlove *et al.*, 2010; Ajani *et al.*, 2013; Chambers *et al.*, 2017; Ebhuoma and Simatele, 2017). Gadzirayi *et al.* (2006) argue that not all traditional knowledge is indigenous knowledge, in this study these terms will be used interchangeably without distinction (Orlove *et al.*, 2010). Indigenous rural realities contribute to the creation, implementation, and evolution of this body of knowledge, IK manifest agency and resilience in response to exploitation, natural stressors and climate variability and change (Valdivia *et al.*, 2010). Communities can generate, absorb and discard knowledge according to their needs at a particular time, although this might lead to rapid loss of IK because of lack of documentation, it displays adaptability and self-organising process of knowledge systems possessed by the communities (Fernández Llamazares Onrubia, 2015).

There is a gap in the scholarly literature about the use of IK in climate and weather forecasting in the context of African countries (Gadzirayi *et al.*, 2006; Mashoko *et al.*, 2012; Ajani *et al.*, 2013; Jiri *et al.*, 2016; Ebhuoma, 2017; Ebhuoma and Simatele, 2017). This is partly because IKS studies relating to climate and weather are an emerging research field, which aligns with the decolonisation of knowledge systems and methodologies in the global south (Barnhardt and Kawagley, 2005; Robinson and Wallington, 2012; Khuphe, 2017), and the generic factors that inhibit the development of formally recognised studies in African countries i.e. lack of research funds (Davis, 2011). Some research from Nigeria, Uganda, and Zimbabwe demonstrate that Sub-Saharan Africa has rich IK and oral histories informed by phenological cues which are used to track seasonality (Gadzirayi *et al.*, 2006; Orlove *et al.*, 2010; Ebhuoma and Simatele, 2017). More than 80% of rural communities are found in Africa (Dasgupta *et al.*, 2014) and IK is argued to be predominantly developed and used in rural areas, particularly in subsistence agricultural management, however, there is a relatively small amount of peer-reviewed literature in the context of Africa, which is not representative of IK that the content arguably possesses (Gadzirayi *et al.*, 2006; Ebhuoma and Simatele, 2017; Radeny *et al.*, 2019). Nevertheless, the available studies convey the pragmatic reasoning behind the use of IK which warrants the recognition and credibility to using it. Studies continuously emphasise that IK is rooted in cultural cohesion, place-based and is customarily allied with long-settled communities that have strong ties to the natural environment (Gadzirayi *et al.*, 2006; Mafongoya and Ajani, 2009; Lefale, 2010; Chand *et al.*, 2014; Chambers *et al.*, 2019). IKS is based on knowledge and the know-how that is accumulated over generations and has been successful in guiding human societies in their interactions and close observation to their environment (Orlove *et al.*, 2010; Magni, 2017; Mbewe *et al.*, 2019). All the changes in species vegetative phenology and shifts in geographic ranges will impact IKS

short to medium-term weather forecasting and the development of agricultural management strategies (Chambers *et al.*, 2013d; Fitchett and Ebhuoma, 2018).

2.4.1 Indigenous Knowledge Systems and Phenology

Phenology is a significant and most reliable indicator of environmental change and a vital component in IKS weather forecasting (Chidumayo, 2001; Gadzirayi *et al.*, 2006; Mafongoya and Ajayi, 2009; Ebhuoma and Simatele, 2017; Fitchett and Ebhuoma, 2018). Animal behaviour and flora seasonal events are intrinsic indicators for weather changes (Fitchett and Ebhuoma, 2018). Therefore, phenophases are the bases for IKS used in agricultural management in most rural areas, particularly by subsistence farmers, in their important agriculture decisions (Gadzirayi *et al.*, 2006; Ebhuoma and Simatele, 2017). IKS encompasses status monitoring defined by Denny *et al.* (2014), which enables it flexibility in understanding the complex relationships between environmental cues including phenology climate and weather. It has limited quantification of phenological variations within species population as well as across geographic regions (Orlove *et al.*, 2010; Plotz *et al.*, 2017). Similar to most phenology monitoring systems, the key gap in this knowledge system is forecasting and understanding the extent to which plants and animals will be able to track environmental changes (Orlove *et al.*, 2010; Zhao *et al.*, 2013; Plotz *et al.*, 2017; Liu *et al.*, 2018). Therefore, the sensitivity of species to changing environments, and alterations in physiological responses will lead to the misguidance of the communities that rely on indigenous phenological cues for weather forecasting (Fitchett and Ebhuoma, 2018; Chambers *et al.*, 2019). However, the high-resolution offered by IKS and the familiarity with the environment by community members provide an advantage; to ‘react’ and recuperate within a short temporal range, thus limiting severe impacts (Magni, 2017).

There are on-going debates about the future value and credibility of traditional knowledge, particularly in the face of rapidly changing climate and environment while the plasticity in both plants and animals is also changing (Lauer and Aswani, 2010; Ziervogel *et al.*, 2014; Chambers *et al.*, 2017; Fitchett and Ebhuoma, 2018). Anthropogenic climate change will lead to phenological shifts which in turn will change the timing of the indicators used by rural subsistence farmers (Anjani *et al.*, 2013; Magni, 2017; Fitchett and Ebhuoma, 2017). This could lead to complex social issues for rural communities because subsistence farmers in these areas rely on agriculture production for food, livelihoods, and economic support (Jacobs, 2009; Blanc, 2012). Although engagement with IK in scholarly research has only recently gained traction, the studies highlight that IKS monitoring methods have guaranteed usability because they have been used by rural populations to maintain successful food production for over centuries (Mazzocchi, 2006; Orlove *et al.*, 2010; Goduka, 2012; Ebhuoma, 2017; Rukema and Umubyeyi, 2018; Radeny *et al.*, 2019). Furthermore, the spatial specificity of IK information cannot be overemphasized, it offers efficacy to agricultural management in the rural areas and has potential to facilitate mesoscale environmental management (Orlove *et al.*, 2010; Jiri *et al.*, 2016). More research, from different parts of the world, is needed to both avoid erosion IKS and create corpus as a framework for more progressive research (Orlove *et al.*, 2010; Nkomwa *et al.*, 2013; Parsons *et al.*, 2016). This will also facilitate the integration of IK discourse in climate change adaptation policies through increased availability and understanding to broader external communities (Birkmann and Teichman, 2010; Plotz *et al.*, 2017).

Most rural subsistence farmers from different countries can access weather and seasonal forecasts through national meteorology services, but uptake of the information, particularly by rural communities is limited (Fitchett and Ebhuoma, 2017; Chambers *et al.*, 2019; Mbewe *et al.*, 2019).

This is partly because rural subsistence farmers around the globe can forecast daily, seasonal, and extreme weather events through observing their surrounding natural environment (Orlove *et al.*, 2010; Chand *et al.*, 2014; Plotz *et al.*, 2017). The limited uptake of contemporary weather forecasts is mostly because rural populations consider information from national meteorology services irrelevant to local activities and needs (Ebhuoma and Simatele, 2017). Moreover, the forecasts have a coarse spatial resolution, and community members cannot interpret nor comprehend its meaning the technical language used by reporters a (Jiri *et al.*, 2016; Magni, 2017). Furthermore, some regions have low confidence on national meteorology services, having been misled by them in the past, for instance, a case of the Delta state of Nigeria in 2012 (Ebhuoma, 2017; Fitchett and Ebhuoma, 2018). However, in cases of imminent threats, these communities may acknowledge and use national meteorology services in conjunction with their IK (Chambers *et al.*, 2019).

2.4.2 Indigenous Knowledge Production

IK is a tacit and situated form of knowledge, reflecting in-depth experiences that are unlikely to be derived through formalised structures because they are an inherent part of livelihoods and tradition (Kijazi *et al.*, 2013; Fernández Llamazares Onrubia, 2015; Ebhuoma, 2017). Continuous production and evolution of IK are argued to require custodians and neophytes to remain active and close to the production of knowledge through designated social-networks and supporting fora (Chand *et al.*, 2014; Fernández Llamazares Onrubia, 2015). Therefore, there is a need to maintain the integrity of cultural and environmental conditions that facilitate IK pedagogy as this allows continuous production and adaptation of the knowledge (Huntington, 1999; Nyong *et al.*, 2007; Chand *et al.*, 2014; Kassam *et al.*, 2017).

To date, there are still debates about IK epistemology because IKS are based on experiences, thus is inherently perceptual (Watson-Verran and Turnbull, 1995; Bisong and Andrew-Essein, 2010; Agrawal, 2014; Fernández Llamazares Onrubia, 2015). Furthermore, there are significant differences in suggested methods of documentation, which has contributed to the relatively slow progress in IK acceptance in the western science scene (Dlamini and Ocholla, 2018). The *ex situ* documentation of IK is noted to be contradictory to the localised and adjusted nature of IK, which is mainly for addressing the needs of its custodians (Briggs, 2005; Agrawal, 2014). However, this view overlooks the progressive nature of all epistemologies (Nyong *et al.*, 2007; Ajani *et al.*, 2013; Ludwig, 2016). IK research and documentation contributes to the preservation of cultures and provides a framework for ecology-based strategies useful to conservation land managers (Gadzirayi *et al.*, 2006; Jones *et al.*, 2012).

It is always imperative that knowledge produced is credible, legitimate and has strong epistemic authority for public sphere purposes (Robinson and Wallington, 2012). Jensen (2005) points out that to effectively procure knowledge there must be a clear process of understanding, reframing and learning. For example, acceptance of IKS is based on the observed practicality of a strategy, while in dominant western philosophical discourse the agency of knowledge is acknowledged before everyday relatability and applicability are confirmed (Mazzocchi, 2006; Ludwig, 2016). This presents challenges in the integration of these knowledge systems because the western discourse is documented, has been considered the arbiter of knowledge and formed part of a curriculum for generations (Mazzocchi, 2006; Kijazi *et al.*, 2013). Therefore, means of validating IK are based on western discourse recognizing it as a contribution to livelihoods and a legitimate form of knowledge (Parsons *et al.*, 2016; Roue and Nakashima, 2018). Therefore, the tendency to accept IK only when its methods can be explained by heavily Eurocentric discourse is another

factor limiting effective integration of knowledge systems (Archaya, 2011; Parsons *et al.*, 2016; Magni, 2017). In view of this, Robinson and Wallington (2012) put forth the importance of boundary management in knowledge production. This management strategy prioritises recognising different knowledge systems without altering their integrity (Robinson and Wallington, 2012). This is particularly important in IK, as noted by Njiraine *et al.* (2010) and Chambers *et al.* (2017). Chambers *et al.* (2017) highlight that several challenges regarding knowledge owned by communities and ensuring intellectual property rights that will protect data from appropriation and commercialization have to be addressed for proper dissemination of IK (Tong, 2017). Njiraine *et al.* (2010) emphasises the urgency for policymakers to include IK management in legislation, particularly in Africa to inform national efforts of environmental conservation and increase IK adoption simultaneously. In view of this, there are arguments advocating for ontological pluralism and different ways of interpretation pointing out that IK does not have to be compatible merged to western discourse to be effective (Jones *et al.*, 2012; Robinson and Wallington, 2012; Ludwig, 2016; Parsons *et al.*, 2016).

For IKS to be truly transformative in climate change adaptation, IK development in climate science research must acknowledge the colonial heritage of research methods and knowledge dissemination (Chand *et al.*, 2014; Armatas *et al.*, 2016). The colonial heritage in research methods needs to be revised to accurately co-produce and disseminate IK based climate change adaptation strategies (Jones *et al.*, 2012; Kramer *et al.*, 2019). The accumulation of data in IK research argued to contradict with what qualifies as admissible research methods in academic institutions (Khuphe, 2014). For example, Parsons *et al.* (2016) state that the establishing relationships with participants and conforming to culturally appropriate ways of communicating is a valuable component in IK studies but is not overtly encouraged in academic research because

it is perceived to reduce the objectivity required to produce valuable results. Therefore, research methods transformation is required, particularly in the global south to facilitate effective IKS research (Kramer *et al.*, 2019). Wulijeng *et al.* (2018) also point out that the simplistic approach adopted by some IK researchers of framing IK custodians and users as pre-modern citizens and overlooking colonial histories and indigenous lifeways diversity risks losing fundamental components of indigenous realities and compromises the credibility of IK strategies (Kramer *et al.*, 2019). While acknowledging the colonial and Eurocentric foundations of research methods is important, it is also advised that IK research extends beyond resilience of western views and emphasise the fundamental need to acknowledge indigenous epistemologies in environmental conservation and climate change adaptation research (Zuma-Netshiukhwi *et al.*, 2013; Parsons, *et al.*, 2016). Furthermore, it is important to note that not all traditional knowledge-based adaptation strategies are ecologically sustainable, because some methods are becoming maladaptive due to rapid environmental changes (Archaya, 2010; Jones *et al.*, 2012; Chand *et al.*, 2014). This is partly attributed to the overwhelming dependence on natural resources and the lack of quantitative estimates to provide optimal adaptation (Jiri *et al.*, 2016). Moreover, there are innate uncertainties regarding the extent of the effects of climate change on the ability of ecosystems to provide adaptation services, which transcends knowledge systems (Jones *et al.*, 2012; Fitchett and Ebhuoma, 2017). Nonetheless, it is still important that IKS and indigenous realities are considered in the development of adaptive strategies (Jones *et al.*, 2012; Plotz *et al.*, 2017; Chambers *et al.*, 2019).

Effective climate change adaptation requires responsibility sharing between governments, academics and primary resource users to sustain socio-economic security (Aparna and Trivedi, 2011; Chand *et al.*, 2014). IK has been demonstrated as a significant component in climate change

adaption, particularly in agriculture because it offers a high spatio-temporal resolution that is fundamental in adaptation knowledge production (Huntington, 1999; Fabayi and Oloukoi, 2013; Ebhuoma and Simatele, 2017). IKS facilitates the development and effective implementation of adaptation measures to rural communities; the most vulnerable groups to the effects of climate change in southern Africa (Chambers *et al.*, 2017; Ebhuoma and Simatele, 2019). Co-management through responsibility and knowledge sharing does not only promote capturing the adaptive capacity of social and ecological systems, but it also promotes knowledge development and data inventory for IK and creates a framework for more rigorous research (Archaya, 2011; Reniko *et al.*, 2018). While the importance of IK, particularly in biodiversity conservation and climate change adaptation is emphasised (Njiraine *et al.*, 2010; Chambers *et al.*, 2013; Kassam *et al.*, 2017), there are significant challenges in integrating IK and science-based knowledge; lack of respect for IK (Gratani *et al.*, 2014), power dynamics in governance and decision making spaces (Brosius, 2006; Hill *et al.*, 2012). These noted challenges have led to the evident development in scope and depth of IK research and the increase in peer-reviewed literature and supporting forums (Parsons *et al.*, 2016; Ebhuoma and Simatele, 2017).

More recent studies on IKS focus on traditional knowledge as a representation of a broader system of knowledge developed and applied locally passed through generations and sometimes integrated with external sources, but rooted within a certain culture (Njiriane *et al.*, 2010; Ebhuoma, 2017; Chambers *et al.*, 2019). IK promotes sustainability, adaptation to environmental change and culture preservation simultaneously (Nyong *et al.*, 2007; Kijazi *et al.*, 2013; Fernández Llamazares Onrubia, 2015). There is a recognised need to exhibit IK beyond poverty and avoid constantly associating it with pre-modernism because IK epistemology can offer solutions to current global issues (Mafongoya and Ajani, 2009; Parsons *et al.*, 2016). IKS in short-and

medium-term weather forecasting has been influential for small scale food production in Sub-Saharan Africa (Benyei *et al.*, 2020). This is because national meteorology service reports in most African countries lack contextual relevance for subsistence farmers (Orlove *et al.*, 2010; Archaya, 2011; Fabayi and Oloukoi, 2013; Ebhuoma, 2017; Radeny *et al.*, 2019). This contributes the continued use of IKS, but the overwhelming dependence to environmental viability for survival, productivity and livelihoods is the main reason for the rich archives of IKS found in the continent (Mafongoya and Ajani, 2009; Orlove *et al.*, 2010; Chand *et al.*, 2014; Chambers *et al.*, 2019).

2.4.3 Indigenous Knowledge Systems in Climate Change Adaptation

Adaptation to climate variability and change is necessary to reduce the vulnerability of communities to short- and long-term climate effects (Gadzirayi *et al.*, 2006; Ford *et al.*, 2011; Chand *et al.*, 2014). IKS is one of the most significant strategies considered for climate change adaptation, particularly for rural communities (Orlove *et al.*, 2010; Jones *et al.*, 2012; Ebhuoma, 2017; Chambers *et al.*, 2019). IKS is also widely argued to promote sustainable development goals SDG 2030, particularly goal number two and three, which are, zero hunger and good health, and wellbeing in most developing countries (Adger *et al.*, 2003; Chambers *et al.*, 2017, 2019).

Co-production of knowledge promotes the development of easily accessible and holistic adaptation strategies (Huntington, 1999; Birkmann and Teichman, 2010; Arbuckle *et al.*, 2015). Furthermore, developing nations are the most vulnerable to environmental changes because they rely on primary sectors like mining and agriculture for livelihoods and economy, so they can benefit from the high spatio-temporal resolution offered by the majority of IKS methods (Ziervogel *et al.*, 2014; Jiri *et al.*, 2016). Therefore, there is an emphasis on employing different approaches in the development of pragmatic adaptation strategies, and the importance of documenting IK and

acknowledging its custodians by several authors (Orlove *et al.*, 2010; Chand *et al.*, 2014; Plotz *et al.*, 2017; Chamber *et al.*, 2019). Fernández Llamazares Onrubia (2015) highlights the need to understand traditional knowledge and incorporate it in natural resource management for policymakers to adopt both traditional and modern resources to protect residents and ensure production of food in an area. In the Pacific, there have been observed benefits of using IKS, to reduce expected mortalities and natural resource preservation during flood events (Chambers *et al.*, 2017, 2019).

There are considerable advantages in understanding and documenting traditional ecological knowledge from indigenous communities and comprehending its application to cope with the extreme and rapid changes (Mafongoya and Ajayi, 2009; Lefale *et al.*, 2010; Dlamini and Ocholla, 2018). Custodians of IK are regarded the most essential part of IK research because they have a direct relationship with the changing environments (Govender *et al.*, 2013; Mathibela *et al.*, 2015). After decades of exposure to a wide range of vulnerabilities, custodians have and continue to acquire knowledge that its sole purpose is to reduce risks to livelihoods that arise as a result of environmental and development changes (Morton, 2007; Thorlakson and Neufeldt, 2012; Mathibela *et al.*, 2015; Magni, 2017). Apart from the natural inclination to survive in the face of crisis, IK also brings a framework of social, cultural coherence, food, shelter and healing to communities (Govender *et al.*, 2013; Chambers *et al.*, 2017; Magni, 2017). Documenting indigenous systems is argued to potentially reduce the observed erosion of this IKS that is caused by ignoring traditional knowledge in favour of western science, and disinterest by the youth to adopt IK while the custodians are dying (Dweba and Mearns, 2011; Reniko *et al.*, 2018). In addition, it will reduce the observed ‘disrespect’ from western discourse because of the lack of records and translation (Robinson and Wallington, 2012). Gadziray *et al.* (2006) additionally

notes that urbanisation and excessive dependence on new technologies have decreased the value of traditional knowledge. The transmission of IK is also inhibited by introduced agricultural and health policies that hinder access to traditional flora through limiting access to forests due to the perceived degradation (Bisong and Andrew-Essein, 2010; Parrotta *et al.*, 2016; Benyei *et al.*, 2020).

Some research suggests that traditional management systems and agroecological based management strategies may represent the only robust action to increase plant productivity and thus ensure food security for small scale farmers (Orlove *et al.*, 2010; Altieri and Nicholls, 2013). Given this, Mandelsohn and Dinar (1999) point out that although extreme climatic events have significant impacts on food security on both global and national scale, peer-reviewed records are mostly a gross approximation at the heterogeneity of subsistence agriculture and do not factor in the resilience of subsistence farmers acquired through a series of traditional agroecological practices which are borne from an extensive understanding of the natural environment (Gadzirayi *et al.*, 2006; Ebhuoma and Simatele, 2017). Severe changes in climate are met with strategised traditionally informed preparations and adaptation measure reducing the effect of climate extremes (Aparna and Trivedi, 2011; Adger *et al.*, 2013; Apraku *et al.*, 2018).

2.5 Integration of Knowledge Systems

The increased frequency of climate stressors requires engagement with cultural systems, social structures, and individual actions, all within a specific ecological context to assure effective response (Nkomwa *et al.*, 2013; Kassam *et al.*, 2016; Magni, 2017). Therefore, the development of effective responses to climate change effects needs to be collaborative and involve societal perspectives and experimented practices (Jiri *et al.*, 2016; Magni, 2017). IKS is increasingly

recognised as an important factor in building community's resilience to extreme climate events and has gained traction in climate change adaptation research (Kassam *et al.*, 2017; Plotz *et al.*, 2017). Merging IKS with contemporary weather forecasts to provide forecasts that are relevant and specific to the activities in rural communities is argued to be a valuable component facilitating the uptake of weather forecasts from government weather reports thus facilitating the application of the information in developing cautionary measures in rural communities (Chambers *et al.*, 2017; Ebhuoma, 2017). Furthermore, cognitive diversity amongst problem solvers is contended to be paramount if climate change is to be addressed in ways that are beneficial and ethical to both urban and rural regions (Bisong and Andrew-Essein, 2010; Adger *et al.*, 2013; Kassam *et al.*, 2017). Therefore, collaborative approach between IKS holders and contemporary forecasting can avert potential social and economic challenges posed by climate change, especially in vulnerable regions such as Sub-Saharan Africa, where food production depends on climatic variables (Fabiya and Oloukoi, 2013; Plotz *et al.*, 2017).

Most rural community members do not have a scientific understanding of the concept of climate change, particularly because of the technical language used by decision-makers and media outlets in communicating this subject (Ebhuoma, 2017). Nonetheless, rural farmers successfully still adapt to the changes (Adger *et al.*, 2003; Fernández Llamazares Onrubia, 2015; Plotz *et al.*, 2017). This depicts the valuable climate change adaptation information and methods possessed by rural communities and suggests that incorporating IKS in national meteorology forecasts, ensuring that effective dissemination, and establishing contextual relevance of the forecasts to end users can improve adaptive capacity and resilience of rural communities (Bisong and Adrew-Essein, 2010; Fabiya and Oloukoi, 2013; Ebhuoma and Simatele, 2019). Weather reports must be communicated in understandable languages and have a direct agency to farming and daily activities (Jiri *et al.*,

2016; Magni, 2017). Chambers *et al.* (2019) argues that clearer understanding of the knowledge used by local communities in weather forecasting, and knowing the barriers to its use and application will allow national meteorology services to adjust their information and communications avenues to ensure that communities understand it, and can respond to thus increasing adaptive capacity. IK is inherently diverse, and strongly connected to habitat but it has the capacity to transform perspectives, practices, and policies (Lefale, 2010; Orlove *et al.*, 2010; Mashoko *et al.*, 2012). Kassam *et al.* (2017) strongly argue that mixed approaches in climate change adaptation will facilitate the progress of the developed measures thus increase the resilience of marginalized communities to the effects of climate change.

2.6 Indigenous Knowledge Transmission and Conservation

Rural areas are rich environments for developing contextual knowledge, hence subsistence farming from rural areas is a good environment for teaching and learning indigenous systems (Bisong and Andrew-Essein, 2010; Kassam *et al.*, 2017; Magni, 2017). Although IK is developed in rural areas, several studies have argued that it can offer relief to both local and global environmental challenges (Huntington, 1999; Magni, 2017). Traditional knowledge is passed on from generation to generation through folktales, songs, and rituals (Gadzirayi *et al.*, 2006; Orlove *et al.*, 2010; Chambers *et al.*, 2017). Grider (1995) argues that folklore is the most important factor in assuring cultural continuity from generation to generation and tradition bearers. Custodians are considered the master teachers while the succeeding generations are learners (Govender *et al.*, 2013; Grider, 1995). Folklore is defined as knowledge that is passed on through word of mouth and all crafts and techniques learned by imitation or the products of those crafts (Ben-Amos, 1971). The knowledge from folklore is a product of individual experiences, society experience,

or community experiences. Accordingly, IK is based on experiments, trial and error by the users and its custodians (Gadzirayi *et al.*, 2006; Orlove *et al.*, 2010; Ajani *et al.*, 2013; Chambers *et al.*, 2017). IKS uptake depends on the availability of knowledgeable elders/masters and eager neophytes (Ben-Amos, 1971; Grider, 1995; Parsons *et al.*, 2016).

One of the main concerns in the IKS domain is the decreasing value of traditional knowledge in the face of increasing economic development, rapid urbanisation and climate change (Dweba and Mearns, 2011; Chambers *et al.*, 2017; Aswani *et al.*, 2018). IK is threatened by rapid cultural transformations and environmental change (Birkmann and Tiechman, 2010; Parsons *et al.*, 2016). For example, Ford *et al.* (2006) noted that, as a result of western focused economic, cultural and social lifestyle trends in the Arctic, traditional social networks within which adaptive capacity is built are being eroded. This is because these trends decrease inter-generational engagement and degrade established social networks within the communities (Ford *et al.*, 2006; Mauser *et al.*, 2013; Magni, 2017). IK gradually is fading and devalued due to its perceived association with poverty and the invasion of western concepts that promise development goals or solutions (van Rensburg Willem *et al.*, 2007; Parrota *et al.*, 2016; Magni, 2017; Plotz *et al.*, 2017). The youth's resistance in acknowledging IK is attached to the negative attitudes towards seemingly outdated and unpopular practices in contrast to the perceived acceptable knowledge (Owiny *et al.*, 2014; Dweba and Mearns, 2011). Erosion of indigenous knowledge systems threatens livelihoods and health of traditionally living rural communities (Dweba and Mearns, 2011; Aswani *et al.*, 2018). This is considered one of the dominant threats to the sustainability of natural resources and knowledge disintegration in rural Africa (Dweba and Mearns, 2011; Jones *et al.*, 2012; Owiny *et al.*, 2014; Aswani *et al.*, 2018). Although several scholars point out that most of IK based methods are more sustainable than western methods (Fabiyyi and Oloukoi, 2013; Nkomwa *et al.*, 2013;

Plotz *et al.*, 2017), the uptake by expected neophytes is minimal (Dweba and Mearns, 2011). The implications of the disappearance of this knowledge can be detrimental when local skills, teachings, and expertise are lost (Dweba and Mearns, 2011; Chambers *et al.*, 2017). This will render the rural poor vulnerable to food insecurity, famine, and poverty that may arise as a result of climate change (Adger *et al.*, 2003; Dweba and Mearns, 2011; Aswani *et al.*, 2018; Ebhuoma *et al.*, 2020). In the Eastern Cape Province, South Africa, Dweba and Mearns (2011) found that erosion of indigenous knowledge required to maintain traditional vegetable plants poses a great threat of extinction vegetables than the plants' vulnerability to environmental change. Traditional vegetables are consumable plants that can be used as vegetables, they do not require high input to thrive and they are part of tradition production systems because of the indigenous knowledge required in identifying and in their preparation for consumption (Keller *et al.*, 2005; van Rensburg Willem *et al.*, 2007; Mavengahama *et al.*, 2013). The disappearance of this knowledge leads to a decrease in traditional vegetable consumption thus, micronutrient deficiency and food insecurity for the rural poor (Gockowski *et al.*, 2003; Flyman and Afolayan, 2006; Joshi *et al.*, 2007; Dweba and Mearns, 2011; Mavengahama *et al.*, 2013).

The widespread recognition of indigenous knowledge by research and organizations have highlighted its significance, particularly in rural settings and provided information which warrants more intensive research on the subject of phenology and environmental change (Berkes *et al.*, 2007; Ajani *et al.*, 2013; Ebhuoma, 2017). Mafongoya and Ajani (2009) note that some policymakers and development practitioners are now relatively familiar with the concept of IK and acknowledge its importance as a component of livelihoods. This is attributed to the growing awareness that western scientific knowledge alone is not adequate for solving the climate crisis without compromising the environment and inferior social groups (Berkes *et al.*, 2007; Chambers

et al., 2017; Radeny *et al.*, 2019). Several scholars argue that comprehending IK by policy planners and climate specialists will enable the integration of IK with scientific knowledge thus leading to more environmentally and socially sustainable development initiatives (Kassam *et al.*, 2017; Magni, 2017; Plotz *et al.*, 2017). This has led to a growing interest in documenting and storing this knowledge (Chambers *et al.*, 2017; Magni 2017; Dlamini and Ocholla, 2018; Benyei *et al.*, 2020). However, there are controversies regarding the protection of the knowledge and sustaining its integrity (Kabudi, 2004; Moahi, 2007; Chambers *et al.*, 2017; Magni, 2017). Chambers *et al.* (2017) state that there are issues regarding the suitable way to store and manage the information that will be collected from the locals (Moahi, 2007; Dlamini and Ocholla, 2018). She argues that when IK databases are developed and managed by other parties other than the knowledge holders, protection of knowledge holders' rights, cultural and intellectual property sensitivities need to be considered more attentively. Therefore, although documenting and storing IK is recommended, there are several challenges need to be addressed, pertaining the protection of intellectual knowledge that belongs to a whole community (McCarter *et al.*, 2014; Chambers *et al.*, 2017; Tong, 2017; Dlamini and Ocholla, 2018). IKS strategies are mostly reactive to observed changes, they are based experience and mainly aim to promote survival and produce food despite the rapid significant developmental and environmental changes (Kijazi *et al.*, 2013; Magni, 2017). As a result, some countries have established government ministries that have varying degrees of interest and investment in IK to better comprehend the rural community needs and ways in which these communities can be uplifted and assisted in coping with natural stressors while highlighting the value of IK (Gorjestani, 2004; Magni, 2017).

The diverse forms of knowledge in rural areas, which are deeply rooted in their relationship with the environment and cultural cohesion, have allowed rural communities to maintain a sustainable

use and management of natural resources, protect their environment and strengthen their resilience, whilst facing new and complex circumstances (Jones *et al.*, 2012; Ford *et al.*, 2016). This indicates the need to understand various intrinsic IKS indicators that are developed and applied in most rural areas globally (Egeru, 2012; Arbuckle *et al.*, 2015; Ebhuoma, 2017). Recently, studies have gained momentum in investigating the use of IKS in climate change adaptation, IKS is perceived as the remedy for many challenges caused by development and natural environmental changes (Jiri *et al.*, 2016; Chambers *et al.*, 2017; Ebhuoma, 2017; Plotz *et al.*, 2017). As a result, governments in the pacific are developing avenues to research, understand and store IK to offset the soviet discouragement in its use and credibility by the western science (Magni, 2017; Malsale *et al.*, 2018).

2.7 Conclusion

Overall, there is a consensus in the literature that climate change will present devastating impacts on the most vulnerable groups, particularly subsistence farmers in southern Africa. These impacts will further deteriorate every aspect of the socio-economic state of the region, particularly poor rural communities. There is no deliberate focus on commercial farming in IKS and climate change adaptation studies, this suggests that there is a notable divide in strategies and resources exposed to rural and commercial farmers. However, more research is needed to explore these differences and find ways to minimise the gap. Nonetheless, researchers found that rural subsistence farmers use their expertise that they gain through overwhelming dependence on environmental viability for food production. Rural subsistence farmers facilitate household food production through developing and implementation of cost-effective locally developed IK strategies. These farmers mostly use phenological and meteorological indicators for weather forecasting to inform

agricultural decision making. As a result of the effects of climate change on flora and fauna seasonal cycles, the credibility of IK based weather forecasts is threatened. Given this, scholars state that more research that focuses on the integration of knowledge systems is required to facilitate holistic climate change adaptation. There is an acknowledgement of challenges that may arise in the process of acquiring and documenting community based and culturally embedded knowledge, in which social science research suggests the introduction of boundary management and ontological pluralism to ensure validity, credibility and integrity of knowledge production.

3. Study Area Description

This section introduces the study areas, Umzimkulu and Lusikisiki from their broader spatial location within Eastern Cape and KwaZulu-Natal Provinces in South Africa. An overview of the key aspects of the two regions and specific study locations is presented to familiarize the reader with the characteristics relevant to this study. This chapter highlights rainfall patterns and some of the weather systems that influence the climate in the two provinces. It further discusses socio-economic conditions and broader use of IKS in the provinces. Then agricultural activities within Umzimkulu and Lusikisiki are detailed.

3.1 KwaZulu-Natal and Eastern Cape, South Africa

3.1.1 Descriptive Geography

KwaZulu-Natal and the Eastern Cape Province are both located in the eastern region of South Africa (Figure 3.1). KwaZulu-Natal is bordered by three South African provinces: Eastern Cape, Free State and Mpumalanga, and two southern African countries: Lesotho and Swaziland (Figure 3.1). The Eastern Cape Province is surrounded by Lesotho and four other South African provinces: KwaZulu-Natal, the Free State, Northern Cape, and the Western Cape Province (Figure 3.1). Both KwaZulu-Natal and the Eastern Cape Province are bounded by the Indian Ocean in the east and the Drakensberg Escarpment in the north of Eastern Cape and South of KwaZulu-Natal, near Lesotho (Figure 3.1; Molekwa, 2013). Therefore, their topography varies from a relatively flat coastal plain (<300 m. asl) that rises moving inland to approximately 3,300 m.asl along the Drakensburg Escarpment mountains (Figure 3.1; Lakhraj-Govender and Grab, 2018). The diverse topography influences spatial rainfall distribution within the two provinces through inducing orographic rainfall (Molekwa, 2013).

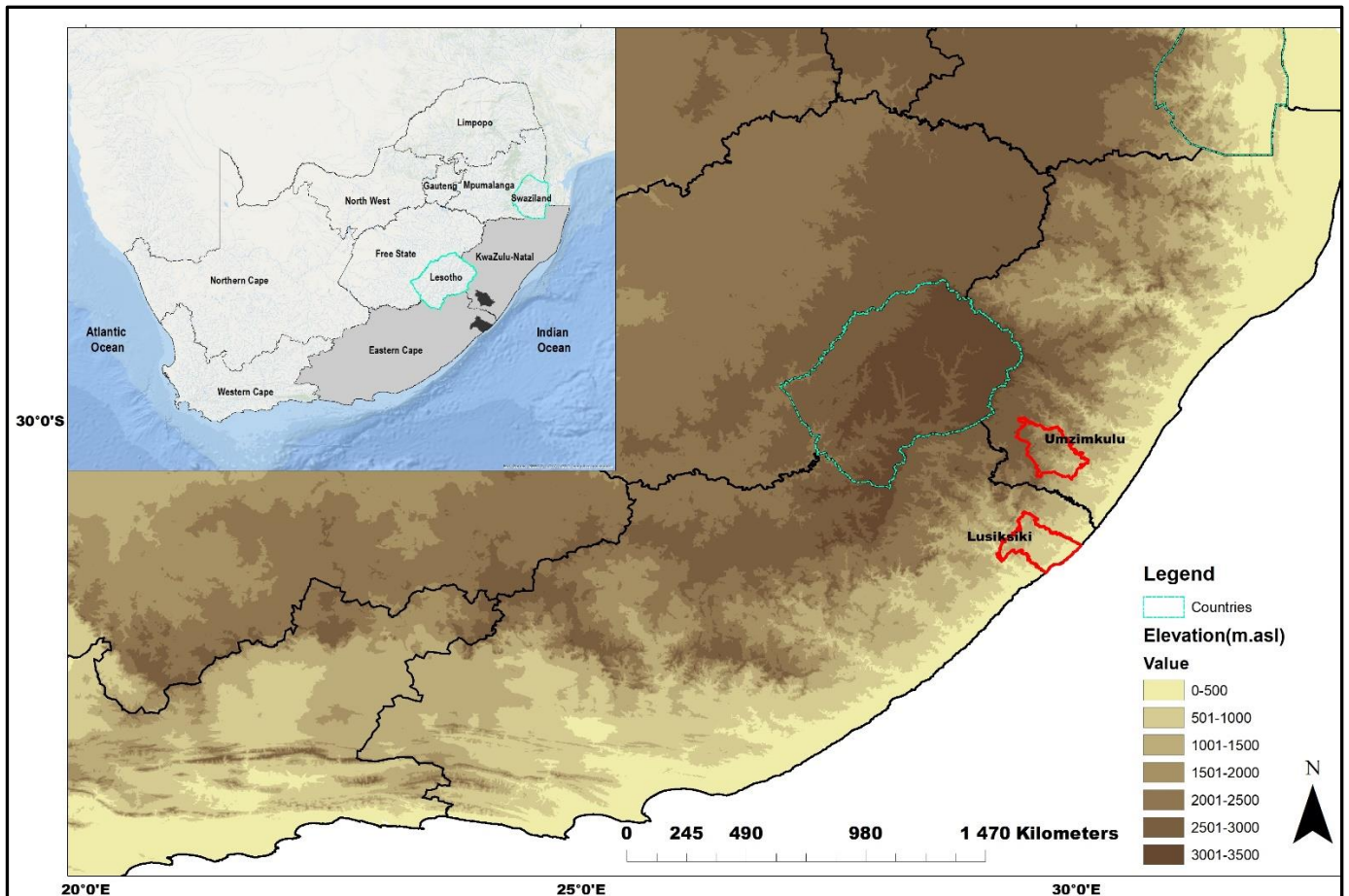


Figure3.1: Location of Umzimkulu and Lusikiski within KwaZulu-Natal and Eastern Cape, South Africa

The climate and topography of KwaZulu-Natal and Eastern Cape Provinces contribute to the steep environmental and vegetation gradients resulting in a combination of floristic elements, particularly in the Eastern Cape (Abdel-Humid *et al.*, 2020; Graw *et al.*, 2020). The Eastern Cape Province supports eight of the nine biomes found in South Africa, ranging from Savanna near the Indian Ocean coastal belt, forests along the south coast, Fynbos, Succulent Karoo and Albany Thicket in the Southwest near the Cape fold mountains, Nama Karoo in the north-west around the Northern Cape Province border and Grassland in the interior to the northeast near Lesotho and KwaZulu-Natal borders (Mucina and Rutherford, 2006; Walz *et al.*, 2020). KwaZulu-Natal is predominantly comprised of Grassland and Savanna biome and has forests near the coast and

inland around Pietermaritzburg, north of Umzimkulu (Mucina and Rutherford, 2006). The biodiversity, especially grasslands, are essential for both commercial and subsistence agriculture (i.e. livestock grazing) in both KwaZulu-Natal and Eastern Cape (Masubelele *et al.*, 2015; Bengtsson *et al.*, 2019). The biodiversity also contributes to IKS and the broad indicator species diversity in rural areas (Mwinga *et al.*, 2019; Cámara-Leret *et al.*, 2019). In both KwaZulu-Natal and Eastern Cape, the indigenous plants are a significant part of botanical traditional medicine and cosmetics (Mwinga *et al.*, 2019; Ndawonde, 2020). The biodiversity within these provinces is projected to change due to climate change-related stressors (Jewitt *et al.*, 2015; Masubelele *et al.*, 2015). This means that natural resource reserves and IKS of KwaZulu-Natal and Eastern Cape Province will be jeopardised (Masubelele *et al.*, 2015). These changes have a direct influence on sustenance and livelihoods of rural community members within the provinces.

3.1.2 Climate and Drivers of Variability in the Provinces

South Africa is classified as a semi-arid country because of its low mean annual rainfall of ~450mm/year, which is almost half of the global mean annual rainfall of approximately 860mm/year (Meissner and Funke, 2014; van de Walt and Fitchett, 2020). The country is characterised by complex rainfall and temperature climatology owing to its geographic position (between 22-25° S and 16-33° E), in the subtropics (van de Walt and Fitchett, 2020; Roffe *et al.*, 2020b). Therefore, the climate in KwaZulu-Natal and Eastern Cape provinces results from a complex interaction of topography, western boundary current in the Indian Ocean and the position of South Africa relative to significant atmospheric circulation features (Ndlovu and Damlie, 2020; van de Walt and Fitchett, 2020).

The climate in the KwaZulu-Natal and Eastern Cape Provinces is generally mild and has warm temperatures with subtropical conditions near the coast (Landman *et al.*, 2017; Lakhraj-Govender and Grab, 2018; Abdel-Hamid *et al.*, 2020; Graw *et al.*, 2020). It is noteworthy to highlight that, seasonal classification on the bases of both temperature and rainfall metrics are complex and poorly understood in South Africa (van de Walt and Fitchett, 2020; Roffe *et al.*, 2020a). Nonetheless, KwaZulu-Natal and the Eastern Cape Provinces are characterised by warm humid and rainy summers with approximately 25°C mean temperature and 800mm rainfall that starts around September and ends in March (Ndlovu and Damlie, 2020). Winters are relatively cold and dry; mean temperatures are often below <20°C and rainfall frequency is low, this season spans from April to August (Ndlovu and Damlie, 2020). However, cut-off lows can bring significant amounts of rainfall in these locations during winter (Favre *et al.*, 2013; Landman *et al.*, 2017).

As a result of complex rainfall seasonality and characteristics, South Africa has three broadly accepted rainfall zones, namely, the Summer rainfall zone (SRZ), Winter rainfall zone (WRZ) and year-round rainfall zone (YRZ; Roffe *et al.*, 2020a,b). The eastern region of South Africa is predominantly comprised of SRZ locations, but the southwestern part of Eastern Cape merges to the YRZ (Roffe *et al.*, 2020a). The western coast of the Eastern Cape Province is situated in the transition between summer and winter rainfall zones, contributing to the complex meteorology of the province (Molekwa, 2013; Mahlalela *et al.*, 2020). However, both KwaZulu-Natal and Eastern Cape receive rain from both summer and winter rainfall-producing systems, mostly the ridging high-pressure system and tropical-temperate trough cloud bands (Favre *et al.*, 2013; Roffe *et al.*, 2020b). A significant percentage of summer rainfall in the SRZ locations is produced by tropical-temperate trough cloud bands, followed by the ridging high-pressure systems; the remainder is

produced by mesoscale convective complexes (Blamey and Reason, 2013; Mahlalela *et al.*, 2020; Roffe *et al.*, 2020b).

Generally, locations in the SRZ receive rainfall from October-March, with the highest rainfall quantities received between November and February (Roffe *et al.*, 2020b). However, the eastern coastal areas are classified as long SRZ locations, which means that the rainfall season in these locations starts early, around the 1-28 September and ends in March (Roffe *et al.*, 2020a). According to Roffe *et al.*'s (2020a) finer scale seasonal classification, both Umzimkulu and Lusikisiki are long summer rainfall locations. The early summer rainfall in these long SRZ locations is attributed to moisture influx from the warm Agulhas current, cut-off lows and ridging anticyclones (Roffe *et al.*, 2020a). Agulhas Current in the Indian Ocean causes the east coast to be significantly warmer and humid (Landman *et al.*, 2017). The moist air from the Indian Ocean provides moisture for rainfall through transporting latent heat required by onshore flowing winds in the east coast (Nel *et al.*, 2010; Landman *et al.*, 2017; Koseki and Semissie, 2018). The warm moist air from the Indian Ocean rises along the steep topography to the eastern escarpment and results in orographic rainfall along the escarpment (Nel *et al.*, 2010; Landman *et al.*, 2017). This is also partly responsible for the broad spatial rainfall variability within the provinces, where orographic rainfall near the Drakensberg Escarpment contributes to the highest rainfall totals (~1000mm/year) recorded near that area, and the restricted flow into the inland causes the lowest (~500mm/year) rainfall received in the western interior of both KwaZulu-Natal and the Eastern Cape Province (Hosu *et al.*, 2016; Landman *et al.*, 2017; Mahlalela *et al.*, 2020). In Eastern Cape, the spatial variability is more complex because of the YRZ in the southwest of the province (Mowlekwa, 2013; Abdel-Humid *et al.*, 2020). Rainfall also varies on broad temporal scales in both provinces (i.e. over intra-annual, and inter-annual to inter-decadal scales) associated with El

Niño southern Oscillation (ENSO), southern Annular Mode (SAM) and Indian Ocean sea surface temperature (Landman *et al.*, 2017; Abdel-Hamid *et al.*, 2020). Climate and rainfall seasonality are fundamental to the agricultural productivity of both subsistence and commercial farmers within KwaZulu-Natal and the Eastern Cape Province (Caister, 2012). Therefore, it is important that rainfall characteristics and seasonality are extensively understood because these variables are projected to change as a result of climate change (Roffe *et al.*, 2020b). Changes in rainfall seasonality and other climate variables will hinder crop production and food availability in the country, therefore, vulnerabilities that may arise as a result of climate change must be determined to minimise risks and ensure effective adaptation (Masipa, 2017; Roffe *et al.*, 2020b).

3.2 Socio-Economic Conditions

3.2.1 KwaZulu-Natal

KwaZulu-Natal covers 93,350 km² (STATSSA, 2017; Ndlovu and Damlie, 2020). In 2017, the province was recorded as the second most populated province in South Africa with a population of approximately 11 million residents (STATSSA, 2017). KwaZulu-Natal is predominantly comprised of the Zulu tribe and therefore isiZulu is the common language of expression (Rudwick, 2008). The province plays an important role in the country's economy, generating approximately 16% of the GDP, which makes it the second-largest contributor to the economy after the Gauteng Province (STATSSA, 2017). The most prominent economic spheres in KwaZulu-Natal are tourism, manufacturing, agriculture, finance, and community services (STATSSA, 2017; KwaZulu-Natal Economics and Trade, 2019). The agriculture sector of KwaZulu-Natal contributes 3.5% to the national GDP (KwaZulu-Natal Economic and Trade, 2019). The trademark crops are maize, soybeans and wheat and dry beans (KwaZulu-Natal Economics and Trade, 2019). The trade of indigenous medicinal plants is presumed to be worth

R62 million/year, and considerably higher than maize trade, but it is predominantly an informal sector, thus its contribution to the national GDP is not clear (KwaZulu-Natal Economics and Trade, 2019). The agriculture sector is comprised of both livestock farming and crop production (Table 3.1). Farming productivity in KwaZulu-Natal is important for food availability in the country and agricultural export trade (KwaZulu-Natal Economics and Trade).

Table 3.1: KwaZulu-Natal contributions to the country's production of goods

Good/animal	Contribution to the country's production (%)
Pigs	10.0
Broilers (Chicken meat)	10.3
Layers (eggs)	10.3
Goats	13.0
Cattle	19.0
Commercial pork	36.0

(Adapted from KwaZulu-Natal Economics and Trade, 2019)

KwaZulu-Natal hosts a considerable proportion of South Africa's subsistence farmers (STATSSA, 2017). However, subsistence farmers are not considered significant contributors to the agricultural productivity of the province (Rukema and Umubyeyi, 2019). Approximately 15% of the province's surface area is arable, but only 3.3% of it is regarded as high potential lands, and it is mainly owned by commercial farmers, owing to the 1913 natives Land Act (Modise and Mtshiselwa, 2013; KwaZulu-Natal Socio-Economic Review Outlook, 2019). Therefore, the livestock production data (Table 3.1) is an aggregation of commercial farming productivity and mostly does not account for subsistence farming productivity (KwaZulu-Natal Economics and Trade, 2019). Nonetheless, subsistence farming plays a significant role in rural household food availability and accessibility, which accounts for 50% of the food security components (Tibesigwa and Visser, 2015; Shisanya and Mafongoya, 2016). In addition, approximately 37% of the population in KwaZulu-Natal are beneficiaries of government grants (Chpfupa and Wale, 2020). This means that the province has the fourth-highest percentage of households receiving

social grants in the country (STATSSA, 2017). Higher social grant beneficiary percentages indicate low salary-based incomes, which is mostly correlated with poverty and food insecurity (Chakona and Sheklton, 2019). This is because social grants do not fulfil households needs, specifically food security (Chakona and Sheklton, 2019; Waidler and Devereux, 2019). Therefore, subsistence farming is an important food source and assures food availability for most rural community members (D'Haese *et al.*, 2013; Bakre and Dorosamy, 2015). Subsistence farmers in these areas mainly use IKS to secure adequate annual yields (Ngcoya and Kumarakulasingam, 2017; Rukema and Umubyeyi, 2019). Nonetheless, food insecurity is still a problem for a majority of households in the province, and the country in general, despite several claims of national food security (D'Haese *et al.*, 2013; Shisanya and Mafongoya, 2016).

Some studies highlight the importance of IKS in food production and climate change adaptation, particularly for subsistence farmers in the province, this research has mostly focused in Northern KwaZulu-Natal (Basdew *et al.*, 2017; Ngcoya and Kumarakulasingam, 2017; Rukema and Umubyeyi, 2018). The studies were conducted in the interior KwaZulu-Natal, all the locations are North of Umzimkulu; Umlalazi (143 km northeast), Umgungundlovu (107 km north), eMtubatuba (376 km northeast) and Umsinga (253 km North), respectively. The research represents IK that is crucial to communities' survival and sustainability. More than 70% of KwaZulu-Natal adult population practice subsistence farming (Bakre and Dorasamy, 2015). Therefore, although the documented provincial agriculture statistics are mostly representative of commercial farming, IKS informed subsistence farming plays an important role in food availability for rural households.

3.2.2 The Eastern Cape Province

The Eastern Cape Province is dominated by AmaXhosa tribe, and IsiXhosa is the common medium of expression amongst the residents (Mwinda *et al.*, 2019). It is the second-largest province in South Africa, covering 168,966 km² and home to 12.6% of the country's population (Mapeiyada *et al.*, 2020; 2016; STATSSA, 2017). The primary resource sectors (i.e. agriculture and mining) from the Eastern Cape Province account for 1.7% of the national GDP while the province overall contributes 8% to the South African GDP (STATSSA, 2017). The Eastern Cape Province is considered the poorest province in South Africa, with 41.8% of its population relying on social government transfers (Musemwa *et al.*, 2015; Santhia *et al.*, 2018). Poverty in this province is attributed to the high unemployment rate (28.6%), and in 2018, this was higher than the national unemployment rate of 26.7% (STATSSA, 2017; Ngumbela *et al.*, 2019). This status is a result of the sub-optimal performance of provincial economic activities and overall national decline in economy (Santhia *et al.*, 2018). Therefore, high poverty levels are one of the top social challenges in the province (approximately 70% of the population living below the poverty line), followed by significant disparities in service delivery between rural and semi-urban and/or urban areas (Lupuwana, 2008). Income and service delivery inequalities have strong historical roots in South Africa, they are still pervasive more than 20 years post-apartheid and are advancing within racial groups in the Eastern Cape Province (Westaway, 2013; Ebenezer and Abyssinia, 2018). These challenges are attributed to dysfunctional government structures and high levels of corruption (Lupuwana, 2008; Santhia *et al.*, 2018). The frequent climate-related extremes and poorly developed adaptation policies contribute to the high levels of food insecurity in the province, which mostly affects the rural poor populations (Santhia *et al.*, 2018). The Eastern Cape Province is predominantly rural (Goduka, 2012). Therefore, inequalities in service delivery are biased against a majority of the population, also, food insecurity and poverty are notably

associated with rurality (Jacobs, 2009; Goduka, 2012; D’Haese *et al.*, 2013). As a result, the province has the highest net rural-urban and inter-provincial migration in the country, because the youth and a majority of the male population are moving to other provinces to seek better opportunities for sustaining their livelihoods (Lupuwana, 2008; Walz *et al.*, 2020). The high net migration to other provinces contributes to disruption of IK transmission social networks and still does not adequately alleviate poverty and food insecurity in the Eastern Cape Province (Lupuwana, 2008; Basdew *et al.*, 2017).

The eastern part of the Eastern Cape Province is predominantly comprised of rural areas and communal lands (Molekwa, 2013). This region is the former homeland and has the highest population density in the province (Graw *et al.*, 2020). The homelands or Bantustan areas were created during the apartheid era to enforce residential segregation and marginalise the black population from major political and socioeconomic activities (Tode and Turok, 2018; Kwenda *et al.*, 2020). Former homelands are still mostly poverty-stricken and still struggle with service delivery (Kwenda *et al.*, 2020). Farms in the eastern part of the province are mostly owned by households with the lowest income and therefore, are an important resource for food production (Molekwa, 2013; Graw *et al.*, 2020). Moreover, agricultural activities in these areas are mainly rain-fed, therefore climate changes, particularly rainfall seasonality have negative impacts on farming productivity and food availability in rural areas of Eastern Cape (Madleni, 2010; Kibirige and Obi, 2015). Mandleni (2010) state that climate variability and change has led to fundamental losses in subsistence agriculture through droughts that caused water and feed shortages (Kibirige and Obi; 2015). However, some studies have demonstrated that community members from rural areas in the Eastern Cape Province use IKS to facilitate food production and adapt to climate

change (Lupuwana, 2008; Dweba and Mearns, 2011; Garutsa and Nekhwevha, 2018). The research also reinforces the need for rediscovery and preservation of IKS to promote environmental and cultural conservation in the province (Goduka, 2012; Meyiwa *et al.*, 2013; Yusuf *et al.*, 2014; Garutsa and Nekhwevha, 2018). Dweba and Mearns (2011) point out that neglect of IKS is partly responsible for the rising food insecurity in some areas in the Eastern Cape Province. This is because neglect of IKS leads to a loss of valuable and inexpensive agricultural strategies and perpetuates disregard for low input traditional wild vegetables (Dweba and Mearns, 2011; Mavengahama *et al.*, 2013). Therefore, more research is required to explore IKS and highlight its value for climate change adaptation and food production simultaneously.

3.3 Description of Umzimkulu and Lusikisiki

3.3.1 Lusikisiki, Eastern Cape

Lusikisiki (31.3683° S, 29.5688° E) is the capital area of the Mpondo Kingdom in Ingquza Hill local municipality. This town is under OR Tambo district, which is one of five (Amathole, Alfred Nzo, Chris Hani, Joe Gqabi) district municipalities that are characterised by high population density, severely poor rural areas and intensely underdeveloped towns that mainly serve as trading hubs (EC Vision 2030 Provincial Development Plan; Table 3.2). Lusikisiki is located in the northeast of the Eastern Cape Province and is part of the former homeland areas (Figure 3.1; Graw *et al.*, 2020).

Table 3.2: Demography of the study areas

	Umzimkulu	Lusikisiki
Province	KwaZulu-Natal	Eastern Cape
District Municipality	Harry Gwala	O.R. Tambo
Population	180,302	278,481
Racial Make-Up	Black Africa-95%	Black Africa-94%
	Coloured-3.5%	Coloured-1.9%
	Indian and Asian- 0.9%	Indian and Asian-1.8%
	Other-0.9%	White-0.7%

Languages	Isixhosa isiZulu English Afrikaans	Other-1.6% IsiXhosa English isiZulu
Annual Average rainfall	768 mm/year	1016 mm/year
Average Temperature	25°C	16.8°C
Elevation	813 m. asl	612 m. asl

(Adopted from STATSSA, 2011; Umzimkulu Integrated Development Plan, 2014; Ingquza Hill Integrated Development Plan, 2017).

The area is predominantly rural and comprised of some of the lowest-earning households in the country (Molekwa, 2013). Lusikisiki has vast communal lands that are used for both livestock grazing and crop farming. Ingquza Hill local municipality is argued to be in one of the municipalities with the largest arable land in the province (EC Vision 2030 Provincial Development Plan). However, rural community members within the municipality mostly practice subsistence farming, therefore this natural resource is under-utilised. This is mostly due to insufficient financial and mechanical resources available to community members, which adds to the poverty and hunger in this area (Ngumbela *et al.*, 2019; EC Vision 2030 Provincial Development Plan). Furthermore, Lusikisiki is one of the areas with the least number of formally educated women in the Eastern Cape Province and has many female-headed households (Tawiah and Quan-Baffour, 2017). This means that most household leaders in the area have limited options on the type of socio-economic activities they can engage in, thus have insufficient alternate food sources (Tawiah and Quan-Baffour, 2017; Chakona and Sheklton, 2019).

3.3.2 Umzimkulu, KwaZulu-Natal

Umzimkulu (30.2642° S, 29.9191° E) is in the southern interior of KwaZulu-Natal. This area was classified as an Eastern Cape area within KwaZulu-Natal. It is bordered by KwaZulu-Natal areas,

including Ixopo (24km north), Harding (45km south) and Kokstad (85km south-west) (Umzimkulu Municipality Integrated Development Plan, 2014). Umzimkulu was declared a part of KwaZulu-Natal in 2006, in accord with the erstwhile redetermination of municipal boundaries (Umzimkulu Municipality Housing sector Plan, 2008). Umzimkulu is now classified as one of five local municipalities under the Harry Gwala District, but some scholarly research still classifies it as part of the Eastern Cape Province (Umzimkulu Integrated Development Plan, 2014; Mahlalela *et al.*, 2020). The Harry Gwala District is home to approximately 5% of the KwaZulu-Natal population, and Umzimkulu is the most populated local municipality in the district (STATSSA, 2011). Umzimkulu is a rural local municipality with 98% of its population residing in rural areas and the remainder in living semi-urban areas (Umzimkulu Municipality Housing sector Plan, 2008). Less than 10% of the households in Umzimkulu have access to piped water, this is one of several service delivery issues in this area (i.e. 8.3% refuse removal and 6.4% access to sanitation services) (STATSSA, 2011). This is also a marker of poverty and neglect by the government (STATSSA, 2011). Although 95% of the households that practice agriculture in the area are black Africans (STATSSA, 2011), this is not representative of the major contributors of food production in this area, evidence suggests that this industry still mirrors past sociopolitical status prior 1994 (Mthethwa, 2015).

3.3.3 Types of Farming in Umzimkulu and Lusikisiki

Subsistence crop farming is the most practiced type of agriculture in Umzimkulu and Lusikisiki since the dissolution of the Transkei Agricultural Corporation (TRACOR) in 1995 (Jongisa, 2005). The areas were both under the Transkei Corporation which was formed by the former Transkei government to fortify conventional farming through service delivery for all commercial field activities (Jack, 1997). The dissolution of TRACOR resulted in reduced cultivated

commercial land because the landowners did not generate enough capital to support production costs (Mkile, 2001). Although TRACOR funded commercial farming, which was predominantly white farmers, there is no evidence to suggest that the communities were victims of the Group Areas Act of the apartheid era that mostly entailed community displacement and land dispossession (Modise and Mtshiselwa, 2013; Molekwa, 2013). However, they also did not receive agricultural support from the government. This suggests that IK agricultural management and adaptation measures for subsistence farming have been used for generations in these two areas and are not implemented to replenish farmlands that community members are not familiar with working on. Various types of crops are sowed in the areas (Jongisa, 2005). Potatoes, cabbage and spinach being the most common crops, and corn is the main staple food (Jongisa, 2005). Most community members practice poultry farming, and more than half of the households have at least two cows and other livestock (Umzimkulu Integrated Development Plan, 2014; O.R. Tambo Master Agri-Park Business Plan).

3.4 Conclusion

The general climate of KwaZulu-Natal and Eastern Cape suggests that Umzimkulu and Lusikisiki may have complex climate conditions and rainfall seasonality. Furthermore, Umzimkulu and Lusikisiki are poor rural areas that have a significant number of community members who practice subsistence farming. Therefore, they are good areas for investigating IKS in agricultural management. These two study areas are located in the SRZ where rainfall seasonality is argued to change. This means that subsistence farmers within the areas have had to implement adaptive strategies to ensure agricultural productivity and therefore can provide the data required to achieve the aims and objectives of this study.

4. Methodology

This chapter covers the processes involved in the collection and analysis of data in this study. This chapter begins with the researcher's reflexivity because positionality within the study areas played a role in data collection and analysis. After the researcher's positionality, the research design and methodologies are outlined. The chapter concludes with stating ethical considerations and practical measures that were considered to protect the respondents and the integrity of the data.

4.1 Researcher's Positionality

Positionality is concerned with people's perception of the world from various embodied locations (Martin, 2017). In research, it refers to the views and the position a researcher adopts in relation to the topic of study (Manohar *et al.*, 2017). The position that a researcher adopt is influenced by factors such as age, sexuality, ethnicity, social class, linguistics, geographical and intellectual location, culture, and race (Qin, 2016). This largely represents the background experiences that form a researcher's perception and mainly display intersectionality of social identities for most researchers, including myself (Carstensen, 2014). Bourke (2014) states that although presenting objective results and analysis is the main component in contributing to knowledge and scholarly literature, researchers must be aware of their subjectivities, particularly in qualitative studies. There is always a degree of subjectivity involved in collecting and analyzing qualitative data (Hoogendoorn and Visser, 2012). Therefore, my perceptions and beliefs influence the way I ask questions, and understand information and interpret responses. Furthermore, my characteristics such as ethnicity, race and gender mainly influence the way participants of the study perceived me.

I am 24-year-old black woman . I was born and raised in Clydesdale location in Umzimkulu. I attended both primary and high school in Clydesdale, South Africa. I have a relationship with both study areas, Lusikisiki, my home from my father's side and Umzimkulu, my home from my mother's side. I spent most of my time in Umzimkulu but visited Lusikisiki for winter and summer holidays. Therefore, my own IK is constructed by, and similar to, the communities that I will be engaging within this study. My IK is mostly influenced by Umzimkulu culture and history, but I identify as an indigenous community member of both areas and I am perceived in that manner by the community members in these places. I grew up in a female-headed household. There were not distinguished gender roles between me and my brothers in our household, which was viewed as unconventional by some community members. This was never a topic for discussion in my household because my grandmother constantly reminded us that we were all children, and that was the only thing she considered when we were required to do chores. At home, we were poor and predominantly food insecure when I was growing. This was not uncommon in our community, although from my view, at home, we were the poorest and most food-insecure within the 5km radius. I arrived at this conclusion through observing the rate at which we would borrow food such as mealie meal, salt and cooking oil from other households compared to how other households borrowed from us. Needless to say, we never had enough food to be able to lend people anyway. We have always been involved in different scales of subsistence farming, therefore, relatively adequate food availability was largely seasonal because we did not have alternate food sources and my grandmothers' government grant, and my aunts' and mothers' temporary retail store jobs did not fulfil all the needs of a more than 10 person household. Food availability was usually greater during the summer and beginning of autumn (December-March). This was because in September my grandmother sowed in her garden and most of the crops

matured at the end of November to the beginning of December and then in February to March we would start eating 'autumn foods'. Therefore, my initial perception of the world is largely formed by the lens of poverty, rurality, and family unity.

One of the most important values instilled in me by my family is the importance of education as a tool against poverty, hunger and the betterment of myself. However, my mother, aunts and my grandmother all had high school and/or college education and it did not lead to poverty alleviation for them. My family has always advocated for education, but the contextual inefficiency and cultural detachment of western knowledge have also been constantly highlighted. Therefore, there has always been a clear demarcation between the two knowledge systems and an indication to always maintain these boundaries unless the information unequivocally parallels or compliments each other. However, although the relationship between these epistemologies was not formally established, I sometimes used IK exposure to understand and memorise information from school. For example, I was introduced to the use of kraal manure as a fertiliser at home, without extensive explanation on the science behind its practicality. This experience facilitated my understanding of the concept once it was introduced to me at school.

From a young age, I knew that seeing fog in the morning, meant that I did not have to wear or carry a jersey at school that day because it was going to be hot. I was always involved in farming, whether through assisting with tilling, following my mother with kraal manure when she was sowing corn or weeding after a few weeks of sowing. I have also been habitually exposed to IK strategies for agricultural management, daily activities and risk reduction. However, these observations and activities were not explained to me, I copied and deduced from my elders and sometimes I was following instructions to do so. In my household and the culture of our community generally, challenging elders and probing for more information than they feel I need

to know is discouraged and a sign of disrespect. These cultural limitations prevented rigorous conversations added to my skepticism of IK and facilitated the futile comparison between IK and western science. This was founded on the basic appreciation that western science offered me more background, underlying causes and thus more conviction, and also emphasised the importance of empirical evidence for knowledge.

I was introduced to natural western science through natural science (NS) subject in Grade Four and an expanded form including landscapes and climatology in Geography in Grade 10. I was intrigued by NS in grade five when the concept of pollination was introduced, because from that moment the observation of bees and butterflies moving from one plant to the next, an act I have seen for most of my life prior, suddenly had meaning. This is when my love and passion for the natural environment transpired and carried meaning to me. From this moment, I have always tried to find scientific explanations for my observations, particularly related to plants and animals. Before the introduction of a compartmentalised view of nature, my perception of nature was informed by the everyday interactions that varied depending on seasons because of various activities governed by meteorological seasons. Moffat (2016) emphasises that there is more than one way of knowing and applying knowledge. Being born and raised in a rural community and engaged in subsistence farming, I have always been aware of this. My personal ontology is significantly influenced by both IK and western science information, but this is the first time I merge these systems in an equilibrium stance that seeks to draw informed conclusions and contribute to broader knowledge. These two parts of my identity influence my perceptions on IK, agricultural management and climate change adaptation. I believe that poverty in my childhood added to my recently changed belief of associating IKS with lack of better resources rather than an extensive knowledge resource that sustains cultural identity and a significant tool to preserve

community values and contribute to environmental management. Regardless of this perception of IK, I have always been curious to understand the processes behind used indicators and the keen skills displayed by my elders in weather forecasting and risk reduction and I was trying to situate these components within scientific discourse. As a result, this study was inspired by my desire to understand the relationship between ringing metal and abating a hail storm, from physical science and/or climatological perspective. Although this research does not address this particular question, this demonstrates the influence of IK in my world views and the constant search to situate the significant part of my roots and ontology within scientific discourse.

4.1.1 Access

Positionality can inhibit or facilitate different aspects of the research process (Qin, 2016). My background and ethnicity facilitated both physical and intellectual access to the study areas. I did not require extended time to establish a relationship and/or trust to communicate with the participants. However, as an indigenous community member, I am aware that western systems can exploit our communities. Therefore, because of the cognizance of my power as a researcher, I was hyper-aware of my outsider position as a postgraduate student and the assumed perceptions of my participants towards me. Furthermore, I am particularly mindful of cultural norms and respectful language around elders, which may have limited my exploration of the subject topic. I ascertained to stay within the bounds of both community and the university's ethics and not present exploitative attitude towards community members and our IK. Nonetheless, some respondents viewed me as one of the children in the community and most of their perceptions and comments about me were regarding my age and not my level of education nor researcher status, with statements like:

“You children, you are not interested in farming though, young boys do not even know how to milk a cow. Can you even hold a garden hoe and plough? I doubt it.” (NMZ 1.3, 1.4, 2. 3A)

While my cultural lens allows me to identify with community members and understand IK in these areas, my experience because of my age and level of involvement in farming activities limits my value in the research topic. It was important that I understand this fact before and during data collection and throughout the data analysis process. This facilitated presentation of results that are a representation of the participants’ views and are not distorted by my western-influenced beliefs about the natural environment, climate change and IKS. Furthermore, this awareness forced me to broaden my questions to enquire about information that is considered ‘general’ information in the communities. I did this to ensure that I do not discount valuable IK because of the conception that it is not knowledge and presumed that all community members perceive it in the manner I and my family do. It is crucial that I understood my pre-conceived perceptions and understanding to ensure that my biases do not steer data analysis but use my insider identity to inform a deeper understanding of information and facilitate data collection and analysis (Erlingsson and Bryiewicz, 2017).

4.1.2 Power

Culturally, racially and with language and ethnicity, I consider myself an insider in the communities. However, I understand that my position as a university student and a researcher who is collecting data, and the age gap between myself and most of the participants deemed me an outsider to some community members (Milligan, 2016). As a member of the communities, I am also aware of the appraisal of education in these two study areas. My communities, appreciate

and encourage education, I knew this before embarking on the data collection process. Therefore, my researcher position allowed me access to rigorously engage with elders in an approach they would commonly be skeptical in if I am just a child from the community. Furthermore, as a postgraduate student, I am aware of the perceived and absolute regard of my intellect that most participants assumed when I explain the study. Therefore, I highlighted the importance of my participants' contribution to knowledge creation and research to regulate power dynamics. This emphasised co-construction of knowledge between myself and the participants. As a result, I exhibited an average understanding of information on the areas' IK strategies without overshadowing the views and of the participants and, constantly emphasising the value of their knowledge in this research. This was important to me to display indigenous insider knowledge and affirm the concept of co-production of knowledge, display genuine interest and ensure trust.

4.1.3 Participants' Perception on the Researcher's Identity and Position

My identity and my positionality as an indigenous insider with outsider influence did not exempt me from the perception of some participants towards me and questions regarding my motives for conducting this study in these specific areas. With statements such as:

“Are you one of these political parties that are always coming here and promising us things?” (EC 2.3)

“Who are you doing this research for? It is not like we will see or use this information.” (EC 1.4)

Furthermore, other participants challenged my interest in the study and my positionality through the statements:

“So you want information about our farming. I hear you, and I will give it to you but I doubt you can even carry a garden hoe and plough or pluck weed. You are here with just your pen and books. What are you going to do with this information then?” (EC 2.1)

My position as a researcher offered me the power to probe and seek understanding of the community members' perceptions regardless of their doubts. I would generally be limited to rigorously engage in as just a young woman with my elders, particularly after they decided that I am not genuinely interested. Nonetheless, most of the comments about my education were seeking to understand the content and the reason for my chosen degree, while others were asking the cost of education immediately followed by encouragement to take care of my parents whom they assumed were paying for my education. Overall, my interactions with participants were simplified by my familiarity with the communities and the community members' s views on education and eagerness support any child's education in the area.

4.2. Research Design

This research makes use of qualitative design and methods employed by Ebhuoma (2017) and Rukema and Umubyeyi (2019). These studies engage in rigorous interactions with community members of the research study areas to understand community perceptions on environmental change, adaptation actions and reasoning behind their views (Ebhuoma, 2017; Rukema and Umubyeyi, 2019). IK for weather forecasting and agricultural management is mostly developed and used by rural substance farmers, therefore they are custodians of traditional knowledge informed management strategies (Gadzirayi *et al.*, 2006; Orlove *et al.*, 2010; Robinson and Wallington, 2012; Chambers *et al.*, 2017; Ebhuoma, 2017). This relationship is argued to be motivated and maintained by their close relationship to the natural environment because of the

overwhelming dependence on environmental viability for agriculture productivity (Robinson and Wallington, 2012; Chambers *et al.*, 2019). Therefore, this study engaged with subsistence farmers from two rural areas, Umzimkulu and Lusikisiki to achieve the objectives. This research also adopted interpretivism, which is based on exploring a phenomenon through the perspective of those who experienced and make sense of it (Suter, 1996; Mojtaba *et al.*, 2013). Furthermore, interpretivism aligns with the core attributes of IK because it is founded on the notion that people develop practical strategies without deliberate consideration of the laws of science or nature (Rahman, 2017). The research is informed by primary data collected through semi-structured interviews with subsistence farmers from Umzimkulu and Lusikisiki. Participants were selected purposefully and met eligibility criterion that signifies potential to inform the research question and provide understanding for the phenomenon under study. The criterion was developed based on questions of study and influenced by supporting literature (Chambers *et al.*, 2013; Ebhuoma, 2017). The aim was to investigate various IKS cues essential in subsistence agricultural management in Umzimkulu and Lusikisiki. Qualitative research design offered an opportunity to establish depth in community members' beliefs about the indicators and adaptation strategies used (Longhurst, 2003). This was important in introducing dialogue about the used indicators, perceived reliability and the reasoning behind participants' views, particularly regarding preferences between IK and national service weather reports. Qualitative research design and the adopted methodology in this study also promoted investigation of the phenomenon in respondents' homes, their regular and comfortable environment. This also presented an opportunity for the researcher to observe the different stages of farming each farmer were in (i.e. the dormant gardens after harvest or growing winter crops) and sometimes participate in farming activities with some respondents during interview sessions. In addition, the semi-structured

individual interviews approach allowed the participants to express their views on IK and plant and animal behaviour for tracking seasonality, without the restrictions associated with the close-ended nature of structured interviews or quantitative inquiry (Elkatawneh, 2016). The home setting also removed participants from potential disapproval and judgement from other community members (Tongco, 2007). All participants involved in the study were chosen using and eligibility criteria that determined basic similarities that qualifies them as productive members of the study.

4.2.1 Sampling and Eligibility Criteria

The researcher intended to extensively investigate subsistence farmers' perception of climate variability and change perception on agriculture, use of IKS indicators, and their perceived reliability in informing agricultural management. Homogenous purposive sampling was applied in selecting respondents, to sought participants that had similarities fundamental in providing relevant data. The descriptive variables were based potential value of information on climate change, climate change adaptation experience in agriculture and IKS in agricultural management (Orlove *et al.*, 2010; Chambers *et al.*, 2013; Ebhuoma, 2017). These similarities between respondents maximise the value of the data collected (Etikan *et al.*, 2016). Participants share similar characteristics that qualified them to be part of the study, which are:

- i. Respondents are residents of and practice subsistence farming in Umzimkulu or Lusikisiki for at least 15 years.
- ii. All participants are over the age of 30 years old.

These eligibility requirements represent experience in subsistence farming in these areas and a level of awareness of climate conditions (Deressa *et al.*, 2011). Some participants were identified

through snowball sampling through recommendations by their neighbours and/or relatives. Subsistence farming in rural areas depends on environmental viability (Ebhuoma, 2017). Therefore, practicing farming for a minimum of 15 years suggests that community members have had to develop and implement pragmatic adaptation measures for climate variability and change to promote yield success (Gill, 1991; Seoraji-Pillai, 2011). Goduka (2012) states that it is paramount for any IK researcher to establish the number of years a respondent has been residing in an area because this represents the kinds of natural resources they have been exposed to, which is a significant part of their experience and contribution to research. Furthermore, although age is conversely related to farm output it is highly correlated to farm experience and ultimately IK experience in rural areas (Ford *et al.*, 2016). Therefore, in this study, participants over the age of 55 are considered custodians and teachers of the knowledge, this is because these respondents have been practicing farming since they were teenagers and therefore possess more than three decades worth of experience. The criterion was used to purposefully select participants that provided rich and in-depth information about the use and practicality of IKS in these areas.

This study is not focusing on drawing broad generalisations about IK phenomenon or creating a statistically representative quantitative database but rather aims to understand IK that is prominent in agricultural management Umzimkulu and Lusikisiki. The sample size was, therefore, determined by data saturation of the information relevant to complete research objectives (Etikan *et al.*, 2016). Most of the participants engaged with have ancestry in the areas where they practice subsistence farming, therefore their views on IK and climate change perception represent multi-generational knowledge of the study topic (Lowma and Mayblin, 2011; Sonn *et al.*, 2013). This provided a synopsis of qualitative changes relative to what is considered normal in the natural environment and highlights local range variability (Savo *et al.*, 2016). Moreover, it facilitated

proper articulation of recalled memories and experiences to illuminate the interpretation of past events within narratives thus increased credibility of the data (Sonn *et al.*, 2013). This criterion also assured internal and external validity of the study, on the premise that the similarities between participants facilitate access to credible detailed data about subsistence agricultural management in these areas (Olsen, 2013; Palinkas *et al.*, 2015). Furthermore, purposive sampling assured collection of relevant data within a given time period and with the financial resources available to the researcher. This sampling procedure also reduces the likelihood of error because it targets participants that are knowledgeable about the topic of investigation (Palinkas *et al.*, 2015). This is particularly important for investigating a cultural domain with knowledgeable individuals within it because the goal is to gain as much in-depth insight in the subject matter being researched without proportionality being a major concern (Ebhuoma, 2017).

In total, twenty-two households were involved in this study, with a total of 28 participants. A household represents an institution that fosters IK, promotes the adoption of the tacit knowledge entrenched in indigenous worldviews by the youth (Goduka, 2012). Although engaging with more than one family member was due to respecting cultural norms, it presented an opportunity to extensively engage in discussion regarding IK perceptions on climate variability and change, phenology informed IK, its value and reliability with at least two generations in each family. This demonstrated some differences and significant similarities in the perception of IK in a family. Subsistence farming is argued to be feminised in rural areas (Ebhuoma, 2017), this study is not opposed to this view but the researcher sought male and female respondents equally, admittedly, there were more female participants than males, but gender was not deliberately considered in data analysis. This is because this study is not addressing different views on agricultural management based on gender. Furthermore, there was no indication that female participants

needed permission from or were uncomfortable expressing their views in front of their male counterparts during interview sessions, as it has been suggested by other studies on IK topics (Ebhuoma and Simatele, 2019).

4.3. Data collection

The study is informed by qualitative data obtained through semi-structured interviews with subsistence farmers from Umzimkulu and Lusikisiki. Fieldwork for data collection was divided into two parts, this was mainly because of time and financial resources available to the researcher. The first part of data collection started on the 20th of June 2019 and ended on 11th July 2019, and the second part of that collection started on 27 August 2019 to 13 September 2019. The interviews were held at the homes of participants and the sessions were at least 45 minutes each.

4.3.1. Interviews

The study involved 16 participants from Lusikisiki in Eastern Cape and 14 participants from Umzimkulu KwaZulu-Natal. Each participant represents a household and often the views informed by knowledge gained from other community members. These farmers were asked prompting questions regarding their chosen farming strategies aimed to understand their reasons for chosen agricultural management strategies. Some questions arose from observations during interviews, especially when the researcher was assisting in garden activities during the interview session i.e. watering, harvesting or weeding. This is because community members perceived me as a child and expected me to assist while they were working. Semi-structured nature of the interviews granted the researcher room to establish rapport with the participants and have an in-depth conversation about their perceptions (Boyce, 2006). Conducting interviews in respondent's

homes using local dialect further facilitated the conversational style of data collection, thus ensuring the collection of rich non-restricted information (Marshall, 1996; Longhurst, 2003).

Some of the questions that were asked to participants are (Appendix 3):

- I. When do you start sowing?
- II. Why do start sowing around that time?
- III. Did you always saw around this time?
- IV. How did you know this was the right time to start sowing, who taught/told you?

These types of questions implicitly and explicitly invited participants to recount stories, some from their childhood, and others as young brides of the areas from more than 30 years ago. These narratives of agricultural activities provided the main framework to form an analytical structure through identifying trends and developing themes that align with the study objectives (Coffey and Atkison, 1996). From these narratives and direct answers to some questions, participants' perception on climate variability and change were noted and their beliefs about the underlying causes for the observed changes were discussed. Therefore, providing insight into the relationship and the dependence of farmers on the natural environment (Ajani *et al.*, 2013). Furthermore, the researcher sought to explore the types of IK informed indicators used in agricultural management. This was achieved by asking more follow-up questions regarding the sowing season, by asking questions such as:

- I. How do you know when it is nearing sowing season?
- II. Have you ever not started sowing around the time you usually do? Why?
- III. Are there things, except weather conditions that you also notice when it is nearing sowing season?

The questions above are not exhaustive of the questions asked during data collection but they were part of all interview sessions with participants from both Umzimkulu and Lusikisiki. They were asked to explore information about the observed changes in IK informed indicators and farming strategies. This enabled collection of rich data that adequately captured respondents' views and their reasoning, thus contributing to achieving objectives aimed at understanding the perceived reliability of IK indicators. Furthermore, the stories by respondents led to the establishment of latent themes in the study concerning knowledge sharing and development (Coffey and Atkinson, 1996; Bradshaw and Stratford, 2010). The whole data collection process was simplified by the researcher's familiarity with both study areas and understanding of local dialect because I did not need a translator except for the minimal description of certain terms by the participants. This also contributed to understanding perceptions of the respondents, however, this relationship also has its limitations that I needed to be mindful of (Section 1.4).

4.5 Data Analysis

The information from the interview audios was transcribed verbatim and then thematically coded after identifying recurring information relevant to certain study questions and objectives. This allowed the presentation of the observed patterns from the interviews, assign meaning to each category, and explore the reasoning of the participants (Richards and Hemphill, 2018). Data analysis was divided into four distinct steps (Figure 4.1).

<p><u>Planning</u></p> <p style="text-align: center;">Aim</p> <p style="text-align: center;">To investigate various phenological cues intrinsic in Indigenous Knowledge Systems for agricultural management in Lusikisiki and Umzimkulu.</p> <p style="text-align: center;">Sample and Unit of analysis</p> <p style="text-align: center;">Subsistence farmers who have been residents of Umzimkulu and Lusikisiki for more than 30 years.</p>

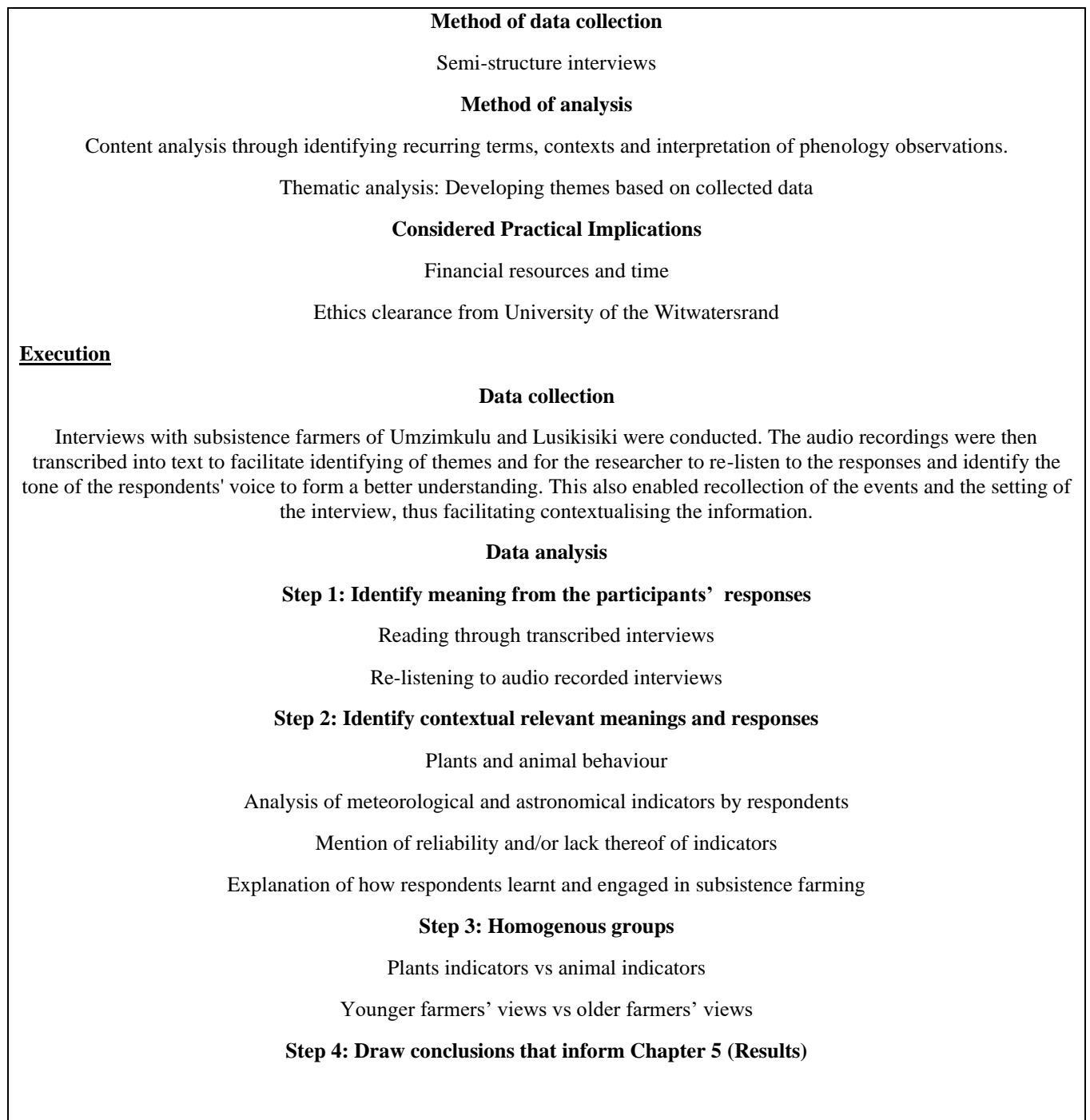


Figure 4.1: Outline of the methodology for this study (adapted from Bengtsson, 2016)

The data was deductively and inductively coded, most of the themes were informed by peer-reviewed literature prior to data collection thus facilitating reliability and relevance of the data collected (Bengtsson, 2016). Categorising data within certain themes required the researcher to

collect and analyse data simultaneously to ensure that the information followed a logical chain of reasoning, which also promoted the development of new themes (Marshall, 1996; Srivastava and Hopwood, 2009). Therefore, data analysis for this study mainly involved identifying trends from collected data, building themes that correlate with empirical findings and connecting findings to broader literature to form educated conclusions for results reporting.

4.6 Ethics

Ethical clearance was obtained from the faculty of science at the University of the Witwatersrand before engaging in any contact with the intended interviewees. The Non-medical Human Research Ethics board granted ethics clearance certificate, protocol No: H19/04/10. Before interview sessions began, the purpose of the interview and the overview of the study was explained to the participants. Community members were also informed of their right to ask questions, not engaging in topics they were not comfortable talking about and discontinuing the interview if they do not wish to continue. Participants were also provided with consent forms which stipulated the right to remain anonymous and ensured confidentiality (Appendix 2). Admittedly, most respondents did not appreciate the options that granted anonymity. In addition to the ethics clearance issued by the faculty of science, the researcher abided with cultural norms and respectful conversation styles of both study areas. Respondents were also asked for permission to record the interview (Appendix 1), and were told that they can agree or deny, or even ask the researcher to stop recording during the interview if they were not comfortable.

5. Results

This chapter presents the results obtained in Umzimkulu and Lusikisiki about climate change perceptions, the use of IKS, and the importance of phenology indicators in agricultural management. The empirical evidence is fundamental in addressing the main aim of this and the objectives of this study. This chapter first describes the vernacular terms used by community members to describe their natural environment variables (Section 5.1). Some of the terms are written in vernacular throughout the research report while others are directly or loosely translated to English, and the variables that do have English and/or scientific names then those names are written in English throughout the document. The translated and scientific names are based on the descriptions provided by community members. This chapter then presents the results relevant in answering the questions and achieving objectives of the research. The broad themes covered in this section are climate awareness, phenological indicators and agricultural climate change adaptation. This chapter also uses direct quotes to explain the results of the study. Direct quotes from participants from Umzimkulu are labelled as NMZ while quotes from participants in Lusikisiki are labelled as EC.

5.1. Respondents' Demographics

The study aimed to document the views and perceptions of subsistence farmers from Umzimkulu and Lusikisiki on climate variability and change and the ways in which they have used IKS to inform agricultural management and promote adaptation. Therefore, community members that can provide information which represents cumulative knowledge that has evolved through adaptive processes, orally transmitted through generations, and by the active involvement of the neophytes in implementation of developed strategies were chosen. Participants were selected due to their long-time residence in Umzimkulu and Lusikisiki and their involvement in seasonal

and/or annual farming. These respondents have been residing in these areas for a minimum of 30 years. However, some respondents, particularly individuals who came to their current locations through marriage still consider themselves incomers. For example, a respondent (70-80 years old) from Hopewell in Umzimkulu stated:

“I am not from here, I arrived here in 1980, but the environment has been good to me.”

(NMZ 2.2)

Similarly, another participant (45-55 years old) in Lusikisiki kwaDiki stated:

“I am not from here my home is behind that mountain, just walk across the mountain and

I get home.” EC 2.3

While another community member (70- 80 years old) in KwaDukada states:

“I did not grow up here, I only came here when I got married, that is my home there

(pointing across the river). Just down there.” ECI.1

Nonetheless, these community members possess repositories of knowledge gained through closely observing the natural environment, which is important for survival and, mitigation and adaption to environmental change. Furthermore, incomers possess a unique ability to enhance or transform strategies by incorporating information from their places of birth to local strategies to inform agricultural management methods. In Umzimkulu a participant (50-59 years old) stated:

“I knew the sowing date back from KwaSondzaba, when I got here in Hopewell, things

*were slightly different, but I managed. I even brought some intshungu (*Momordica foetida*)*

from home and grew it here, some of the plants grew some died, and one has to be careful.”

(NMZ 2.3A)

Most of the participants are unemployed and living on government grants. Retired and currently employed personnel constitute only three respondents. Some respondents trade their produce, but they do not engage in agriculture as a main source of income, but rather to alleviate household hunger. Gender is not a variable that was considered in the analysis of this data. For the purpose of this study gender roles are not considered to affect the objectivity required in noting and marking IK based indicators. The objectives of this study were not aimed at identifying gender-based knowledge and disparities. Nevertheless, it was noted that most of the respondents were female, which is representative of the most active demography is subsistence farming in both areas.

5.2. Terminology

There are local names for flora and fauna species, weather conditions, and phenophases which are used in these communities. These common names were used by community members in narrating the stories within which the results of the study were deduced from, some of the terms have established and English and scientific names while others are explained through characteristics, because of the spatial specificity of their occurrence they do not have English/scientific names. However, for some species, English names could not be provided (NA) because of the limited description provided by community members (Table 5.1). The list also provides both vernacular and English descriptions of food, weather conditions and activities that are important for the content of this research.

Table 5.1: Local names for plants, weather conditions, foods and animals relevant to this study.

	Vernacular Term	Area	English Name	Scientific Name	Description by respondents
Animal Species	Amagwababa	Umzimkulu	Pied crow	<i>Corvus albus</i>	A black and white bird that eats corn and chicks.
	Umahlaba nkomo/ Iknonjane	Umzimkulu and Lusikisiki	Barn Swallow	<i>Hirundo rustica</i>	A small dark grey bird with a red peak.
	Isiphephane	Umzimkulu			It is a bird but the physical description is not clear.
	Phezukomkhono	Umzimkulu			A bird that indicates spring onset for Umzimkulu community members
	Uvethe	Lusikisiki			A small white frog.
	Intlwabusuku	Umzimkulu	Termite	<i>Isoptera</i>	
	Intsingizi	Umzimkulu and Lusikisiki	Southern Groundhornbill		A big black bird that makes booming sounds
	Ingududu	Umzimkulu	Southern Groundhornbill	<i>Bucorvus leadbeateri</i>	
	Amagwababa	Umzimkulu	Pied crow	<i>Corvus albus</i>	A black and white bird that eats corn and chicks.
Plants	Unopiyo	Lusikisiki			A small plant that blooms red flowers.
	Amagosi	Umzimkulu	NA		A traditional fruit that grows in the garden before tillage.
	Unoncwembu	Lusikisiki			A small plant that indicated spring onset.
	Umsalingi	Umzimkulu	Chinaberry	<i>Melia azedarach</i>	A tree that has brown fruits with wood seeds inside.
Foods	Imifino i.e. <i>intshungu</i>		(<i>Momordica foetida</i>)		Leafy vegetables. Mostly refers to wild vegetables
	Amarhewu		NA	NA	Fermented porridge
	Amasi		Mass	NA	A mixture of fermented milk and pap
	Isangcobe	Lusikisiki	NA	NA	A meal made from harvested corn that was exposed to rainfall/water.
Weather Conditions	Uzamcolo	Umzimkulu	Floods	NA	Intense floods that last occurred in 1989, in Umzimkulu. They are known to have a 30 years recurrence interval.
	Umvingi	Umzimkulu and Lusikisiki	NA	NA	Gentle rains that occur at the beginning of spring and last for two days to a week.
	Imbozisa Mahlanga	Umzimkulu	NA	NA	Last winter rainfall: heavy and cold rainfall that commonly occur after harvest.
	Umbolisa ndiza	Lusikisiki	NA	NA	Last heavy rains of winter, usually occur at the end of July, after harvest

Most of the vernacular names are based on the behaviour of flora or fauna and the weather condition or season they indicate. One bird, in particular, is named phezukomkhono, because it arrives in the beginning of spring when farmers are preparing for sowing season onset and therefore its sing-song sound is interpreted as phe—zu-kom-khono, which means align along the furrows. Participants do not describe the physical appearance of this bird but know its sound and the importance of its arrival for their farming calendars.

One participant (71 years old) extensively explained:

“We had poems in school about phezikomkhono, it meant that people must start preparing for the sowing season. Lazy people must wake up, families must align along the lines in their farms because it is time to till.” (NMZ 1.1)

Some species, including amagosi, unopiyo and unoncwembu have disappeared. Therefore, although community members recall them as significant seasonal indicators, they provided little or no physical descriptions of them and therefore could not be identified or described by the researcher. One participant in Lusikisiki stated that these flora indicators have decreased abundance and they are mainly found in the forest. This is also the reason for the inaccessibility of most wild vegetables and medicinal plants.

5.3 Farming Practices in Umzimkulu and Lusikisiki

All participants of the study engage in moderately diverse farming practices to ensure household food availability. Community members in Umzimkulu and Lusikisiki plant a variety of crops; annual, perennial and non-perennial that are important for food availability (Table 5.2). Some crops, mostly introduced do not have local names, they are called by their English/ store names. These include spinach, green peppers and carrots.

Table 5.2: Crops that are important in the food availability of the study areas. This table only includes crops that do have local names.

Local Names	English Names	Scientific name	Type	Use
Ikabishi	Cabbage	<i>Brassica oleracea var. capitata</i>	Seasonal	Relish and salads
Ithanga	Butternut/squash	<i>Cucurbita moschata</i> 'Butternut'		
Umbila/Umbona	Corn	<i>Zea mays</i>	Annual crop	Staple Food. Maize Meal is the main ingredient in making a majority of stable foods
Upelepele	Chilli peppers	<i>Capsicum annuum</i>	Perennial crop	Medicine, salad and relish Substitute intshungu Salads
Amazambane	Potatoes	<i>Solanum tuberosum</i>	Perennial	Relish, Salads and Staple
Intshungu		<i>Momordica foetida</i>	Wild vegetable Annual plant	Medicine, relish and spice
Udwabaza		Not clear	Wild vegetable Annual plant	Relish

Observations and participant responses indicate that subsistence farming activities are vulnerable environmental change in Umzimkulu and Lusiksiki. This is because participants suggested that they have low asset portfolios due to lack of financial and mechanical resources and observations indicate that natural water sources (streams closer to households) are drying. All respondents also overtly mentioned that important environmental variables that determine farming productivity vary annually. As a result, the size of land tilled, physical labour required for different farming activities, and the expected yield are not the same for growing different seasons. These agricultural management variables are predominantly dependent on climatic components. However, farmers asserted that their expertise on weather patterns of the respective areas, and knowing the environmental requirements for different crops help them sustain annual productivity and reduce losses. For example, one participant explained that the size of land tilled is determined by spring rainfall onset, she (71 years old) stated:

"Last year I wanted to sow in the big garden but there were no significant rainfalls until end of December and by then it was too late. So, I only had corn in my small garden."

(NMZ 1.1)

Umzimkulu and Lusikisiki communities are maize-based subsistence farming areas. Although there are changes in dietary needs in these communities, corn is still considered the most important staple food and/or cereal. Other crops are mainly prepared as a relish (Table 5.2). Most of the vegetables are used as a relish and are planted any time in the year, these include spinach, carrots, beetroot and cabbage. Nevertheless, community members reiterate that the beginning of spring is still the most appropriate sowing season onset. A respondent (70-80 years old) from Umzimkulu stated:

"Spring is the right time to plant, everything becomes alive in spring. Right now, we can sow, you see my neighbour there has some crops and even though she waters them, you can still see that they are winter plants. Once spring begins her garden will be more beautiful and her plants will thrive." (NMZ 1.3A)

Community members are cognisant of the importance of weather conditions in crop growth. Moreover, weather conditions are argued to affect farming productivity even beyond the growing season in these study areas. Proper preservation of corn after harvest governs the contribution of the yield to food availability. This is because if corn is exposed to moisture or rainfall after harvest, it can be damaged and will not be useful for preparing food or choosing seeds for the next season. Respondents re-use grains from the yield of a previous harvest as seeds for the following sowing season to avoid paying for new seeds. This strategy is argued to assure yield success, deduced from previous season's productivity. They asserted that this selection depends

on the quality and quantity of the yield. These farmers displayed confidence in their ability to identify high-quality seeds, one participant (50-59 years old) stated:

"I chose those 10 cobs to be my seeds for this coming sowing season, you cannot just choose any cobs though, and you have to know corn. Also, you must make sure it is not old seeds...I can only reuse these seeds for a certain number of times, after that they will no longer give me great results." (NMZ 2.3A)

Farmers have to maintain the quality of the seeds for approximately 3-4 months after harvest until the next sowing date. This includes ensuring the seeds are dry and have no fungus and insect infestation. In Lusikisiki a participant (70-80 years old) explained:

"We did not buy seeds in the past, even right now I have corn from my last harvest that is going to be my seed for the next sowing season and then I will put the pill, preparing it. It has a good yield. The pill is poison, it ensures that insects do not eat it, it is a small pill. I put it in the pot with corn, we only need its smell. You put it in a plastic bag and close the container then no insects will get in the pot." (EC 1.1)

If the harvested corn is fungus or insect-infested, it limits food availability and adds an expense for buying seeds at the beginning of the following growing season. Contrastingly, most vegetables that are used as a relish: spinach, cabbage and carrot are not harvested or stored because they are used immediately after they mature. This is partly because respondents do not have measures in place to store and preserve these crops for later consumption after reaping. Nonetheless, they display good capability to store and preserve corn, potatoes and Cucurbitaceae crops for their multiple uses as cereal, relish and staple foods. Low productivity of these plants results in insignificant yields and consequently no produced to harvest.

5.4. Weather Awareness

Participants from both areas acknowledged that weather conditions are an integral part of their daily and agricultural activities. Therefore, they recognise the importance of understanding an areas' seasonal weather conditions and noting significant changes, particularly changes that determine food production. Due to long term residency, respondents have cumulative knowledge of weather patterns, which provides a basic framework for climate variability and change and is critical in ensuring resilience in communities. There is no definite distinction between climate and weather in these communities; in vernacular, they are referred to as general weather of the area and daily/seasonal weather conditions, respectively. Climate changes are inherently linked to changes in agronomic patterns and practices. Therefore, the assessment of climate change perceptions in Umzimkulu and Lusikisiki is imperative in exploring IK informed agricultural management strategies. Thus, highlights the use of IK to understand and adapt to environmental change.

Community members displayed an awareness of the vulnerability to climate-related stressors because of limited agriculture assets and financial resources required for increasing resilience. This is because respondents note that they mainly rely on environmental viability because their agricultural activities are predominantly rain-fed in these areas. Therefore, they echoed the significant influence of seasonality and their vulnerability to climate stressors compared to financially stable commercial counterparts. More than three participants stated:

“Winter is winter, and you cannot sow mealies in winter, because unlike white people with big farms, we do not have irrigation systems.” (NMZ 1.1, 1.6; EC 2.3)

The farmers' dependence on the natural environment and their perception of environmental change breeds the value bestowed on seasonal variability forecasting and phenological informed

indicators used in these areas. Hence community members state that their knowledge of the landscape and the experience in farming acquires them expertise that is important in ensuring food production. All respondents emphasised the significance of understanding crops seasonal niches based on a considerate recollection of seasonality characteristics and the crops' weather condition needs. Comprehending several factors that influence successful agricultural activities is a valued capability that enables seasonal and annual food production in these areas. Although this knowledge is valuable in agricultural activities of these areas, there are no systematic records of it, especially in Lusikisiki. In Umzimkulu, community members with basic formal school recall indicators, particularly spring phenology from school poems. However in Lusikisiki respondents did not display interrelationship between home IKS and formal institutions. When enquired about different seasonal indicators, a participant (55-65 years old) from Umzimkulu in Highlands said:

"I am not sure if I can remember any, but we do have them, they might not be as precise as they used to be. We used to have several poems in school about the beginning of spring and the beauty that comes with it, birds chirping and flowers blooming." (NMZ 1.2A)

"We had an IsiXhosa poem at school, we used to recite it, and it went like:

Phez'ukomkhono

Vukani mavila ndini intwasa hlob'ifikile." (NMZ 1.1; 71 years old)

The direct translation of the poem

"Wake up lazy people, spring is here.

Align along the furrows."

Most respondents in both study areas do not consider IK informed agricultural management strategies 'knowledge' nor did they display a scientific understanding of agronomic activities and correlation between the two knowledge systems. Indigenous knowledge strategies are

generic and the essential "know-how" used to ensure farming success. Community members were asked about the essential indicators that inform their conclusions on sowing time onset one respondent (71 years old) explained:

“We use our minds, we just know, we look at things. We see changes and we just know what to do. We have been doing this for a long time, so we know.” (NMZ 1.1)

Nevertheless, climatic conditions are regarded as the vital aspect of agriculture activities, the onset and duration of the sowing season, harvest time and subsequently the yield. Therefore, changes in climatic factors, particularly rainfall are marked in both areas; changes in rainfall patterns coupled with high temperatures were overtly mentioned. Apart from progressing frequent dry spells that are highlighted in both areas, in Lusikisiki, community members marked the 2019 rainfall scarcity during the winter season; last rainfall received before harvest, as a significant change in seasonal climatic conditions. Although respondents retorted that there has been an observed change in climate variability throughout the years, four out of 16 respondents stated that the extent of the 2019 dry spell is novel. One respondent in her eighties (80-89 years old) stated:

“I do not understand what is happening this year; we have not received significant rainfall since before harvest. This has never happened here before” (EC 2.5)

In Umzimkulu community members did not point out any considerable changes for 2019, however, stated that inter-annual and inter-seasonal climate has significantly changed, marked by the temporal inconsistency of the occurrence or non-arrival last winter rainfall. Furthermore, they pointed out that prolonged dry spells are commonly coupled with extremely high-intensity rainfall that further derails or halt their agricultural activities later in the sowing season; waterlogging, formation of springs, ruining harvest and injuring livestock, depending on the date on the agricultural calendar. Respondents (71 years old) explained:

“The weather has changed, sometimes we will not get rainfall for a long time and when it comes it damages the little that we were trying to grow or prevent us from sowing. For example, in 2018, I wanted to sow, but it was dry and hot until the end of November and then when it rained in December, my garden had ponds. After that, it was January, it was too hot and relatively late to start sowing corn.” (NMZ 1.1)

In Lusikisiki, respondents stated that the prolonged dry spell from June to the beginning of September in 2019 is a novel event, they stated that it indicates a high probability of poor 2019-2020 growing season. Respondents in both areas consider late rainfall onset in spring is considered an indicator for less rainfall frequency throughout the growing season in both areas. It is also a correlation with the apparent increase in rainfall intensity within the season. In Lusikisiki community members explained that rainfall activity can be observed at the beginning of the season and be replaced by dry spells mid or end of the season, which is detrimental to crop productivity. These variations are most detrimental in January-February (when corn is flowering) because they can negate the effects of early seasonal rainfall on projected corn productivity. Albeit acknowledging the changes in the reliability of meteorology indicators and the myriad of factors that can negate forecasts, seasonal rainfall onset is still considered an important indicator for rainfall characteristics within the growing season.

5.4.1 Climate of the Study Site

Community members in Umzimkulu described the climate of the area as characterised by warm summers with high rainfall frequency and cold winters with relatively low rainfall frequency and significant winter rains occurring mid to end of July. These characteristics of winter rainfalls are marked as an important indicator for the productivity of the oncoming growing season. In

Lusikisiki, three out of the 16 of the respondents reported that there are insignificant differences between summer and winter in the area. One community member (40-50 years old) explained:

“In winter it is supposed to be cold, and we are supposed to see frost, right? We do not have that here, though it does not rain as much in winter, we commonly do receive rainfall, but the temperatures are not too low. Some might say that we do not have winter, but things are changing.” (EC 1.3)

Community members pointed out that climate conditions in each region determine the types of plants that can be sowed and thrive in certain areas while weather conditions in a particular season govern the quality and quantity of the yield per unit area for crops during harvest. There is a broad understanding of inter and intra-annual climate variability that are predominantly marked by differences in rainfall frequency and plant-animal life cycles. Extreme high temperatures are interpreted to be exacerbated by, or an aftermath of rainfall scarcity. In Umzinkulu, most participants stated that December-January are generally hot months, regardless of rainfall frequency. Moreover, community members recognize that climatic factors associated with different meteorological seasons and rainfall intervals are significant for their agricultural activities. Furthermore, they highlight that being able to identify types of rainfall relevant in an area is fundamental for agriculture planning. Therefore, respondents explained that there is a difference between the winter's last rainfalls, which occurs approximately three weeks before the spring rainfall onset and the spring onset rainfall that occur within the first few weeks of spring. It is vital to know the difference between the two to ensure the start of sowing dates are well-timed and plants will not be exposed to long dry spells. A respondent (45-55 years old) from Lusikisiki explained:

“We are governed by the weather, because if it were to rain right now (beginning of September) we would sow, if not exactly tomorrow, maybe in a few weeks. Right now, we have not done anything because it is not raining. However, although the end of winter rainfall is important, we would have not sowed then because it is still cold, and we would have to wait a long time for spring rainfall.” (EC 2.3)

While another respondent (60-70 years old) from Lusikisiki stated:

“It is important to wait after the first spring rainfall. This is to ensure that our plants will not be exposed to prolonged dry days, but if we receive substantial rainfall maybe a week or two after the first rain then we can start sowing.” (EC 2.4)

Community members further elucidated that agronomic activities at the beginning of spring can be affected by winter rainfall activity. They remarked that although there is a waiting period between first spring rainfalls and sowing onset, high-frequency rainfall during the winter season indicates a good rainfall year. Therefore, reduces the risks associated with sowing during or immediately after the first spring rainfall onset. Participants in both study areas displayed a comprehensive understanding of seasonal variability and associated weather conditions accordingly, using IK informed meteorological and phenological indicators for agricultural management. This knowledge is not contingent on scientific understanding of climate variables or plant and animal life cycles by the participants. However, it has been successfully used to inform agricultural management strategies in these areas through status monitoring carried out by farmers for generation and is still used. However, respondents asserted that there are noted inconsistencies with previously reliable weather forecasting methods. At the beginning of an interview, one participant (55-65 years old) said:

“You are going to make me lie because some of the most important things we relied on as rainfall indicators are not as reliable as they used to. Hearing a southern ground hornbill humming used to be a 100% indicator of rain coming in a few hours, but now we can hear them for a week and only receive rain in a week or two after. Although sometimes they still indicate imminent rain, it is not like they used to. Times have changes” (NMZ 1.2A)

Furthermore, there is a noted change in distribution and abundance of fauna and flora species important in IKS forecasts and agricultural management. These changes are associated with environmental degradation and climate change in the study areas. Apart from possibly rendering meteorological and phenological IK informed forecasts unreliable, erratic changes in climate variables have inherent consequences for productivity, particularly for corn in Umzimkulu and Lusikisiki. Community members from Umzimkulu also reiterated that there are microclimates in the region and stated that it is important to know the differences between locations within Umzimkulu. For example, participants in his forties (41-49 years old) from KwaMeyi stated:

“In Highlands, they usually receive more rainfall than us here because they are in the wet belt, I always wanted to understand why they generally get more yield and receive more rainfall, so I read about it. So, they can get a good yield even when most of us do not, also their soil is good for potatoes.” (NMZ 1.5)

In Lusikisiki, community members did not indicate knowledge of specific microclimates. Unlike in, Umzimkulu where community members stated notable differences in rainfall occurrence, at the same time, between locations, and the benefits associated with these weather conditions, in Lusikisiki community members did not mention any significant temporal disparities between climatic factors. However, they infer weather conditions of their area from forecasts of neighbouring towns. This is the case for both study areas because of the coarse

spatial resolution-based reports from South African Weather Services (SAWS). This contributes to the lack of trust and perception that SAWS weather reports are inaccurate for subsistence farmers in the study areas.

5.4.2 Reliability of National Weather Service Reports

Community members in Umzimkulu and Lusikisiki have access to national meteorological services reports by the SAWS through television and radio reports. However, there is limited confidence in these reports, especially for informing farming decisions. Therefore, management of agricultural activities is largely dependent on IK forecasts, which are argued to be typically more reliable. Community members stated that this is because IK precedes access to national weather service reports in the areas. Also, they expressed that they do not completely understand SAWS forecasts variables because of the jargon used by reporters. However, some participants acknowledge the importance of SAWS weather reports for daily forecasts, but others indicated that SAWS contribution to unemployment alleviation is the main reason they still listen to reported weather forecasts. One participant from Emause explained:

“These children went to school to study that, they need to get paid. So, I continue watching.” (NMZ 1.3A) 70-80 years old

However, in the same household, a participant in his early thirties argued that contemporary weather reports are important, particularly for daily forecasts, he explained:

“No, mom, you cannot say youth employment is the only reason because these weathermen are useful, especially when you have to travel the next day. They tell you the weather for Durban while you are still here so you can dress accordingly. Although IK forecasts are useful

things have changed a lot, so the weathermen also have their important role to play.” (NMZ

1.3B) 35-45 years old

All participants reiterated the observed changes in weather and climate for the two areas. They also pointed out the notably reduced reliability of phenological, astronomical and meteorological informed IK indicators for local weather forecasting. Nevertheless, respondents still rely on IKS cues, they argue that there is always a high probability of accuracy in spatial specific information in traditional weather forecasting. This is important for domestic and agricultural activities, especially astronomic indicators. Astronomy indicators are usually accurate for short term weather forecasts, particularly in Umzimkulu. Furthermore, community members note that SAWS reports do not offer information relevant to local farming activities. One participant (60-69 years old) stated:

“They try because we know that when they say it will rain countrywide then we will also get some water. However, they do not have direct information specific to our area, but when you hear the frog you know that it will rain here even if it is not today but it will be here.” (EC 1.4)

Therefore, although the decreasing reliability of bio-indicators is noted, the spatial resolution of IK based forecasts is still more valued for agricultural management. SAWS weather forecast information is used for domestic shortterm decisions such as choice of clothing and travelling, by both the custodians and the younger participants, but its reliability is constantly questioned. The limited understanding of weather report variables coupled with the lack of local context for the areas informs most of the farmers’ views on contemporary weather forecasts. Participants display a lack of interpretation skills for contemporary weather forecasts, they constantly confuse the probability of rainfall in percentage with expected

rainfall in millimeters. This is a challenge in both study areas, across all age groups involved in the study. Participants equated the probability of rainfall in percentage with the amount of rainfall in millimetres, one participant in Lusikisiki stated:

“These weathermen said that we will receive 80% rainfall but as you can see outside, it is just drizzling, and that is just 30%. They are not reliable.” (EC 2.1) 30-40 years old

Furthermore, most participants stated that not hearing the name of their exact area on television and radio weather reports also contributes to their skepticism towards these reports. One participant (70-80 years old) stated:

“They usually talk about Port St Johns, and we deduce from those forecasts, but it is not the same. We are close to Port St Johns, but the weather is not the same so, although we listen it is not directed to us.” (EC 1.1)

In Umzimkulu a respondent (41-49 years old) stated:

“We do watch weather reports from television, but you know it is macro, so it is a give or take. We have our climate here that is evident from things we can see, for example, I look at peach trees when they start showing their first leaves, and then I know the temperatures are getting ready. While on television they will be giving me averages for Pietermaritzburg (Umzimkulu gets their forecasts there) that do not align with what I see.” (NMZ 1.5)

Farmers also expressed that SAWS meteorological information does not consider distinct microclimates that prevail in different regions. They emphasised that IKS indicators have provided useful and predominantly more accurate forecasts because they are at a smaller spatial scale with considerable temporal depth. Although these farmers acknowledge that contemporary weather reports are helpful in daily activities and preparing for school days, they voice out that the information is insignificant for agricultural management. They emphasised that weather

conditions are efficient indicators for the start of the sowing season and useful representation of the season's general climate.

5.4.3 Environmental Change

All respondents pointed out that there are changes in the natural environment leading to uncertainty in farming practices. Although impacts of climate variability and change on livelihoods and agriculture are not systematically quantified, community members highlight the changes in sowing season commencement and unpredictability of the yield as a significant indicator for environmental change. Furthermore, in Umzimkulu, community members stated that the absence of *uzamcolo* is another marker for environmental change; a participant from Emause stated that the 1989 occurrence of *Uzamcolo* marks the last time they received substantial yield and was followed by a notable decrease in yield annually to date. According to community members 2019 marked 30 years since the last occurrence of this hydrological event and its absence indicates significant environmental change, he (41-49 years old) explained:

“When it rained a lot at the beginning of this year I thought it was it, but zamcolo takes longer and has much more rain. Also I think it used to occur in December, not February”
(NMZ 1.5)

Respondents also note the continuously decreasing yield and attribute it to changes in rainfall patterns and ambiguity of seasonal weather conditions.

You see when we were growing up... let me just say the 1970s were not like in the 1960s, the fertility of soils is decreasing, when we were young food was abundant...but now there is not as much. The rain was frequent, the fields were always green and there was food.

Now, people who get food are the ones who are not lazy because in the past we did not need to water as much, you would just plant and water a few times then rains will come and grow your food. The 1980s changed things a lot, from towards the end of the 1970s to 1980s things changed a lot. I remember there was a huge storm in 1975 and in 1976 there was so much corn we did not know what to do with it. Back then we did not even sow in lines, we would throw corn grains in the garden and let oxen do their work ploughing but now you cannot do that because even when you use kraal manure only, your corn does not turn out as beautiful. (NMZ 1.4)

Decreasing abundance and disappearance of previously abundant and useful traditional vegetables such as *amagosi*, *intshungu*, and medicinal plants also characterise changes in weather and soil structure conducive for their growth in the area. Subsistence farmers in Umzimkulu mentioned that some of their indigenous plants are dying even after they sowed them from seeds collected in the forests. A respondent (50-60 years old) explained:

“Now I just use chilli pepper in my green porridge (isgwamba) because my intshungu plants died, and I tried to plant them several times.” (NMZ 2.3A)

Community members in Umzimkulu and Lusikisiki acknowledge unprecedented changes in the natural environment. They expressed that there are changes in soil fertility, thus emphasised on using soil fertility-boosting agents before the sowing season onset. All farmers pointed out that kraal manure is still the most preferred agent, despite the availability of commercial fertilisers. They argue that kraal manure is more effective and is readily available. Furthermore, community members commend using kraal manure because they believe that it revitalises and maintains soil structure, thus promotes holistic soil quality. However, these farmers also point out that due to changes in farming methods, the use of kraal manure has become less convenient, stating that it

is time and labour-intensive because farmers sometimes have to weed more than once in a growing season. One participant (41-49 years old) explained:

“In the past, when we plough at a certain stage, we would spread butternut seeds so that weeds could be stunted, butternuts form a canopy, and beans grew by sticking to the stem of the corn plant. All of this led to a relatively less labour-intensive growing season. Now we mostly plant corn and butternut separately I do not know why we started doing that because now weeds grow freely.” (NMZ 1.5)

Nonetheless, farmers still incorporate kraal manure and other livestock composts in their farming, sometimes they combine manures with commercial fertilisers. Although community members state that there are negative impacts associated with excessive use of western methods, they appreciate their efficiency. A respondent (41-49 years old) explained:

“Fertilisers help ensure crop success, however, they can lead to the eradication of weeds and insects in the area. These are not necessarily bad results for our farming because insects and weeds are not good for crops’ success, but lack of these insects and worms in soils indicate low soil quality. High-quality soil is commonly dark and can sustain life; worms, insects and weeds.” (NMZ 1.5)

In addition to deteriorating soil quality for crop productivity, farmers also note an increased frequency and complexity of disease and insects affecting fitness and health of livestock. Furthermore, the changes in distribution and abundance of wild plants are argued to undermine traditional medication strategies for livestock. Therefore, making community members more dependent on western medicine and pesticides for their livestock. A respondent in Umzimkulu stated:

“We never had to buy medication for our cows. We used herbs and roots from the forests, and they worked. These days, having a cow is like raising a child, animals even have doctors, and they are always sick.” (NMZ 1.1)

Another participant (70-80 years old) in Lusikisiki stated:

“We can no longer just go to the forest and get herbs for our cows, there are too many diseases and medications these days.” (EC 1.1)

Community members do not directly associate changes in abundance and disappearance of important wild plants with climate change. Some farmers state that the observed negative changes in the natural environment are a result of God’s anger and a punishment for the way they changed their lifestyles and disrespected the natural environment. Farmers remark that their actions have altered the abundance of natural indicators that are important for tracking seasonality. One subsistence farmer who is also a traditional healer from Lusikisiki lamented that these changes not only reduce wild vegetable reserves but also limits availability and access to important medicinal plants and herbs from the forests. She (40-49 years old) stated:

“You see my child; the way people live has changed a lot. In my view that is the reason why our land is like this.” (EC 1.2)

Community members lament that as a result of environmental change yields per square meter of land is also decreasing. This requires increased input requirements such as per plot: fertilizer, herbicides and manual labour. Therefore, most farmers have reduced sowing plots to ensure effective agricultural management and inherently reduced yield. Respondents demonstrated a notable comprehension of climate and cognizance of the changes in the respective areas. Since they believe that observed changes are God’s acts and changing times, these farmers also believe that if they respect the natural environment and are not lazy to work on their farms God will reward them

through agricultural success and ultimately more food availability. Notwithstanding, the religious beliefs, these community members are not passive actors, they engage in activities that ensure resilience and responsive capacity to facilitate farming productivity.

5.5 Farming Calendar

The length of the growing season in Umzimkulu and Lusikisi is defined by climatic variables, mainly air temperature and precipitation. For a majority of respondents in Umzimkulu, the end of the growing season is marked by the first frost that occurs at the end of autumn. All respondents from Umzimkulu stated that they limit agricultural activities in winter to avoid frost damage. They also employ some protective measures to limit frost damage on perennial plants to ensure that the plants can still be productive on the following growing season.



Figure 5.1: A farmer in Emause, Umzimkulu covered green pepper trees with plastics to limit frost damage on the plant. Image captured on 26/09/2019

The farmer explained that she will remove the covers after the first spring onset. In Lusikisiki, community members expressed that relatively low or no agricultural activities in their backyard

gardens in winter are due to the observed changes in winter rainfall frequency. Another contributing factor in Lusikisiki is that farmers are avoiding livestock damage on crops in winter because cows are usually brought back from *elubala* around this time. Regardless of limited knowledge of meteorological season start dates, community members understand the important timelines for farming practices. One community member stated:

“You cannot just sow anything at any time of the year. Although there are plants that can endure all seasons’ conditions, ultimately, they have a season which we know they thrive most in. Then there are crops that you just cannot sow unless it is their season, like corn, you cannot just sow corn now in winter. That would be a waste of time and energy.” (NMZ 1.3A)

A farmer from Lusikisiki explained:

“You see when I was growing up, we even sowed in August and by December we were eating corn. It would rain in August; corn grew well, and we ate it. It rained umvimbi but now we don’t have rain, this place was never dry, we couldn’t light up veld fires because the grass was always wet and green but now...things have changed, sometimes I look at things and feel like I do not know anything because times have changed.” (EC 2.2) 70-80 years old

Community members pointed out that as a result of noted changes in weather, they have to be more attentive because bio-indicators have become somewhat less reliable and some have disappeared. Therefore, they must consider the disarray that current indicators present and adjust farming practices accordingly to minimise losses and ensure productivity. Respondents from both areas highlighted that it is important to know appropriate sowing dates, properly consider rainfall patterns in the area, soil types, and the type of seed (between yellow and white corn) they are

going to use. Farmers also pointed out that the success of a growing season can be understood through weather conditions occurring before its commencement. Therefore, they argue that although rainfall onset is significant, it is also important to consider general rainfall characteristics throughout the year. Respondents emphasised that winter rainfall, in particular, can provide insight about the oncoming sowing season. One participant from eBorder in Umzimkulu explained this concept stating:

“Sometimes, it will rain early in September, but I will wait a little bit to see if it rains again in a week or two before I sow. But if it was raining even in winter, I do not have to wait because I know it will be a good year.” (NMZ 1.6)

Respondents also believe that the time dedicated to ensuring tidiness and health of a garden is an important component in ensuring a successful season. However, adhering to established sowing dates (Figure 5.3) is still considered more important.

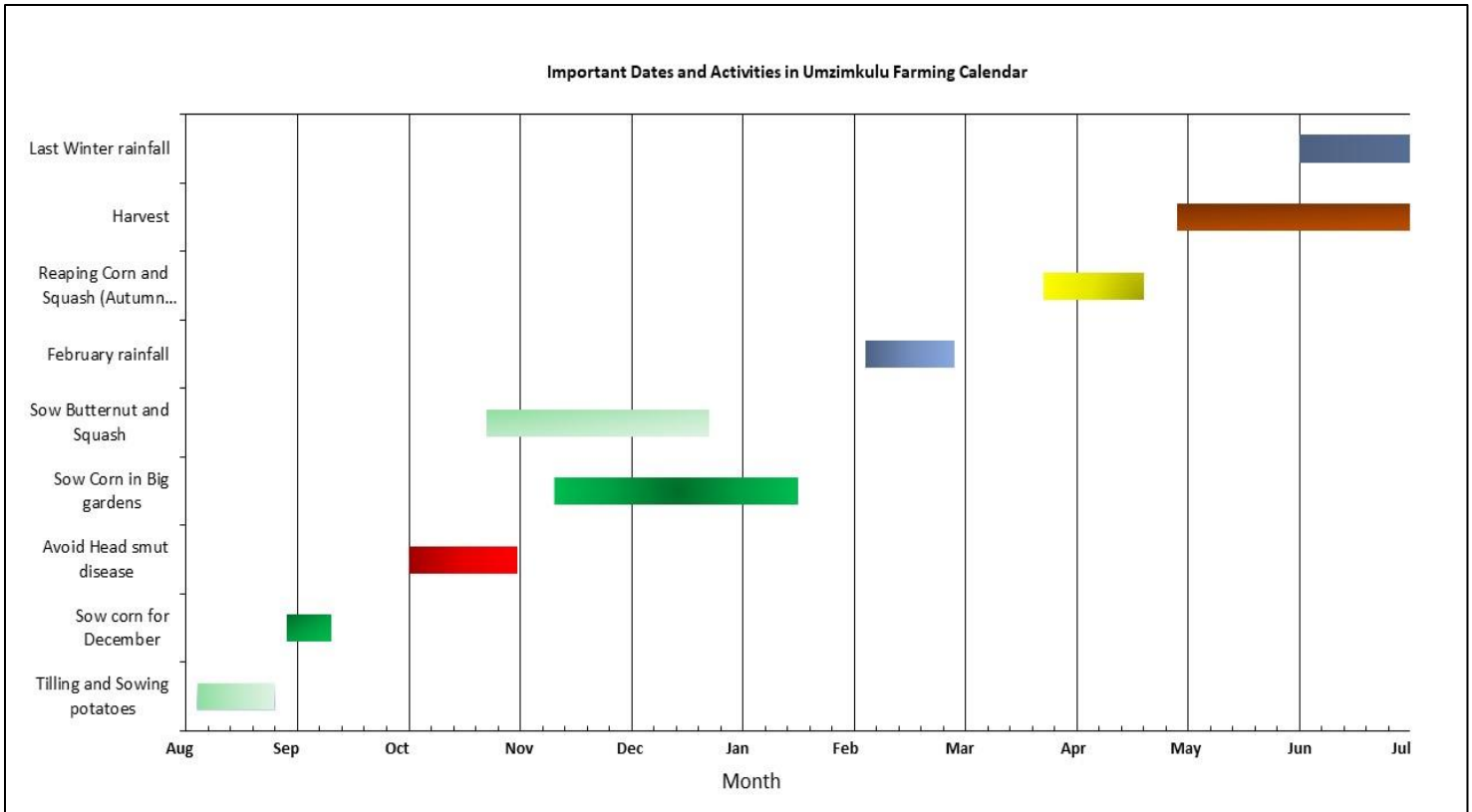


Figure 5.2: Important Dates and activities in Umzimkulu agricultural management calendar

Participants from both study areas highlighted that spring onset (September) is the most suitable time to commence sowing (Figure 5.3, 5.4). However, their details on the time they start reaping and harvesting timeline indicate that the different sowing dates within the sowing season are not overtly marked (Figure 1). Furthermore, in Lusikisiki, community members stated that the beginning of September marks the beginning of suitable weather conditions, but they begin sowing in the big gardens in November-December.

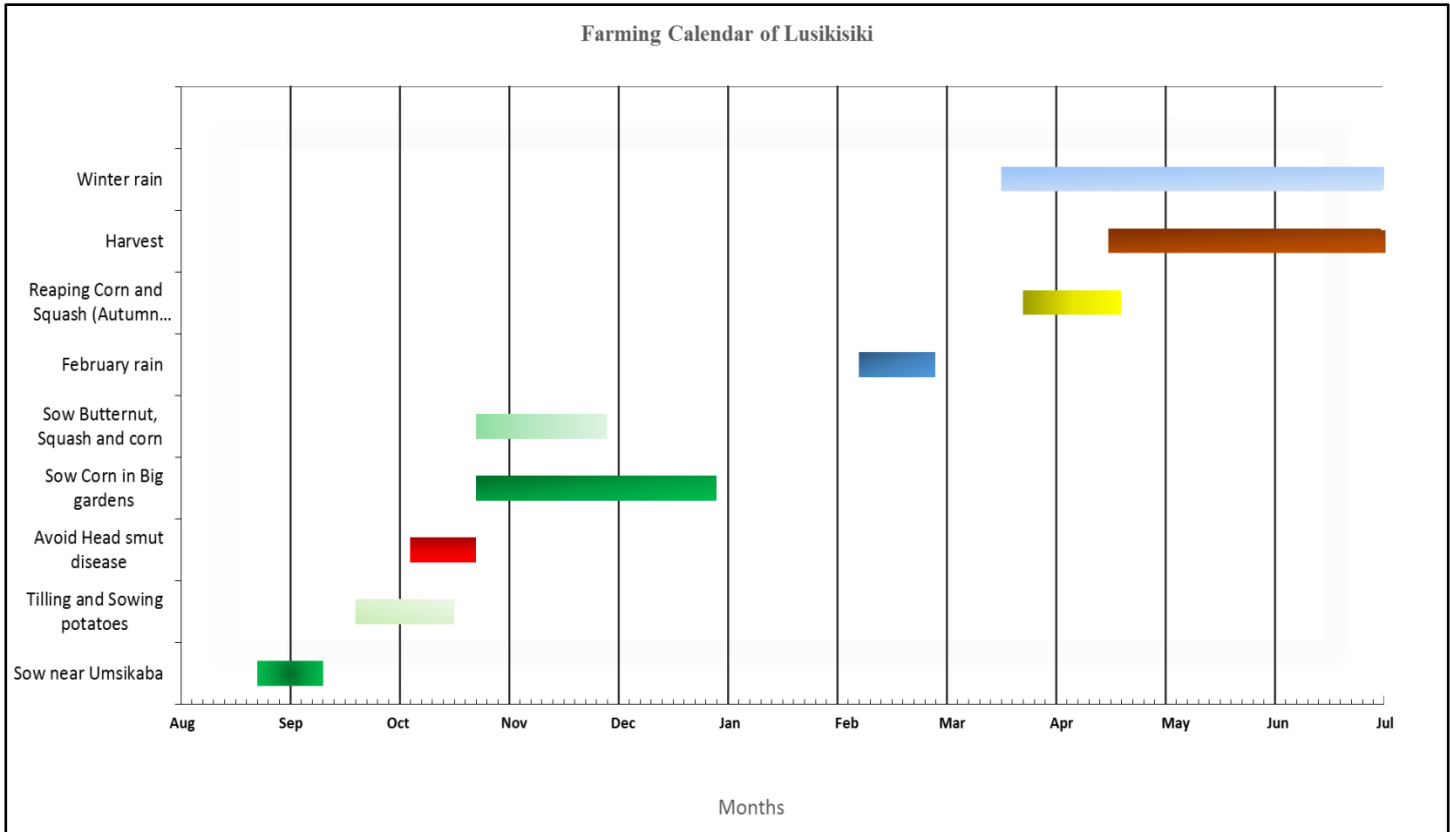


Figure 5.3: Important Dates and activities in Lusikisiki agricultural management calendar

For example, farmers state that it takes three to four months for corn to mature but reaping in March-April is not consistent with the overtly mentioned September-beginning of November sowing start date. This indicates that these communities use event-based monitoring to mark the onset of the sowing season, thus there is often no distinct marked calendar date, for example, a respondent stated:

Mealies is sowed in November because we are trying to avoid head smut disease, when you plant early your mealies will get it. The best dates are after 15 November but then again it differs with different people, others plant in December. (NMZ 1.3A)

While a respondent (55-65 years old) in Umzimkulu stated:

“Corn can be sowed from September to December, others can do it even in January but after the 16th of January then it will not grow at all.” (NMZ1.4)

The end of sowing season is marked by the first killing frost, but this does not signal an abrupt stop in agricultural activities, because during the first part of data collection (June-July) some respondents in Umzimklu were growing crops including cabbage, beetroot and spinach in their small backyard gardens. These crops are argued to be relatively frost resistant and mainly depend on irrigation because there is low rainfall frequency, hence few farmers sow in winter.



Figure 5.4: Some of the winter plants (spinach and cabbage) sowed in Emause, in Umzimkulu. Image captured on 26/09/2019

Both areas have dates (mostly similar), that are important on their farming calendars (Figure 5.1, 5.2). Community members further demonstrated an understanding of crop phenology, various abiotic pressures that influence phenophases and subsequently the quality and quantity of the yield. For instance, all respondents mentioned that January-February rains are critical to the quality and quantity of corn (Figure 5.1). This is because corn in big gardens usually flowers around this time. All respondents stated that rainfall scarcity or moisture deficiency during this

time inhibits healthy cob development resulting in smaller yields, regardless of the healthy state that might have been observed during the leafing stage. A community member in Lusikisiki explained:

“Rainfall is very important when the corn flowers, but it must not be too much because if it is, then the corn will rot.” (EC 2.3)

Another participant (55-65 years old) in Umzimkulu also highlighted the importance of February rains, she said:

“February is a sign whether or not there will be a great yield for that year, we see that when the mealies flowers then it creates cobs. But when it becomes too hot in February, that year is dead.” (NMZ.1.4)

The synchrony between flowering and rainfall occurrence is contingent on the sowing dates, corn sowed at the end of November to the first week of December flowers in January-February, thus more likely to receive January-February rainfall during the flowering stage. Farmers in both areas mention that corn sowed before November dates flowers before February, but there is a range of factors that can limit yield success and are not directly linked to moisture deficiency i.e. head smut disease when corn is sowed in October. Moreover, respondents explained that there are some extrinsic factors that affect farming timelines. For example, although participants from Lusikisiki mention that June to mid-July is the most suitable time for harvesting, they stated that they often have to advance this date because of livestock, which most of the time is not herded and may eat corn before it is harvested and stored. In Umzikulu farmers advance harvesting dates due to preference, because livestock is reared near homesteads and is herded to kraals every afternoon, except for days where there are heavy rains after harvest, then livestock is left to graze in gardens. In Lusikisiki livestock is sent to rangelands far from homesteads during sowing season and then

brought back near homesteads to graze on dormant gardens during harvest time. These differences in livestock rearing stem from different beliefs about fencing homes, in Lusikisiki home fencing is not considered a priority by a majority of participants, particularly fencing gardens. Some participant in Lusikisiki have fencing for houses, but gardens, for most of the participants are not fenced. On the contrary, in Umzimkulu home fencing is associated with the integrity of the household, and enables sowing of perennial vegetables and winter crops.

Erratic fluctuations in rainfall resulted in significant shifts in farming timelines with exception to few introduced vegetables that respondents stated can be sowed annually. Respondents argue that these crops can still grow in winter despite limited soil moisture and cold temperatures. However, participants in both Umzimkulu and Lusikisiki noted that there is a notable decrease in the yield, for all crops. This is associate with the increased inter-annual variability in rainfall frequency and reduced fertility. Also, in Umzimkulu there were several religious remarks about the changes in climate, particularly for high temperatures, in Lusikisiki these changes are mostly just attributed to progressing times.

5.5.1 Factors affecting Farmers' Productivity

As a result of changes in rainfall frequency and intensity, cropping calendars in both Umzimkulu and Lusikisiki have changed. Although all respondents are aware of the myriad components involved in farming, including seed quality, soil quality, and insect damage, they all stated that the increased frequency of prolonged dry spells and high temperatures are the main factors hampering agriculture productivity. In addition to being crucial for intrinsic biophysical plant growth and various phenophases, rainfall frequency and intensity governs the amount of time and resources community members can dedicate to farming activities because it is also linked to

domestic water availability. Therefore, there were constant remarks about domestic water supply around the discussions of prolonged dry spells impacts on agriculture. One participant in Lusikisiki explained:

“When it does not rain, we have to go to the river, which is far away, sometimes with elderly people because their children are in school or they are lazy. Old people already have little energy so they cannot manage to go to the river and come back and go to the garden. Even for us younger people, that can be too much work.” (EC 2.2B)

Community members asserted that high rainfall frequency often leads to relatively less physical labour and resources required to maintain farms, which contributes to the efficacy of agricultural management. They seem to understand that agricultural activities are vulnerable to the impacts of changes in climate. Moreover, farmers stated that adverse changes in climate variables will likely lead to permanent soil infertility or create unfavourable conditions for all grown crops. One participant (70-80 years old) in Lusikisiki explained:

“Maybe we will end up being like other places where people do not even plant anymore because of rain scarcity and the high temperatures. You know there are areas where people do not sow anymore because they do not get rain, right? We cannot dispute that possibility because we can see that things are changing.” (EC 1.1)

This information and projections are based on cumulative experience and observations and demonstrate information sharing amongst community members from different areas. It also displays the agency of IKS and reaffirms that indigenous weather awareness is influential for daily activities and agricultural decision making in these communities. In addition, this exhibits cognisance of the environmental factors essential in agricultural productivity in these rural

communities. As a result, there are several strategies that participants from both areas apply to ensure and/or restore farming productivity. Farmers mentioned that weather conditions affect crops in different ways at particular stages of growth. For example, hail, thunderstorms, and windy conditions are detrimental to corn productivity at its flowering stage, because they can damage the leaves and break stems, thus limiting cob development. These weather conditions do not have the same consequence in the early leafing phase because of the physiology of the plant. However, extremely frequent high-intensity rainfall is noted to negatively affect corn in all stages of growth and beyond with a myriad of consequences: flooding the seeds before emergence, waterlogging during the growing phase, and rotting the yield after harvest. On the other hand, high temperatures and prolonged dry spells are argued to be more detrimental after flowering because they supposedly lower the expected yield regardless of indicative conditions that might have been observed during the early stages.

5.5.2 Changing Agricultural Practices

Community members in Umzimkulu and Lusikisiki reported that agricultural methods and practices have changed. Participants expressed that several factors influence their decisions to adjust farming methods i.e. reducing garden plots for the staple crop (corn), use of chemicals, and changes in planting strategies. The driving factors for this change include decreased household demand for the crops due to household economic development, climate changes and arable land availability. All community members stated that in the past it was necessary to sow bigger plots to ensure the production of various foods (*samp*, *mealie meal*, *isangcobe*) from corn. Now the increased availability and access to other food sources due to household financial development caused the employment of family members, or government grants minimises the

dependence of families on subsistence farming for food production. Community members in Lusiksiki reported that the reduced dependence on farming for food is the main reason they no longer sow in the forest, in Umsikaba river floodplains. These community members used to sow in the floods plains earlier than in their home gardens to ensure food availability for Christmas. This farming practice was motivated by high soil fertility and water availability along the river bed, and convenience, because it enabled multi-tasking for young brides as they were required to collect firewood at least five times a week. Therefore, they were able to attend to garden plots and collect firewood in one place. Household economic development has reduced the sensitivity of community members to climate stress-induced food shortages. Admittedly, respondents above 60 years old expressed dissatisfaction with the store-bought foods. Custodians also stated that the use of fertilisers compromised the quality and abundance of wild vegetables thus further contributing to excessive dependence on market-based food sources. Changes in farming practices are results of household economic development, but they are a good marker for environmental change, changes in farming practices and phenology. The older community members indicated that although overwhelming dependence on the natural environment was mostly motivated by financial poverty, it offered food sovereignty, and prevented and addressed medical needs at the same time. Intshungu is one of the repeatedly mentioned disappearing wild plants.

“When you are beaten by a snake and drink it (insthingu) then the effects will subside or be insignificant until you get professional help. It also helps with diabetes and high blood pressure. You boil it and then drink the residue; it helps with a lot of things.” (NMZ 2.3 A and B)

While another participant stated from Umzimkulu stated:

“Now we sometimes have to add chillies in isgwaba because intshungu is scarce, I think it is disappearing.” (NMZ 1.3A)

This indicates the influence of environmental change on the dietary choices on these rural areas. Furthermore, community members have to use the money to buy alternatives to the previously readily available wild vegetables, which increases household expenditure and affects livelihoods.

5.5.2.1 Sowing Date Adjustment

Agricultural activities in the study areas are mainly rain-fed, this promotes the development and precise implementation of adaptation strategies because growing season has to coincide with high rainfall activity. Spring rainfall onset is marked as an indicator for sowing onset date in both areas because it conveys increased domestic water and soil moisture availability. Farmers in Umzimkulu and Lusikisiki frequently execute preventative and responsive strategies that facilitate food production and reduce losses in the face of perceived environmental change. They develop these strategies using keen skills that they possess because of long term residence in their communities and dependence on the natural environment for agricultural success, which fosters a close relationship with the natural environment. In Umzimkulu, respondents mentioned that salt is a multipurpose ingredient in environmental change adaptation. Salt is used to retain soil moisture during and/or after winter’s last rainfall to ensure that sowing season is not delayed in case spring rainfall onset is extremely delayed. Salt is also added to cow feed to promote bone and muscle health, especially during the cold winter rainfall to avoid injuries. Farmers stated:

“When the end of winter rainfall is not as heavy, we add kosher salt to the poultry compost and apply this while it is still raining, this ensures that plants roots will not be exposed to extremely dry conditions during the growing season.” (NMZ 2.3)

While another respondent said:

“We pour salt on dry corn stems after harvest, store those stems and then feed them to our livestock during the last rains of winter.” (NMZ 1.1)

Respondents stated that the process of adding salt to dry corn stems for cattle feed is useful regardless of the occurrence of winter rains because when there is rainfall scarcity and veldt fires, they still manage to feed livestock. Another participant from Emause, also in Umzmkulu stated that the intensity of winter rainfall and snow indicates relatively early sowing season onset. She (55-65 years old) explained that she uses kraal manure to retain soil moisture. She stated:

“Kraal manure warms the soil and retains moisture, so if I pour it around May and we receive snow in June, the soil will be moist and fertile then I can start sowing early.”(NMZ 1.4)

This strategy is argued to support sowing before rainfall onset but it is also contingent on the density of snow after pouring kraal manure. These farmers have various IK measures that contribute to the development of localised adaptation strategies to escape the effects of environmental change. All participants indicated that the farming calendar is mostly informed by inter-annual experiences and is result based knowledge. As a result, a respondent from Lusikisiki, KwaDukada expressed concerns about the quality of the information he was providing He argued that because of erratic weather changes, more adjustments may be required for oncoming sowing season, thus rendering the information provided during the data collection period ineffectual. Also, respondents emphasised that although there are known seasonal variations and timelines for farming activities, it is important to be attentive to essential environmental changes to develop and apply adaptation measures accordingly and ensure productivity. At the beginning of a sowing

season, important information deduced from empirical observations, and experiences from the previous growing season including, sowing dates, type of seeds, amount of fertiliser used and acquired yield are carefully considered. However, participants reported that the predictability of the yield and efficiency of traditional methods is currently less reliable because of erratic change in rainfall seasonality. One participant in Lusikisiki stated:

“Times have changed, we do not know what to do now because you might sow in October this year and get a good yield but when you repeat the same thing next year, it does not work.” (2.3EC)

Therefore, some methods are continuously adjusted depending on observed changes to reduce losses. These adjustments are based on the farmers’ knowledge of their landscape and understanding of crops’ environmental requirements. One of the most efficient adaptive measures, particularly for corn is delaying the sowing dates to ensure that it coincides with rainfall onset or more frequent rainfall, thus limiting moisture deficiency that would be detrimental to the crops’ success. For instances, during the second part (27 August 2019 to 13 September 2019) of data collection, farmers stated that sowing season was already delayed because of the prolonged dry spell. A participant (60-70 years old) in Lusikisiki stated:

“I cannot just now go out there and start tilling, the soil has cracks, it is just too dry to do anything on it, that corn will not grow.” (EC 2.4)

Some farmers had already planted potatoes, but they stated that potatoes do not require as much rainfall as corn because they ‘eat from the roots’. Furthermore, they emphasised that potatoes can always recover as long as it eventually rains because they are perennial plants. Umzimkulu and Lusikisiki community members’ diligence in farming informs their extensive knowledge about

plant responses to various climatic factors and soil properties. In these communities, this is referred to as ‘just knowing’. Spring rainfall onset determines the start date of the farming calendar, but several community members expressed that it is important to sow regardless of rainfall onset. They explained that late rainfall onset does not justify inactivity throughout the growing season because there are adaptation measures that can be employed to address risks imposed by climate stressors. Furthermore, in the event of extremely delayed spring rainfall onset, community members believe that God will deliver rainfall if they start sowing, which is consistent with participants’ belief that God will reward them if they work on and respect their land. One respondent explained:

“Mr Mngonyama, my neighbour used to say that is all laziness, to not work because there is no rainfall. “Plant and see if God will give you rain or not,” he said, but to just sit because there is no rain, that is just laziness. What if it rains and you have nothing, it is plain laziness to say you will not work because it is hot and there is no rain.” (NMZ 1.1)

Another respondent in Umzimkulu said:

“Even when it is not raining, we still work and sow, it will die if it dies and we will put some seeds again because we need food, until it rains.” (NMZ 1.3A)

In Lusikisiki another respondent reiterated:

“Sometimes the rain will start at the beginning of spring and we would start sowing but it will then be followed by prolonged dry spell mid-season. In that case, the seed will rot underground but we wait when the conditions are more conducive, we plant again.” (EC 2.3)

Notwithstanding, community members from both areas still emphasised that rainfall is essential for plant growth, thus sowing before rainfall onset, unless rainfall extremely delayed, is ill-advised. These subsistence farmers from Umzimkulu and Lusikisiki displayed adaptability in their farming methods despite the environmental change, while maximising the benefits of climate variability. Furthermore, they demonstrate remarkable ingenuity in adopting modern knowledge and assistance from government avenues such as the KwaZulu-Natal Department of Agriculture and Rural Development, but they still maintain and integrate indigenous practices to overcome vagaries by environmental change. This is because IK relating to weather is still the framework for pragmatic adaptation measures developed for agronomic purposes and domestic water availability in the study areas.

5.6. Phenology Awareness

5.6.1. Indicators

Subsistence farmers in Umzimkulu and Lusikisiki have confidence in intrinsic environmental elements to forecast daily and seasonal weather conditions and inform their agricultural management and daily domestic or travelling decisions. Indicators that are significant in these areas include phenological events (flowering and leafing), astronomical (sun, moon, and stars) and meteorological conditions (clouds and wind direction). Farmers' description and responses to phenology indicators suggest that vegetation phenology in these communities is predominantly influenced by air temperatures and precipitation. For example, a participant (41-49 years old) from Umzimkulu stated:

“When I start seeing peach tree leaves, then I know the temperatures are ready.” (NMZ

1.5)

There are no formal records of the indigenous indicators but subsistence farmers from Umzimkulu and Lusikisiki possess a repertoire of information that contributes to indigenous agricultural management and tracking seasonality. Most of the flora phenology indicators are noted because of their relationality and agency to the community members, while animal activity is predominantly noted because of their seasonal emergence and mutual or parasitic relationship to grown plants, and livestock. A prominently noted phenological event is the flowering of peach trees, which is argued to indicate spring season onset. Community members alluded that these trees are significant indicators because peaches are a dominant and tasty fruit, while although flowering of *Umsalingi* (China berry) tree also indicates spring onset, it has no significant use and thus not commonly mentioned as a seasonality indicator. Accordingly, in Umzimkulu respondents noted that the arrival of a flock of pied crows within seven days after sowing corn indicates that the emergence stage has initiated because pied crows eat corn at this stage. There is a correlation between phenology indicators for weather and climate, and the agency of the phenophase or animal behaviour in plant productivity. Farmers from both areas demonstrated awareness of the inter-relationship between meteorological conditions, phenological events, and observation of astronomical cues. This study captured several indicators used by the communities for daily weather and seasonality forecast (Table 5.3).

Table 5.3: Indicators for seasonal change and daily weather used by community members in Lusikisiki and Umzimkulu

		Seasonal Change	Daily Weather	Interpretation	
Lusikisiki	Plants	Peach Trees	X	Flowering indicates spring onset. Heavy flowering indicates a good rainy season.	
		Unopiyo	X	When this plant emerges and flowers, it is the beginning of spring.	
		Grass	X	When the grass turns green again, this indicates spring onset	
	Animals	Uvethe		X	Croacking of this frog indicates it will drizzle or there will be a gentle rain
		Iselesele		X	Croacking of this frog indicates heavy rainfall
		Goats		X	When goats bleat and run home, this indicates oncoming rainfall
		Southern Hornbill		X	The humming of this bird indicates rainfall in a few hours
Umzimkulu	Plants	Amagosi	X	When they emerge, it is spring	
		Peach trees	X	When they flower it is spring	
		Chinaberry	X	When chinaberry tree flowers it indicates spring onset.	
		Udwabaza	X	The emergence of this edible wild plant indicates spring onset.	
		Ucadolo	X	The emergence of this plant indicates spring onset.	
		Mushrooms		X	Abound mushrooms in certain parts of mountains indicates oncoming rainfall and thunderstorm
		Grass	X		When it turns green, it indicates spring onset
	Animals	Southern Hornbill		X	When it hums, it will rain in a few hours.
		Phezikomkhono	X		When they hum, it indicates approaching spring onset.
		Intlwabusuku		X	When they emerge it will rain or continues to rain.
		Swallows	X	X	The arrival of swallows indicates spring onset. When a flock of swallows plays in the sky it indicates rainfall, in a few days.
		Pigs		X	Excessive grunting of pigs indicates near rainfall.
		Isiphephane	X		When these birds arrive, this indicates spring onset.
Meteorology	Warm winds from the east		X	Indicates oncoming gentle persistent rain.	
	Dark clouds from the southeast (Cumulonimbus)		X	Indicates imminent Hailstorm and intense rainfall.	
	Reddish clouds from the North		X	This indicates oncoming or occurs concurrently with windy conditions	
	Rain clouds (nimbus clouds)		X	When they prevail, they indicate rainfall for that day	
	Fog in the morning		X	Sunny conditions and high temperatures during the day.	
	Rainfall	X		Early rainfall onset indicates a good rainfall season/ growing season	

Astronomical	Five stars aligning in the South East	X	Indicates spring onset
	Quarter moon facing up	X	Indicates rainfall
	Quarter moon facing down	X	Indicates that rainfall is coming in a few days
	Moon with a halo	X	Means that there will be windy conditions the following day or during the night
	Half-moon during the day on a clear sky	X	This indicates oncoming windy conditions, in a few hours. In some instances, this occurs concurrently with the windy conditions.
Sensory	Smelling mud	X	Indicates oncoming rainfall, in a few hours of days
	Painful athlete's foot	X	When it is raining this indicates that it will be sunny conditions for the following day and vice versa.

The use of the indicators in Table 5.3 for short and medium-term forecasts and farming decision making is based on status monitoring. It is informed by experience on species behaviour and seasonality gained through a long time of heeding species interactions and seasonal functions in the respective areas. Spring season onset and oncoming rainfall; short to medium-term indicators are the most considered variables (Table 5. 3). This is because rainfall is a critical climatic factor affecting farmers' productivity in the areas. Therefore, indicators for other climatic factors such as wind were not frequently mentioned. Farmers from Umzimkulu stated:

“Although wind can damage plants and make the soil dry, we do not experience much of it, except around August, and therefore we do not have many indicators for it. We mostly just see it when it occurs.” (NMZ 1.4; 55-65 years old)

“We focus more on the rain, the wind is...no it is not that important. I do not think there is something that indicates for wind, we just see when it is here but we all know that it is most prevalent in July-August such that Zulu people named July uNtulikazi (mother of dust); it is known as a very windy month.” (NMZ1.2A; 55-65 years)

“Although they (winds) are not as important, we believe that when we see a moon surrounded by a whitish shade or something like dust, it is going to be windy the next morning.” (NMZ1.1)

However, other participants in Umzimkulu remarked that wind direction can be an indicator for the duration and intensity of oncoming rainfall, one respondent explained:

“When it comes to rain, we are mostly governed and rely on the indicators from the south, from the ocean because sometimes it happens that we wake up and see a blanket of fog there (pointing to the south) followed by the cold wind (not too cold) that comes from that side and when it is like that, then the rain will come. That rain is gentle, and rains for a couple of days maybe two or four days.” (NMZ 1.2A; 55-65 years old)

Another respondent (71 years old) had a different interpretation of the cold winds from the south coast argued:

“But in reality, they are just using their ‘new’ education while for us, it was all about noticing wind directions and temperatures we would say “tomorrow it seems like the weather will be bad”, because of the cold winds coming from the south.” (NMZ1.1)

Respondents from Lusikisiki did not mention winds and wind direction as a significant climatic factor in their farming activities or management. In Lusikisiki strong winds were mostly linked to property and fruit tree damages. In both areas plant phenophases indicate seasonal variations while animal behaviour, meteorology and astronomical cues predominantly mark short term weather conditions that will occur in at most a week (Table5.3). In addition, flora indicators noted by respondents occur before seasonal onset while fauna species predominantly mark imminent weather conditions (Table 3). For example, in Umzimkulu, a farmer (30-39 years old) from Highlands explained:

“Udwabaza and ucadolo (Bidens Pilosa) show up before we sow in our gardens but they show that now we can sow and njijela next to kraal they grow.” (NMZ 1.2B)

Another one in Emause (55-65 years old) stated:

“A year that will have enough rainfall, we know by...around August, sometimes we see from how the plants bloom, around August plants start blooming, so when they just shoot and bloom too much then we know that there will be rainfall that year. (NMZ 1.4)

The farmers in Umzimkulu and Lusikisiki commend primary monitoring of plant phenophases, and they state the importance of early observations for implementing adaptation measures to ensure maximum yield, particularly for corn. All respondent from both study areas affirmed that it is important to be able to discern seasonality from observations and deduce the quality of the rainfall season from indicators. For example, the blooming of peach trees indicates spring onset (Table 5.3) but variations in flower abundance indicate the quality and quantity of rainfall, and the fruit yield to be expected. However, community members remarked that there are meteorological factors such as hail that can damage the plant and subsequently lead to less fruit production. Nevertheless, reduced plant productivity does not negate the initial rainfall forecast. On the contrary, a respondent in Lusiksiki argued that grass greenup indicates spring onset but peach tree phenology is not a sufficient marker for sowing season onset. She stated:

“We can see when it is spring onset, outside, in the yard and veldt becomes green and plants bloom. You see outside, the soil has cracks, which means it is dry but peach trees are green, leafing. Peach trees shed and regrow leaves regardless of weather conditions when it is time to do so, they change.” (EC 2.6)

This contradictory with the views of the majority of farmers from both areas, who expressed that peach trees are a significant and most essential marker for seasonal variability and air temperature change. Participants stated that the IK indicators and informed strategies have demonstrated versatility over generations. There are weather forecasts (mostly oncoming rainfall) derived from meteorological conditions (Table 5. 3). Early rainfall onset also indicates good rainfall season, but there are observed changes in the reliability of this indicator, while daily precipitation indicators, including fog and dew, remain more reliable.

Fog is an indicator that it is going to be a very hot and sunny day in summer, fog, and dew in the morning, meaning it is going to be very hot during the day. Even if you did not hear anything from the weatherman, you just know, and truly around 9 am it will start, the sun will come out. (NMZ 1.3A and B)

Apart from the advantages in growing season and plant optimal productivity, respondents mentioned that seasonal variability and pre-season forecasts are vital for the health of livestock. From monitoring meteorological events, farmers can determine the amount and type of medication required to maintain livestock's physical health during the seasonal transition, especially winter to spring transition. Community members stated that the winter to spring transition is critical for livestock because cattle are transitioning from grazing on dry grass and grass scarcity due to veldt fires, to new fast-growing grass which renders livestock prone to grass tetany. Therefore, all farmers echoed the importance of winter-spring vaccination on livestock, especially cows. Rainfall intensity and frequency are two of the main components determining the quantity of medication required. Community members stated that high-frequency rainfall during winter cessation to spring onset suggests that more medication may be required to treat grass tetany and colds.

5.6.2. Local weather forecasting

Community members in both Umzimkulu and Lusiksiki stated that the reliability of indigenous weather indicators and risk reduction methods has decreased. However, traditional weather forecasts still play a significant role in agricultural management, water harvesting and minimizing the effects of extreme weather conditions. This is indicated in the statement from a respondent (35-45 years old) from Hopewell, in Umzimkulu:

“In the past, when we saw dark clouds from South-East; hail storm clouds, we would ring metals to control the coming storm, it subsided, but now once those clouds emerge there is no stopping it, even if we ring metals. However, we still know that rainfall is coming, so prepare.” (NMZ 2.1)

The Ground Hornbill is also singled out as the indicator that used to have more than high accuracy for indicating oncoming rainfall and has predominantly lost reliability in both communities. The arrival of swallows is still used to indicate spring onset in Umzimkulu, and flowering of plants is widely used in Lusikisiki to indicate spring onset (Table 5.3). Community members from both areas noted that there is a change in abundance, distribution, and onset of phenological indicators. Several respondents from Umzimkulu remarked the delay and scarcity of colourful Christmas birds. This change is explained to have occurred in less than ten years ago. While in Lusikisiki, there are plants; unopiyo and unoncwembu that have disappeared, these plants were important indicators for the sowing onset in the forest. Community members from both areas noted the disappearance of spring-summer butterflies which used to mark a seasonal change, and community members attribute this to the use of chemicals. One participant (70-89 years old) from Umzimkulu stated:

“We used to have butterflies, the yellow ones with little black spots on the wings and then the brown ones with black and white spots in the wings. They used to arrive around mid-September, I think the presence of too many chemicals in the air is the reason they disappeared.” (NMZ 2.2)

Meteorological indicators, although important, they do not offer forward-planning for agricultural activities and therefore are mainly important for domestic water harvesting. While the accuracy of nimbus clouds is questioned, community members constantly mentioned cumulonimbus clouds as a reliable indicator for hail and thunderstorm. In Umzimkulu community members remarked that their methods for abating these thunderstorms are less effective. They associate the inefficiency of these methods to prolonged dry spells, stating that when there is rainfall after a prolonged dry spell it is more likely to cause destruction regardless of what they do.

5.6.3 Seasonal Variability

In Umzimkulu and Lusikisiki there is no distinction between spring and summer onset date; both seasons are marked by rainfall which is the most important climatic factor in agricultural activities. Therefore, spring onset indicators are overtly noted while summer onset, although marks the beginning of high-intensity rainfalls relative to spring, is not attentively monitored or labelled by community members. Meteorological starting dates are marked by climatic factors that are associated with various agricultural activities. Therefore, based on changes in temperature and rainfall frequency, community members can infer an ‘early’ spring onset.

“Sometimes spring will come early. We look outside and see the grass is green, flowers are blooming but when you look at the date, it is not yet the end of August or the beginning

of September. If those signs are followed by rainfall, we sow anyway because the conditions are good." (NMZ 1.1)

There are several indicators for spring onset (Table 5.3). This is because spring has favourable weather conditions for crop growth and yield success for most crops that are sowed in the study areas. Weather conditions and species phenology imply the trend climatic variables throughout the season and ultimately agricultural productivity. For instance, respondents stated that early rainfall onset indicates a high probability for high-frequency rainfall throughout the growing season thus assures successful yield. Some seasonal forecasting includes both phenology indicators and empirical observations, one participant (41-49 years old) explained:

"Sometimes it rains in August, but you will feel that it is still cold, but when it rains, and the peach trees are leafing then I know the temperatures are ready. Then I can start sowing." (NMZ 1.5)

Indicators for the beginning of winter and autumn seasons are not distinctly monitored. This is because, although some farmers sow introduced food crops such as carrots, spinach, beetroot and cabbage during these times, the vegetables do not thrive, and are not completely dependent on natural environment viability because they require irrigation in winter. However, community members expressed that the cold and dry weather conditions in winter are good for initiating corn harvest because corn must be dry before harvest to avoid fungus infestation in the reservoirs. Nevertheless, community members did not demonstrate extensive knowledge of winter indicators or high priority significance in their agricultural activities. For instance, although the arrival of birds at the beginning of spring is noted, their disappearing dates are not marked nor noted.

Community members are attentive to the natural environment and recognise that this acquires them sovereignty over farming practices because they depend on environmental viability for

optimal agricultural productivity. Therefore, early weather forecasting through locally observed variables provides an opportunity to improve agricultural management for approaching sowing season, enables ecosystem monitoring and extensive understanding of seasonal events thus facilitate adaptation to the changing environment. In Lusikisiki, majority of the respondents projected that 2019-2020 growing season will be less productive because of the observed rainfall scarcity during winter, which is mostly highlighted by the absence of winter rainfall after harvest and delayed spring rainfall onset. One participant (30-40 years old) stated.

“You see in August there would be that intense rain, or in July that really intense and cold rain called umbolisa ndiza. The last rains of winter, the cold ones, we did not have them this year...now that I think about it, we did not have them last year either.”(EC 2.1)

The end of winter rain is significant in both communities for both domestic water availability and agricultural management purposes. This rainfall signifies the average growing season rainfall potential in Umzimkulu. Therefore, it is important for preparing for sowing onset inputs such as the amount of fertiliser, human capital and predicting yield. Moreover, it is needed to induce grass regrowth for livestock feed. Farmers predict that the noted disarray in its occurrence will have devastating impacts on farming activities in Umzimkulu and Lusikisiki communities.

5.7 Knowledge Development and Ownership

Community members in both Umzimkulu and Lusikisiki share information within their areas, particularly in the case if new and/or excessively abundant insects or pests that are presumed to have a negative influence on crop productivity or livestock health. Respondents from Umzimkulu displayed an ability to mobilise their resources, share agronomic problems and solutions, and compare results to determine the effectiveness of the strategies they develop. Information is

shared through discussing intrinsic or extrinsic challenges that may hinder yield success. Community members also share suggested adaptation and mitigation measures, to counter the risks. For example, a farmer from aBorder (60-70 years old) stated:

“I usually sow in September and/or November to avoid iSihlava (Head smut disease) in October, but my neighbour across the road cannot do that because her soil is different to mine, she tried it because I had told her that those are ideal times since head smut disease is problematic in this area but it did not work for her. She just has to treat head smut disease and sow in October.” (NMZ 1.6)

Community members in Umzimkulu alluded that Head Smut disease was more prevalent in the past when the butterflies that arrive at the beginning of spring were more abundant. These butterflies are agued to have disappeared because of the use of chemicals on plants, which supposedly made the environmental conditions unfavourable for the insects' survival. Although their disappearance attributed to continued use of strong pesticides and chemicals, which is criticised by community members, the benefits of reduced head smut disease abundance are noted. In Lusikisiki, respondents acknowledge that different households apply varying strategies to manage farming activities. However, community members did not display deliberate and strategic sharing of information on sowing and adaptation strategies, particularly during the growing season.

Subsistence farmers in both study areas expressed that they have different preferred strategies to ensure optimal agricultural productivity. These community members recognise that each farmer has individual preferences of agricultural methods that they maintain to assure yield success for their household. However, there is a consensus that everyday monitoring of crops such as weeding and spacing is essential for crop growth. They point out that this helps them track changes,

identify stressors and implement measures to restore crops or adjust agronomic methods within the growing season, thus securing yield. As a result, a majority of custodians do not hire gardeners, despite awareness of the physical constraints caused by their age. Furthermore, custodians mark the decreased use and reliability of indigenous methods but they retort that these strategies are financial inexpensive and are still useful, a respondents Umzimkulu stated:

“Since you are doing research, you will use and record this knowledge, right? So young farmers can have options, when they cannot afford to use conventional farming methods, then they can fall back on these methods.” (NMZ 2.3)

While most respondents reiterated the importance of IKS and the urgency of transmitting it to the younger generation, one respondent from Lusikisiki in her early thirties stated that there is no need to document this knowledge. She explained that this knowledge is not relevant to the household or personal development of this generation she (30-39 years old) stated:

“We need jobs, we went to school and studied but now we are back here and we are told to practice farming. I do not see the need to know all these things that our parents used to do to while working in the garden and farms, these things will not help us. We have the department of agriculture, they can help with that.”(EC2.2A)

This is slightly similar to the views of some custodians in Umzimkulu with statements such as:

“Our children are educated now, they do not need to have this knowledge for survival.”
(NMZ 2.3A)

“Those are all the things we did because of poverty.” (NMZ 2.3B)

On the other hand, a majority of participants argue that the high unemployment rate in the country should be the main reason for teaching IKS and practicing farming in rural areas to ensure food

availability. In the same household as respondent 2.2A, a participant in his late seventies (70-80 years old) stated:

We do not farm as much, retail stores are our gardens. All the things that can be sowed are bought and it costs money, people need money to be alive, in the past, we were able to keep the little money that we had but now we practically live in town because everything we need is in stores. On the other hand, corn is used for samp, maas, amarhewu, traditional beer and all the other things, they come from corn. We need to plant more and save money.” (EC 2.2B)

Albeit acknowledging the value of IKS strategies, most participants in their early forties and younger, state that conventional methods are important for easier information accessibility and adaptive measures. Most respondents in this demographic affirm that indigenous knowledge is effective in agricultural management and was taught to them orally and through practice from a young age. Therefore, these community members mention that the ability to apply IKS is a sign of maturity, and respect to elders. However, they acknowledged that they were also reluctant to adopt indigenous methods until the strategies were corroborated by their experiences in farming and/or information from formal schooling. On the contrary, custodians declared indigenous methods and adaptation strategies common knowledge and ‘knowing what to do’. Admittedly, these farmers also acknowledge that valuing and respecting their cultural identities and willingness to learn from their elders contributed to the swift adoption and application of IKS. This is partially the reason why documenting and preserving this knowledge is not fully recognised because according to custodians IK is embedded in culture, community engagement and common daily activities. Therefore, although practicality and significance of IKS have been established, the value of *ex situ* documentation is not fully acknowledged. Transmission of

knowledge is directly linked to respect for elders, and ultimately respect for the culture. As a result, a majority of custodians argue that IK conservation will be hard because the youth is disrespectful and has no regard for their cultural heritage. One participant (71 years old) from Umzimkulu stated:

“If the younger generation would listen we would be a better nation. Respect is respect. Children, who respect, know right and wrong, they would know that if they follow this way, they will succeed in life.” (NMZ 1.1)

Younger farmers deliberately accept both indigenous and western system views and methods for farming. A younger respondent from Umzimkulu pointed out that conventional methods are efficient for supplementing indigenous strategies to facilitate yield success. This farmer stated that western methods are convenient which is useful in securing food availability within a short period of climate viability in a year. Traditional methods on the other hand offer spatial specific knowledge which is essential to inform agricultural decision-making, ensuring seasonal yield success and adapting to a changing natural environment. Therefore, he commends the integration of systems for optimal agricultural management. He (41-49 years old) stated:

“I use both conventional and traditional ways because I collect kraal manure outside but I also use herbicides and...chemicals to balance things but I am using both because in my belief...when I was growing up, at home we were using cows to plough and we used kraal manure as a fertiliser and everything grew well. I need the chemicals and herbicides because kraal manure supports the growth and health of everything in the garden and I just want crops.” (NMZ 1.5)

Another younger participant, also from Umzimkulu asserted that conventional agriculture methods are predominantly informed by IKS, thus helping assemble and disseminate traditional methods. He stated:

“When you look at it, the methods used by our elders are not so different from what the department of agriculture personnel tries to teach us. There are little differences but not too much.” (NMZ 2.1)

Custodians’ perception of the younger farmers regarding the use of IKS is distorted. Older farmers state that the younger generation is ignorant and does not accept nor respect IKS methods but a majority of younger farmers use both western and IKS to secure optimum yield. This highlights a need to foster a symbiotic relationship and a constructive discourse between these demographics in Umzimkulu and Lusikisiki. This will promote IK development, application and transmission.

5.7.1 Communicating IK

There are several factors hindering transmission and adoption of IK in Umzimkulu and Lusikisiki. Community members admitted that the value and uptake of IK have decreased substantially. This is mainly associated with household economic development obtained mostly through government grants. Custodians also note that rural-urban migration hinders experimental learning for intended neophytes. Furthermore, they point out that the western focused education system inhibits fluency in aboriginal language, thus farther limiting IK transmission. A participant (80-89 years old) from Lusikisiki explained:

“Once our sons get married, they take their wives and leave, we do not even get to see our grandchildren.” (EC 2.8)

The intergenerational gap between the custodians and the youth also accentuates the resistance for acquiring IK. Community members in Umzimkulu and Lusikisiki recognise that traditional tools for transmitting IK are becoming ineffective because of the spatial differences between the custodians and the younger generation. This hinders both fluency in aboriginal language and experiential learning thus limiting IKS transmission. Admittedly, most custodians lamented that the youth who stay in these rural areas is also not interested nor committed to learning traditional strategies. They state that younger people often associate IKS with poverty and are unwilling to participate in farming. In view of this, some respondents believe that IKS adoption must be facilitated through communicating the information on digital platforms that are accessible and appealing to the youth i.e. social media. One respondent (41-49 years old) stated:

“Even when children visit their grandparents, they are not keen on listening and having conversations nor assisting in the garden, so the information should just be added on Instagram and YouTube, they are more likely to listen and believe it. They believe everything found online.” (NMZ 1.5)

As a result of the observed disinterest, custodians expressed that they do not recognise the need to instill IKS agricultural management skills on their grandchildren. Older farmers acknowledge that IK erosion poses a threat to farming productivity and socio-cultural values. Furthermore, they state that traditional foods are associated with an unpleasant taste. These foods carry a vestige of poverty because they are mostly used as a last resort (towards the end of the month when store-bought groceries are finished), therefore are not prepared with sufficient ingredients to produce tasty relish. A respondent (45-55 years old) in Umzimkulu explained:

“My children do not even want to get in the garden to reap the cabbage I sow, they tell me that they ate cabbage a lot when we were poor, and there is no need for it now that I have a job. They want meat every day.” (NMZ2.3B)

In Lusiksiki a participant (30-40 years old) explained:

“When the Indian store food is finished, I always know we have corn and imifino to eat until we get paid our social grant at the end of the month again. Of course, they do not like those kinds of foods as much as they do rice but they do not have a choice or they will starve.” (EC 2.1)

Apart from disregard for IK, this also displays nutrition illiteracy on the youth. Despite a limited scientific understanding of food nutritional values, the preference for natural foods by custodians, based on beliefs and world views regarding food productivity and sovereignty may have some positive health benefits. Custodians are dying out with the knowledge, which threatens conservation and sustainability of traditional methods even more. This issue acknowledged by participants from all age groups in both Umzimkulu and Lusingi.

“Our children will realise late in life that they should have used this opportunity to learn important things because grandparents are dying.” (EC 2.5; 80-89 years old)

Other participants in Umzimkulu stated:

“I do not know who else will help you in this area; we are dying so there are not many people who know these things as I do.” (NMZ 2.2; 70-80 years old)

“It is only now that they are dead and we realise that we should have been more interested, asked more questions and absorbed as much knowledge as we could.” (NMZ 1.5; 40-49 years old)

Although the youth is reluctant to adopt IKS and the reliability of IK informed indicators and strategies is decreasing, the value and adaptability of IK methods are still acknowledged in these

communities. The continued dependence on IKS is predominantly facilitated by lack of alternate resources but it is also embedded in culture and practice. Therefore, IKS adoption is still considered a sign of respect and morale of the youth by custodians. However, this was mainly emphasised on the behaviour of young women, and respect for culture and house rules through a series of expectations and gender-biased rules. A respondent (71 years old) in Clydesdale, Umzimkulu sated:

“Young girls these days eat eggs, when we were growing up, we were told that we do not do that, and we never asked questions or debated with our elders because that is our culture. They even come home late, but when you tell them what they are supposed to be doing, they will argue and ask questions then end up not doing the things we tell them to do.” (NMZ 1.1)

Other participants in Hopewell had the same sentiment, one of them (45-55 years old) said:

“Our children are always arguing with everything we tell them, you tell a girl not to eat, talk or cook a certain way and they do not listen. They are always on their phones we do not even know their boyfriends anymore because they talk on phones and change them often, they have no respect for the culture.” (NMZ 2.3B)

This indicates that women are expected to play a bigger role in IK conservation and culture preservation than their male counterparts. This is based on cultural perceptions that seem to have been effective in these areas in the past. However, these views ostensibly are not providing a sustainable way to communicate IKS as more females are enlightened about the patriarchal foundation some of cultural beliefs and practices. Therefore, these communities have to establish new gender-inclusive ways to communicate and preserve IKS to ensure effective transmission

and conservation of the knowledge. Community members maintain that IK is an important component of their lives and survival, albeit some processes being substituted by conventional methods.

5.8 Synthesis

Subsistence farmers in Umzimkulu and Lusikisiki are more attentive to rainfall seasonality and patterns because their agricultural activities are mainly rain-fed. Therefore, most noted IK indicators are rainfall related. Community members in both study areas displayed an awareness of climate changes in their areas and the influence of socio-economic changes in their vulnerability to climate-related stressors. Although all participants recognise that household economic development increases household resilience to climate stressors, they highlight that this development perpetuates the observed disregard for IKS, particularly to the youth. Subsistence farmers in Umzimkulu and Lusikisiki displayed strong responsiveness to environmental changes; there are IK strategies developed to address changes, however, they did not highlight opportunities or practices that exploit the opportunities presented by environmental change. All respondents from both study areas appreciate the spatial specificity offered by IKS in daily and seasonal forecasts. However, they are also cognisant of the limits and changes in the reliability of IKS, thus some emphasise the need to integrate of knowledge systems to ensure optimum productivity, facilitate IK adoption and ensure conservation. Generally, all participants involved in the study use both western (herbicides, fertilisers) and IKS in their agriculture practice, although others do not explicitly contend for the integration of knowledge system. This is because all farmers involved in this study are result-oriented, and providing substance to their families in their primary goal.

6. Discussion

This discussion chapter analyses the results obtained in this study relative to the arguments about climate change adaptation in agriculture and the use of phenology indicators in IKS and the projected decrease in reliability. The chapter also displays the similarities in rainfall seasonality and agricultural management in Umzimkulu and Lusikisiki. Section 6.2 discusses the use of traditional phenological knowledge in weather forecasting. This section also highlights the noted change in the reliability of IKS cues essential in weather forecasting, in Umzimkulu and Lusikisiki. Section 6.3 addresses weather forecasting and demonstrates the preferred forecasting methods and critically address the effects of environmental change on IKS cues for agricultural management in the context of Umzimkulu and Lusiksiki. Section 6.4 and 6.5 discuss the seasonality of agricultural activities in the study areas and the important factors that community members consider when applying adaptation methods to facilitate farming success. The last section (6.6) is dedicated to the methods of IKS transmission, threats and potential future of IKS in these communities.

6.1 A Comparison of the Agricultural Management Strategies in Umzimkulu and Lusikisiki

There are similarities and slight differences in beliefs, interpretations of environmental variables, and responses to the observed change in the natural environment between Umzimkulu and Lusikisiki. These results are expected because IKS are rooted in the local culture, they are traditionally and locally developed perceptions of nature within a community (Ziervogel and Calder, 2003; Alexander *et al.*, 2011; Magni, 2017; Plotz *et al.*, 2017; Benyei *et al.*, 2020). IKS vary between communities, between areas within a community and between homes in an area (Eakin, 1999; Gokuda, 2012). Therefore, varying interpretations of the biophysical environment between and within communities is an inherent attribute of IKS (Egeru, 2012; Goduka, 2012;

Dlamini and Ocholla, 2018). Community members in Umzimkulu and Lusiksiki value the cultural and spatial context of IKS. For example, KwaSondazaba is an area within Umzimkulu, approximately 12km south of Hopewell, but a respondent in Hopewell highlighted that she adopted some of her strategies from her birth home in KwaSondazaba and implemented them in her marriage home's farming strategies to enhance productivity. Similarly, in Lusikisiki a participant pointed across the river, less than 5km away to emphasise that she is an incomer in her marriage home area and therefore may not possess knowledge she would consider significant to the study, despite her residing in the area for approximately 50 years. Acknowledging contextual differences is one of the most important attributes of IKS because this knowledge system is founded on mutual respect and trust by different territories to facilitate conservation of spatial and temporal specific species and ensure food production (Eakin, 1999; Mauro and Hardison, 2000; Green and Raygorodetsky, 2010; Ebhuoma and Simatele, 2017). Understanding of species behaviour and environmental change inferences by community members in Umzimkulu and Lusiksiki are not based on scientific understanding of meteorology or ecology. However, the ability to mark differences within a small spatial scale suggests that community members are likely to observe even micro shifts in species because they are attentive to the environment in a manner that informally demarcates regions and environmental knowledge. The differences in IKS between locations within the study areas also highlight the spatial specificity of ecological functions that are overtly emphasised in literature (Parmesan and Yohe, 2003; Cleland *et al.*, 2012; Burrows *et al.*, 2014). To the of Umzimkulu and Lusikisiki, knowing these differences represents a fundamental aspect of cultural identity, and the wealth of knowledge and experiences gained through longtime residence in the locations, direct observation of the natural environment and seasonal functions (Mazzochi, 2006; Benyei *et al.*, 2020). This is also a small-

scale representation of the rich cultural diversity within South Africa (Meier and Hartell, 2009; Cocks *et al.*, 2012).

One of the distinct features that influence agricultural activities in Umzimkulu and Lusikisiki is homestead fencing. In Lusikisiki, it is customary that farmers wait for the Chief's announcement that livestock, particularly cows are sent to seclude feeding veldts (*elubala*) before sowing onset, regardless of whether the rainfall onset has occurred. *Elubala* is an area that is mostly used as communal rangelands, it is approximately 15km away from relatively densely populated parts of Lusikisiki. This livestock farming method influences both sowing and harvest times in Lusikisiki. It does not lead to extremely delayed sowing onset, but farmers have had to harvest corn early because cows were brought back from *elubala*. Harvesting corn before it dries risks fungus infestation and could lead to complete yield losses, which would hinder both food production and seed availability for the next sowing season (Chulze, 2010; Channaiah and Maier, 2014). In Umzimkulu, community members have relatively more individual control over sowing and harvest onset dates because of their belief that fencing the homestead dignifies and shows the integrity of the household, and simultaneously reduce the risk of livestock damage on crops.

Community members in Umzimkulu and Lusikisiki reported that climate change has manifested through increased frequency of prolonged dry spells with high temperatures, reduced rainfall frequency and erratic rainfall seasonality. They state that winter rainfall frequency is reduced, spring rainfall onset is consistently delayed and rainfall days within the rainfall season are also reduced. This is consistent with broad climate change impacts on rainfall characteristics in South Africa (Roffe, 2019; Mahlalela *et al.*, 2020; Ndlovu and Damlie, 2020). KwaZulu-Natal is an SRZ location and the western part of Eastern Cape a YRZ location (Mahlalela *et al.*, 2020; Roffe *et al.*, 2020a). Rainfall seasonality has increased, and wet season duration reduced for most SRZ

and YRZ locations in South Africa (Roffe *et al.*, 2020a, 2020b). Therefore, the effects of the climate change experienced in the study areas are consistent with formally recorded changes in rainfall seasonality over the eastern and southeastern regions of South Africa (Rukema and Umubyeyi, 2019; Ndlovu and Damlie, 2020; Mahlalela *et al.*, 2020). The observed increase in temperature is also consistent with the trends recorded by MacKellar *et al.* (2014) regarding changes in temperature across the country. These changes hinder agricultural productivity in Umzimkulu and Lusikisiki because subsistence farmers in these areas depend on rainfall seasonality for farming and cannot afford alternative resources such as irrigation systems to ensure farming productivity during prolonged dry spells. As a result, most community members have reduced the size of the land sown in response to the lack of adequate water resources. They also note that yield per square meter of land is decreasing and attribute this to changing soil fertility. Nonetheless, subsistence farmers in both study areas still plant annually and employ locally developed adaptive measures to ensure productivity.

Methods of adaptation in various locations are determined by contextual components such as the type of climatic stress, cultural features, productive practices, social capital and socio-economic status of communities (Simatele and Simatele, 2015; Abdul-Razak and Kruse, 2017; Ebhuoma and Simatele, 2019). Differences in adaptation strategies in Umzimkulu and Lusikisiki are mostly due to slight variations in climate stresses and different cultural features that determine social capital. For example, in Umzimkulu, community members have multiple uses for salt in both crop and livestock farming. In Lusikisiki, salt is not mentioned at all in relation to agricultural activities, community members mainly just rely on animal and plant behaviour, and manures for agricultural adaptive strategies. In Umzimkulu participants claim that adding salt to moist soil after winter rainfall will retain the moisture. Prior *et al.* (1992) state that high sodium chloride

content in soils leads to soil and crop dehydration and can significantly reduce yields. Therefore, although salt can effectively kill weeds, the relationship between soil moisture and salt is inverse to what farmers in Umzimulu intend for (Ali *et al.*, 2017). Perhaps more research is necessary to investigate the effects soil salt deficiency on crop productivity because most agriculture and soil science research has focused on the dehydration impacts of high soil salinity on crop growth (Prioir *et al.*, 1992; Ali *et al.*, 2017; Cuevas *et al.*, 2019). Community members in Umzimkulu are confident that salt has positive impacts on crop growth. On the other hand, feeding salted corn stems may indeed have health benefits for cows. Phillips *et al.* (1999) found that sodium chloride reduces stereotypical stress behaviour in cattle. Furthermore, salt can promote the production of milk on lactating cows and its supplementation in cow feed is essential to maintain a balanced diet (Phillips *et al.*, 1999; Gaughan and Mader, 2009). This is because sodium chloride deficiency can cause excessive feeding which would be detrimental for the fitness of subsistence livestock given the reduced food availability associated with prolonged dry spells and veld fires in most rural areas (Gaughan and Mader, 2009). These strategies represent the knowledge and views held by farmers in Umzimulu. The prominent use of salt in farming in this area while agriculture and soil science suggests that it could be maladaptive displays the strong localised cultural beliefs and influence of IKS on farming methods. It also highlights locally developed agriculture management methods that represent generational repetitions and/or adjustment of methods and strategies to maintain livelihoods (Orlove *et al.*, 2010; Alexander *et al.*, 2011; Nalau *et al.*, 2018). Community members from both study areas note the significant changes in winter rainfall seasonality. In Umzimkulu these changes are marked by the inconsistency and unpredictability of the last rains of winter. In Lusikisiki they are signified by the reduced winter rainfall days. The observed changes in rainfall characteristics in the study areas are consistent with Roffe *et al.*

(2020a) findings, demonstrating that for most YRZ locations and SRZ locations, rainfall seasonality is increasing, and wet season duration is reduced. Furthermore, in Umzimkulu, community members distinctly note that there has been a gradual change in rainfall seasonality and agricultural productivity since the 1970s. This is consistent with Blamey *et al.* (2018) findings highlighting that there have been significant changes in rainfall seasonality, characterised by prolonged dry spells since the 1970s in Eastern Cape and adjoining KwaZulu-Natal.

These changes in rainfall seasonality continuously affect subsistence food production in the two study areas. Granted, dietary needs and household economies have changed in both areas, but subsistence farming still plays a significant role in food availability and market expenditure reduction, particularly in autumn months (March-May). In both Umzimkulu and Lusikisi community members pointed out that they spend relatively less amount of money on groceries, both in cash and through credit during the maturing stage of corn. Admittedly 'autumn foods' are not popular, especially among the youth but custodians prepare these foods to alleviate hunger towards the end of the month; before they receive government grants.

6.2 Traditional Phenological Knowledge

Observing changes in the natural environment throughout meteorology seasons is a normal part of daily lives in most rural communities (Armatas *et al.*, 2016; Basdew *et al.*, 2017; Kenote, 2020). The results of this study indicate that descriptive phenology has been an important part of environmental management and seasonality tracking in Umzimkulu and Lusikisi for generations. Community members note plant and animal behaviour, and species seasonal cycles to determine weather conditions, organise farming calendars, ensure social capital, and gather financial and human capital required to commence agricultural activities such as tilling, sowing

and harvesting in the study areas. Phenological processes are good indicators for seasonal variability and monitoring proxies for climate change because plants and animals reveal changes in the biophysical environment at high temporal and spatial resolution (Cleland *et al.*, 2012; Armatas *et al.*, 2016). This is because phenology events predominantly occur in a predictable order in response to climate variables, therefore indigenous communities use this reliable sequence to track seasonality for agricultural management and cultural purposes (Lantz and Turner, 2003; Armatas *et al.*, 2016; Elmendorf *et al.*, 2016). The most prominent phenology indicators for seasonal change in Umzimkulu and Lusikisiki is the flowering of peach trees and arrival of migratory birds, which both indicate spring onset. Generally, the arrival of many birds after winter indicates spring onset in the areas but only three birds are declared important in seasonal and weather forecasting in the study areas: phezukomkhono, barn swallows and southern ground hornbill. Bird species behaviours, particularly migration patterns have historically been used to track seasonality (Vähätalo *et al.*, 2004; Lefale, 2010; Orlove *et al.*, 2010). Bird migration patterns and behaviour have also been used by indigenous communities in Mexico (Eakin, 1999), Uganda (Orlove *et al.*, 2010) and in northern KwaZulu-Natal (Rukema and Umbyeyi, 2019) to forecast short and medium-term weather conditions. As a result of climate change, bird migration patterns are changing and this impacts the reliability of IKS cues in rural areas (Vähätalo *et al.*, 2004; Tomatoni *et al.*, 2018). Community members did not report any significant changes in the time of arrival of swallows for spring onset in the study areas. However, there are observed changes in abundance of some birds and the disappearance of others such as 'Christmas birds' and summer butterflies. This is one of several indicators that further climate changes, which are probably in the future, may compromise traditional seasonality tracking and weather forecasting in Umzimkulu and Lusikisiki. Furthermore, because this knowledge is not documented, these

changes may lead to the information getting lost forever (Dweba and Mearns, 2011; Plotz *et al.*, 2017).

Birds that are used in IKS usually have unique vernacular names in rural areas depending on the locality and the relationality of the species to the community (Koopman and Buchmann, 2020; Mulyanto *et al.*, 2020). Most names are a description of size, colour, migration patterns and/or vocalization (Berlin and O'Neill, 1981; Hunn *et al.*, 2010; Mulyanto *et al.*, 2020). This naming method is also used in scientific nomenclature of the naming of species (Hunn *et al.*, 2010; Deikumah *et al.*, 2015). For instance, *Spizella atrogularis* which is a scientific name for black-chinned sparrow is a loose Latin translation for 'black neck' (Deikumah *et al.*, 2015). In Ghana, pied crows (*Corvus albus*) have three different names; 'akonkrain', 'adene' and 'kwaakwaadabi', these names are based on the birds' habit, colour pattern and call respectively (Deikumah *et al.*, 2015). In this study, Phezukomkhono (*Cuculus solitaries*) is the only bird species distinctly named after its calls and connected to the time of its arrival (at the beginning of spring). In other parts of KwaZulu-Natal, this bird is also known as phezukomkhono but indicates sowing commencement regardless of the season (Basdew *et al.*, 2017). However, in Umzimkulu phezukomkhono is only linked to spring onset, which is why its calls are used as an indicator to start furrowing or tilling but not immediate sowing commencement. Southern ground hornbill call, barn swallow arrival and frog calls are also used in other parts of KwaZulu-Natal and Eastern Cape to indicate spring and/ or rainfall onset (Lupuwana, 2008; Yusuf *et al.*, 2014; Basdew *et al.*, 2017; Rakuma and Umbyeyi, 2018). The use of the same species with slightly varying interpretation demonstrates a potential to synthesise information if more extensive research were conducted and clear relationships and differences established.

There are changes in the reliability of traditional indicators for rainfall occurrence in Umzimkulu and Lusikisiki, which is not uncommon for most rural areas depending on IKS for weather forecast (Ebhuoma, 2017; Plotz *et al.*, 2017; Salite, 2019). The most remarkably change in both areas is the significantly reduced reliability of the indirect traditional phenological (TPK) indicator; southern ground hornbill (*Bucorvus leadbeateri*) call. Community members reported that in the past, the southern ground hornbill call was the most accurate indicator for oncoming rainfall in a few hours. Participants in both areas lamented that this indicator currently has the lowest reliability in weather forecasting. The southern ground hornbill is the largest hornbill species, it is carnivorous, territorial, broadly distributed in southern Africa and is one of the highly threatened species in the region (Theron *et al.*, 2013; Daso *et al.*, 2015). Despite its wide distribution and significance in weather forecasting across southern Africa, there is a lack of peer-reviewed literature on this bird (Jerling, 2011; Jordan, 2011; Daso *et al.*, 2015). However, the sparse available literature highlights that the southern ground hornbill is on the red list of globally vulnerable and threatened birds (Jerling, 2011; Witteveen *et al.*, 2013; Daso *et al.*, 2015). The observed declines in the numbers of this bird in Umzimkulu and Lusikisiki are analogous to the recorded declines in the reports from protected areas (Theron *et al.*, 2013). These declines are attributed to accidental and intentional poisoning, food shortages and habitat degradation (Theron *et al.*, 2013; Witteveen *et al.*, 2013). Southern ground hornbills do not vocalise often, therefore the booming sound mostly used by subsistence farmers in Umzimkulu and Lusiksiki in weather forecasting is presumed to be mate selection and/or breeding calls (Engelbrecht *et al.*, 2007; Coeztee, 2010). This bird mainly breeds between October and March (Jerling, 2011; South African Biodiversity Institute, 2018). These months are within the rainfall season is declared by community members of Umzimkulu and Lusiksiki, but there is no empirical evidence suggesting

that southern ground hornbill breeding is dependent on rainfall or humidity (Jerling, 2011; Daso *et al.*, 2015). Therefore, the mismatch between Southern ground hornbill calls and rainfall occurrence may be a result of decreasing co-occurrence of these events as a result of decreasing rainfall frequency and the decline in southern ground hornbill abundance in the study areas. Nevertheless, this demonstrates climate and environmental change threats to both species survival and IKS conservation in Umzimkulu and Lusikisiki. While the reliability of southern ground hornbill call has significantly decreased, barn swallows still arrive at the end of winter and are a confirmation for spring commencement to many farmers. Granted, this is not a quantified behaviour and constancy of arrival dates because TPK is mainly informed by status based monitoring (Denny *et al.*, 2014; Armatas *et al.*, 2016).

Delays and advances in peach tree flowering and barn swallow arrival have not been deliberately noted in Umzimkulu and Lusikisiki. This may be due to the status monitoring nature of IKS, which is concerned with marking the occurrence or absence of the phenological event rather than tracking the exact date of occurrence of the stages (Denny *et al.*, 2014; Lake *et al.*, 2017). Unlike event-based monitoring, status monitoring offers efficacy for tracking changes even to untrained individuals because it is mainly concerned with occurrence or absence of an event, which is important in IK weather forecasting (Denny *et al.*, 2014; Armatas *et al.*, 2016). Accordingly, in the study areas, the most noted change is the disappearance of previously abundant plant and animal species, including summer butterflies, Christmas birds and wild flora; amagosi, unopiyo and intshungu. The disappearance of wild flora also signifies a decreasing abundance of wild vegetables that are important to food availability and are important micronutrient sources for community members (Mavengahama *et al.*, 2013). Wild vegetables are an important food, particularly for maize-based rural subsistence farming communities such as Umzimkulu and

Lusikisiki (Muguti and Maposa, 2012; Sibhatu and Qaim, 2017). These vegetables are also an important domain for IK transmission because their identification and preparation are commonly a tacit practice between children and their parents and/or grandparents (Dweba and Mearns, 2011; Mavhengahama *et al.*, 2013; Fernández Llamazares Onrubia, 2015). Granted, in Umzimkulu and Lusikisiki the custodians lament that the youth is not willing to learn about IK nor consume wild vegetables. Nonetheless, these plants are a good source of micronutrients, require low input variables and are resilient to climatic variability because they are adapted to local climatic conditions (Mavengahama *et al.*, 2013; Dube *et al.*, 2018). Therefore, their disappearance displays the extent of change in ecology and climate of the study areas (Bharucha and Petty, 2010; Dube *et al.*, 2018). This also demonstrates another threat to IKS and food security posed by environmental change (Muguti and Maposa, 2012; Ziervogel *et al.*, 2014; Jiri *et al.*, 2016). The need for more research on traditional knowledge systems in government institutions and inclusion in the basic education system for ensuring conservation of IKS in indigenous communities cannot be overemphasised (Bohensky and Maru, 2011; Hiwasaki *et al.*, 2015; Basdew *et al.*, 2017). Findings of this study indicate that the youth associate IKS with poverty, illiteracy and consider it pre-modern. Perhaps the South African education system can provide an environment that fosters IKS through developing inclusive curricula, which would represent power balance and dynamic discourse between the knowledge systems thus contributing to wide knowledge creation and sharing (Bohensky and Maru, 2011; Cocks *et al.*, 2012; Meyiwa *et al.*, 2013; Dlamini and Ocholla, 2018). This may also emphasise the importance of traditional wild vegetables through more investment in research that investigates these food sources, thus facilitate IKS conservation and agency to communities. Furthermore, IKS will enhance inclusion of contextualised information and strengthen the connection between school, home and the wider community

(Meyiwa *et al.*, 2013). Weather forecasting indicators are mostly the same between Umzimkulu and Lusikisiki, this may be because the locations are spatially close to each other.

The disappearance of some plant species has significant consequences for rural communities (Mavehamgama *et al.*, 2013). However, the disappearance of some insects, although considered a negative environmental change, farmers in Umzimkulu and Lusikisiki also highlight that there are benefits of these changes in agriculture management. For example, the reduced abundance of head smut disease is highly attributed to the disappearance of summer butterflies, especially in Umzimkulu. Head smut disease is a fungus disease caused by *Sporisorium reilianum* which occurs in most corn growing areas (Ali and Baggett, 1990; Zou *et al.*, 2015). Smut diseases can significantly reduce yield success and has a high rate of infection between plants, but there is no empirical evidence to suggest that it is an insect-transmitted pathogen (Angrios, 2008; Jones and Medina, 2020). Therefore, the recognised benefit to agricultural management is not established in literature nor can it be legitimately denied in the context of the study area. Perhaps more investigation is required to establish a relationship or lack thereof between insect abundance and head smut disease because emerging research in molecular biology, vector behaviour and genetics is revealing that there are more elaborate mechanisms in phytopathogen (Zou *et al.*, 2015; Eigebronde *et al.*, 2018; Jones and Medina, 2020). Therefore, some phytosystems need more investigation to form absolute conclusions (Brown *et al.*, 2016). A more clear relationship between insects and yield is that corn success is not contingent on insect pollination (Hatfield and Dold, 2018; Shoko *et al.*, 2019). Therefore, changes on insect distribution have no direct ramifications on the staple yield or general agricultural productivity of these areas, hence it is viewed as somewhat of a positive change (Hatfield and Dold, 2018). Nonetheless, these changes on insect distribution will lead to the disarray of other ecological functions which may affect food

productivity (Gadzirayi *et al.*, 2006; Fernández Llamazares Onrubia, 2015; Shoko *et al.*, 2019). In fact, the disappearance of summer butterflies may be due to geographic range shifting or micro extinctions as a result of environmental change (Alexander *et al.*, 2015; CaraDonna *et al.*, 2018).

6.3 Weather Forecasting

Weather conditions are an integral part of agricultural productivity for subsistence farmers in Umzimkulu and Lusikikik because climatic variables affect crops in all stages of growth and beyond. Agricultural success and yield preservation are dependent on environmental viability in these two areas. Therefore, short term and seasonal weather forecasts are important in agricultural management (Kgakatsi and Rautenbach, 2014; Chand *et al.*, 2014; Jiri *et al.*, 2016; Radeny *et al.*, 2019). This is an overtly emphasised aspect for agricultural management in most Sub-Saharan African countries because agriculture is mostly rain-fed and is a significant component of livelihoods and economic development of the region (Davis, 2011; Ziervogel *et al.*, 2014; Jiri *et al.*, 2016; Roffe *et al.*, 2020b). Therefore, agricultural losses can intensify existing social and economic challenges on a local, national and regional scale (Laux *et al.*, 2010; Muguti and Maposa, 2012; Kgakatsi and Rautenbach, 2014). Furthermore, southern Africa is highly vulnerable to the effects of climate change because of high exposure to climate stresses due to its geographical location in the subtropics (Ziervogel *et al.*, 2014; Gan *et al.*, 2016). Availability of highly accurate, timely and informative weather forecasts and warning systems can effectively reduce the risk of climate stresses to farming activities and promote efficient food production (Kgakatsi and Rautenbach, 2014; Plotz *et al.*, 2017). Subsistence farmers from Umzimkulu and Lusikiki generate weather forecasts through considering several local environment variables e.g. rainfall frequency in winter, the abundance of flowers in peach trees and rainfall frequency in the

first two weeks of spring to infer seasonal weather conditions and rainfall characteristics for the following growing season. This is consistent with the results found by several studies which posit that most subsistence farmers from rural communities still mainly depend on IKS for agricultural management (Gadziray *et al.*, 2006; Mafongoya and Ajayi, 2009; Orlover *et al.*, 2010; Ajani *et al.*, 2013; Nalau *et al.*, 2019). Despite the observed and projected changes in the reliability of IKS cues, there is still a limited shift towards modern meteorological services because of perceived limited accuracy in the context of rural areas (Ebhuoma, 2017; Balehegn *et al.*, 2019).

IKS underpins adaptation efforts to the observed changes in rainfall seasonality in Umzimkulu and Lusiksiki. In both communities meteorological indicators are mostly used for short term weather forecasts such as oncoming hail storm, thus promote short term risk reduction decisions concerning safety and rainwater harvesting. On the other hand, phenological indicators are important for tracking seasonal change and seasonal weather forecasting. There are no prominently noted changes in the reliability of meteorological indicators, but the decreasing agency of traditional risk reduction methods such as ringing metals to abate hail storm are observed. IKS cues are not isolated from the broad spatiotemporal ecological and meteorological changes of the areas and this promotes flexibility in the developed strategies (Salite, 2019). For instance, peach (*Prunus persica*) tree flowering time and abundance is used to indicate rainfall season onset and quantity and quality of the rain. The co-occurrence of peachtree leafing and rainfall means corn sowing can commence immediately in the study areas. Rautela and Karki (2015) found that community members also use peachtree timing and abundance to forecast the onset and quality of the rainfall season in Uttarakhand, Himalaya. Flowering phenology is commonly used to track seasonality across the world (Green and Raygorodetsky, 2010; Archaya, 2011; Nalau *et al.*, 2018). Archaya (2011) found that farmers use the flowering of the night-

flowering jasmine (*Nyctanthes arbor-tristis* L) to also forecast rainfall season onset in India. Peach tree flowering is also used to indicate spring season onset in uMgungundlovu and Msinga, other rural areas in KwaZulu-Natal, and also by some rural areas in the Free State Province (Zuma-Netshiukhwi *et al.*, 2013; Basdew *et al.*, 2017; Rukema and Umbyeyi, 2019). Peaches are a widely grown deciduous fruit in South Africa (Gush *et al.*, 2009). Therefore, the broad use of this plant as an indicator for seasonal change demonstrates that indeed IKS cues are influenced by the rationality and agency of the plant or animal to community members (Okoya and Kroschel, 2013; Kijazi *et al.*, 2013; Dukeimah *et al.*, 2015). This displays some consistencies in IKS informed weather forecasting between and within countries and therefore represent potential to synthesise of IKS indicators.

Peach tree flowering phenology is mainly governed by chilling hours to break dormancy and thermal requirements to bloom (Compoy *et al.*, 2012; Tadeu *et al.*, 2020). Therefore, the constancy in peach tree flowering indicating spring onset suggests that there have not been significant changes in average winter and spring onset temperatures in Umzimkulu and Lusikisiki. Community members claim that abundance of peach tree flowers indicates high-frequency rainfall during the growing season, the relationship between peach tree flowering abundance and rainfall is not established in the literature (Litschmann *et al.*, 2008; Ionela and Baciu, 2015; Tadeu *et al.*, 2020). Descriptive phenology is important for predicting the success of the growing season, but farmers understand that there other interacting variables during the growing season that determine yield success, such as pests, rainfall frequency, livestock destruction, soil quality and time dedicated to farming practices (Section 5.3). This underpins the dynamic nature of IKS and also means that continuous adaptive strategies although limited, are developed and implemented throughout the growing season to promote yield success. Notwithstanding, weather forecasting is

still a significant component of organizing farming calendars, predicting yield, and introducing adaptation measures at the beginning of the sowing season.

There are complex factors determining seasonal rainfall totals (Blamey and Reason, 2013; Roffe, 2019), but community members of Umzimkulu and Lusikisiki are confident that delayed rainfall onsets indicate low rainfall frequency throughout the growing season, thus result in low rainfall totals. Change in these rainfall characteristics is stated as the main cause for low crop productivity and causing ‘bad/dead’ farming season. It is noteworthy that changes in rainfall seasonality have also led to considerable agricultural losses across Sub-Saharan Africa (Gan *et al.*, 2014; Nalau *et al.*, 2018; Ndlovu and Damlie, 2020), and subsistence farmers in Umzimkulu and Lusiksiki have experienced these losses and a myriad of other challenges presented by climate change. These conditions are projected to intensify in the future, and farther threaten crop production and ultimately exacerbate food insecurity, hunger and poverty in South Africa and across the Sub-Saharan Africa region (Davis, 2011; Mampfumo *et al.*, 2016; Roffe *et al.*, 2020b). In both Umzimkulu and Lusikisiki, rainfall frequency also determines domestic water availability, but this was more emphasised by participants from Lusikisiki, Eastern Cape. This may be because Eastern Cape has the poorest service delivery to rural areas amongst South African provinces (STATSSA, 2017). Therefore, significantly reduced winter rainfall frequency also translates to limited domestic water availability for farmers. This consequently affects agricultural productivity because community members cannot dedicate enough time to their farming activities when they have to go to the river to fetch water for the households. Furthermore, most water sources such as streams that passed between homes in Umzimkulu and Lusiksiki have dried leaving muddy ponds or and/or grass growth instead (Figure 6.1a and 6.1b).

a



b



Figure 6.1: Dried water sources **a)** KwaDukada, in Lusiksiki, a drying stream indicated by protruding riverbanks. Also shows the type of settlement in the area, **b)** Shows a dried stream that was an active water source for domestic and farming purposes less than 15 years ago for Clydesdale community members, in Umzimkulu.

Farmers now predominantly depend on rivers far away from their homes for water supply (Jordaan *et al.*, 2019). The Eastern Cape Province has been experiencing droughts during all meteorological seasons since 2015 (Mahlalela *et al.*, 2020), but the results of this study indicate that in Lusikisiki the effects of the drought distinctly manifested through the absence of 2019 winter rainfall after harvest and extremely late spring rainfall onset. These droughts have resulted in some farmers not practicing vegetable farming in winter. Also, spring rainfall contributes approximately 35% of annual rainfall totals in Eastern Cape Province. Therefore, the observed changes in spring rainfall duration may indeed translate to decreased rainfall totals which is consistent with projections noted by one participant (70-80 years old) in Lusikisiki.

"Maybe we will end up being like other places where people do not even plant anymore because of rain scarcity and the high temperatures. You know there are areas where people do not sow anymore because they do not get rain, right? We cannot dispute that possibility because we can see that things are changing." (EC 1.1)

This is also consistent with several studies stating that climate change will lead to significant agricultural losses and exacerbated food insecurity in Sub-Saharan Africa (Calzadilla *et al.*, 2014; Mapfumo *et al.*, 2016; Sibhatu and Qaim, 2017; Radeny *et al.*, 2019). Extensive understanding of the climate of each area is the foundation for short to medium term seasonal forecasts for

farmers Umzimkulu and Lusiksiki. For example, in Lusiksiki the low rainfall frequency throughout the winter season is an indication that the following growing season will be less productive, regardless of rainfall activity at the end of the winter season. While in Umzimkulu low rainfall frequency in winter has relatively less forecasting significance, but the quantity of rain at the end of the winter is the main indicator for the success of the growing season. This represents the experience, locally bound knowledge, *in situ* observations and narratives formed from long time residency and qualitative framework of the climate of the areas, and (Alexander *et al.*, 2011; Chambers *et al.*, 2017) argue that these components are the foundation of effective traditional weather forecasting. The study areas have inherent complex rainfall seasonality, which is characteristic of southern Africa given its latitudinal location, complex topography and surrounding oceans with contrasting sea surface temperatures (Blamey and Reason, 2013; Ndlovu and Damlie, 2020). IKS offers a high spatial and temporal resolution to observe the dynamic seasonal variability and microclimates, infer meaning and implement pragmatic responsive strategies, thus promoting agricultural productivity for subsistence farmers (Alexander *et al.*, 2011; Roffe, 2019; Mahlalela *et al.*, 2020).

6.3.1 Preferred Weather Forecasting System

Most rural areas in South Africa, including Umzimkulu and Lusikisiki, have access to SAWS weather forecasts through radio and television (Basdew *et al.*, 2017; Radeny *et al.*, 2019). However, subsistence farmers from the study areas prefer traditional weather forecasts, especially for informing agricultural management decisions. This is because most community members do not comprehend SAWS weather reports and do not trust the information to advise their farming activities. Therefore, they rely on meteorological, astronomical and phenological observations to

infer weather conditions (Table 5.2). Rural communities across the world have always been able to forecast weather conditions from observing interacting biophysical entities in their vicinity for millennia (Balehegn *et al.*, 2019). These traditional forecasts are still a prominent and affordable source of meteorological information in most rural communities (Orlove *et al.*, 2010; Chambers *et al.*, 2019). Despite the observed changes in IKS cues, challenges of applying coarse spatiotemporal resolution information from contemporary weather forecasts propel the use of traditional weather forecasting, particularly for small scale agricultural management (Muguti and Maposa, 2012; Zuma *et al.*, 2013; Jiri *et al.*, 2016).

The influence of climate change on weather and plant and animal phenology are extensively cited (Parmesan and Yohe, 2003; Cleland *et al.*, 2007; Chambers *et al.*, 2013; Fitchett *et al.*, 2015; Jiri *et al.*, 2016; Doi *et al.*, 2017; Davis, 2011; Mahlalela *et al.*, 2020). Species sensitivity to climatic variables is determined by genetic and hereditary components and dictates the rate and form of response to climatic changes (Cleland *et al.*, 2007; Case *et al.*, 2015; Doi *et al.*, 2017). The species response rate to climate change have direct and indirect impacts on traditional management methods and may potentially cause misguidance to farmers that rely on IKS for weather forecasting, thus undermine the adaptive capacity of rural subsistence farmers (Cleland *et al.*, 2012; Alexander *et al.*, 2019). For example, range shifts may result in the disappearance of indicator species for seasonality tracking, or the introduction of destructive species during significant stages of crop growth, thus leading to significant agricultural losses and exacerbate food insecurity (Peter, 2014; Eigenbrode *et al.*, 2018). In Umzimkulu and Lusikisiki significant changes in abundance and reliability of traditional seasonality and weather forecasting variables have already been observed. However, community members still trust that the probability of IKS cues to be correct coupled with spatial specificity that is lacking in SAWS weather reports

warrants their overwhelming dependence on traditional knowledge for agricultural management. This highlights the need for more SAWS weather stations in the proximity of these areas and deliberate, far-reaching community engagement in the production of information to enhance spatial specificity, maximise the use of government and resources and facilitate agency to end-users; subsistence farmers. Status monitoring that informs traditional weather forecasts lack quantified variables, but it offers flexibility in understanding the complex relationship between environmental variables (Jiri *et al.*, 2016; Chambers *et al.*, 2019). This is essential for subsistence farmers because, for the most part, they cannot understand quantified reports and their methods are result oriented and mostly, only aim to produce enough food for their families.

Community members in Umzimkulu and Lusikisiki also prefer IKS cues because traditional indicators precede the availability of contemporary weather forecasts by SAWS. Furthermore, there is limited intellectual access to the information offered by the national meteorology services, which is a pervasive challenge for most rural communities across the globe (Eakin, 1999; Simatele Ebhuoma, 2017; Plotz *et al.*, 2017; Nalau *et al.*, 2019). In Umzimkulu and Lusikisiki this is perpetuated by the format and mode of weather forecast dissemination, the terminology used by reporters and the lack of portraying relevance of the information to farming activities. The spatial specificity of traditional weather forecasting, which is one of the most distinctive characteristics of IKS is emphasised in both Umzimkulu and Lusiksiki. This IKS characteristic offers efficacy in agricultural management and a significant part of preparing for water harvesting in these areas. IK represents creative planning and action based on observations within the continuously changing natural environment, therefore it is contextual within an area and with various environmental challenges (Kgakatsi and Rutenbach, 2014; Hiwasaki *et al.*, 2015; Magni, 2017). These elements of IK demonstrate the versatility of the knowledge system and ability to

progress within the means and the needs of its users (Magni, 2017; Benyei *et al.*, 2020). The rejection of SAWS weather forecasts by participants for agricultural management displays poor user confidence and possibly miscommunication between intermediaries and intended users of meteorology information. This is a daunting barrier in national meteorology forecasts uptake by most rural subsistence farmers (Jiri *et al.*, 2016; Ebhuoma and Simatele, 2017; Chand *et al.*, 2017; Nalau *et al.*, 2018). Rural communities need to trust intermediaries and understand the significance of the provided weather forecasts to their agricultural activities (Kalanda-Joshua *et al.*, 2011; Muguti and Maposa, 2012; Jiri *et al.*, 2016). This will enhance the adaptive capacity of farmers, especially because the traditional weather forecasting methods are becoming less reliable (Kalanda-Joshua *et al.*, 2011; Kgakatsi and Raudenbach, 2014). Furthermore, these challenges highlight the need for more focused efforts by SAWS to ensure that the information is intellectually accessible and relevant to end-users. Articulate means such as integration of knowledge systems can increase uptake and use of SAWS weather forecasts in Umzimkulu and Lusikisiki.

6.4 Intwasahlobo: Spring Season

Agricultural activities are predominantly seasonal in Umzimkulu and Lusikisiki. The seasonality of subsistence agriculture activities is common across South Africa because this sector is mainly rain-fed and rainfall is predominantly seasonal in the country (Sibhatu and Qaim, 2017; Roffe, 2019; van de Walt and Fitchett, 2020). Although farming seasonality is common across South Africa, in Lusikisiki, the current seasonality of crop farming is attributed to increased rainfall seasonality. Community members from this area state that although sowing season onset has always been noted, they could still produce food on a smaller scale during the year but now

sowing outside of growing season is impractical. The growing season starts at the beginning of September and ceases at the end of March in both Umzimkulu and Lusikisiki, this is also roughly considered the rainfall season in these areas. This stated rainfall season is consistent with Roffe *et al* (2020a) description of long SRZ locations. In these locations, rainfall season starts on the 8th of September and ceases at the beginning of April, which is declared the growing season the Umzimkulu and Lusikisiki (Roffe *et al.*, 2020a). Community members in Umzimkulu and Lusikisiki also emphasise that spring season starts at the beginning of September, and 29% of SAWS stations confirm that September can indeed be categorised in the spring season, on bases of temperature (van de Walt and Fitchett, 2020). The seasonal classification by community members in Umzimkulu and Lusikisiki is mainly on the bases on temperature and rainfall. Results of this study also demonstrate that rainfall patterns have significantly changed in the areas, which is one of the most ubiquitous effects of climate change (Ziervogel *et al.*, 2014; Mahlalela *et al.*, 2020; Roffe *et al.*, 2020b).

The beginning of spring is marked by the flowering of plants and the arrival of migratory birds, including barn swallows, at the beginning of September. This season is the most important time on the farming calendars of Umzimkulu and Lusikisiki. The beginning of September marks the sowing season onset in the study areas, but sowing dates are governed by rainfall onset within spring. Sowing commencement after rainfall onset is more important, and mostly prescribed for the annual staple crop; corn because other crops such as potatoes are commonly planted on dry soil in anticipation of oncoming rainfall because of their perceived resilience to dry conditions. Knowing the appropriate sowing date/s is one the most essential agricultural management strategies because has a significant impact on yield success or failure (Amarasingha *et al.*, 2014;

Hu *et al.*, 2017). This is one of the most deliberately considered agricultural management practices in Umzimkulu and Lusikisiki, especially if rainfall patterns are erratic or more unpredictable in the particular year. Sowing dates, IKS mitigation and adaptation practices, and ecological factors play a significant role in determining crop yield success (Yoldas and Esiyok, 2007; Green and Raygorodetsky, 2010; Eakin *et al.*, 2014).

6.5 Adaptation

The fundamental need for pragmatic adaptation measures to reduce the impacts of climate change in both developing and developed nations is extensively researched (Parry *et al.*, 2007; Eakin *et al.*, 2014; Gratani *et al.*, 2014; Zieversvogel *et al.*, 2014; Ebhuoma, 2017; Radeny *et al.*, 2019). A community's adaptive capacity determines the duration and severity of physical, environmental and social impacts of climate change (Lobell *et al.*, 2008; Eakin *et al.*, 2014). Development and effective implementation of appropriate adaptive measures can help sustenance of vulnerable sectors and/or communities, especially in southern Africa (Ziervogel *et al.*, 2014; Reid and Vogel, 2006). The agriculture sector is extremely undermined by the effects of climate change in Sub-Saharan Africa because activities predominantly rely on environmental viability (Ziervogel *et al.*, 2014; Ebhuoma, 2017). Therefore, changes in rainfall seasonality, excessive soil erosion, droughts and floods directly affect productivity (Lobell *et al.*, 2008; Eakin *et al.*, 2014). This sector needs competently developed and timely implementation of adaptation measures to ensure food availability and accessibility for areas within the region (Jiri *et al.*, 2016; Mthembu and Zwane, 2017; Salite, 2019). Agricultural adaptation methods are context and location-specific, more so for South African resource-constrained subsistence farmers, because of the dynamic rainfall distribution in the country and limited access to other alternate strategies (Bryan *et al.*, 2009; Menike and Arachch, 2016; Shoko *et al.*, 2019). According to the responses from

participants of this study, Umzimkulu and Lusiksiki have not been exposed to high magnitude climate extremes in at least 30 years, the most noted climate-related disaster being *uzamcolo* in 1989 for Umzimkulu. *Uzamcolo* is described as one of the significant hydrological extreme events (floods) in Umzimkulu. One community member explained that he was told by his grandparents that *uzamcolo* has a 30 year recurrence interval. Two more respondents further stated that this high-intensity rainfall event had a duration of at least three weeks in 1989 and resulted in significant property damaged and flooding. However, a municipality Draft Integrated Development Plan (2014) reported that the highest water levels in Umzimkulu were last recorded in 1987. This is consistent with the floods that are widely reported in the literature that led to significant infrastructure damage, and erosion of flood plains and sedimentation of KwaZulu-Natal major rivers (i.e. Umgeni, Tugela and Umvoti) in 1987 (Badenhorst *et al.*, 1989; Owen and Forbes, 1997; Hlahla and Hill, 2018). Nonetheless, community members indicate that Umzimkulu and Lusikisiki are experiencing a non-uniform but progressive decrease in rainfall frequency and increasing temperatures. Changes in these climatic variables are detrimental to farming activities because similar to most rural areas in southern Africa, agricultural activities are rain-fed in these areas, therefore even relatively minor changes in rainfall patterns have significant impacts on livelihoods (Belehegn *et al.*, 2019; Roffe *et al.*, 2020). Yield losses for rural subsistence farmers will intensify as the average temperatures increase and rainfall differences deteriorate (Agoumi, 2003; Altieri and Nicholls, 2013; Calzadilla *et al.*, 2014; Jiri *et al.*, 2016). Subsistence farmers from Umzimkulu and Lusiksiki cannot afford extensive adaptive measures but they display an understanding of the risks posed climatic change. Therefore, they derive forms of adaptation from existing natural resources, with limited expectations to ensure food productivity. In these areas, climate changes adaption is a continuum of practices, from trying to retain soil moisture after

rainfall, using manures to promote soil fertility and quality, and to adjusting sowing dates within the farming calendar.

Farmers' response capacity to rainfall scarcity in Umzimkulu and Lusikisiki is limited because of minimal mechanical assets, low input variables and limited financial resources available, which are innate features of rural subsistence farming (Akinagbe and Irohibe, 2014; Sibhatu and Qaim, 2017). Both study areas have established sowing date ranges; September-early January (Figure 5.1). This means that although sowing season onset is declared to be the beginning of September, sowing dates are adjusted according to rainfall onset, frequency, and duration within the established range. Adjusting sowing dates is the most prominent adaptive strategy in response to changes in rainfall seasonality in both study areas. This strategy does not require financial or mechanical elements to be executed because it is solely contingent on the observation of rainfall occurrence (Muguti and Maposa, 2012; Amarasingha *et al.*, 2014). Farmers in the study areas mentioned that the type of seeds chosen for corn can affect yield success and growing duration, but there is less emphasis on cultivar selection as a means to ensure productivity. This may be partly due to insufficient information about cultivars and limited financial resources for access to cultivar options to form definitive conclusions. Also, farmers reuse presumably viable corn seeds from harvest for the next growing season so they would not have to buy more seeds. Therefore, determining the most appropriate sowing date remains the most fundamental management aspect of crop production in the study areas (Amarasingha *et al.*, 2014; Zhao *et al.*, 2015; Hu *et al.*, 2017). Sowing dates determine the timing of phenology events and ultimately the weather conditions the stages align with (Hu *et al.*, 2017; Patel *et al.*, 2019). Adjusting corn sowing dates to commence after rainfall onset in Umzimkulu and Lusikisiki is mainly to ensure that soil moisture requirements for corn germination are met. The rate and state of germination are one of

the most important aspects that can determine yield success in corn; slow and nonuniform emergence can significantly limit corn productivity and thus reduce yield (Domin *et al.*, 2020). Furthermore, rainfall seasonality changes have resulted in reduced wet season duration, therefore, sowing after rainfall onset increases the likelihood for the growing phase to coincide with relatively high precipitation frequency and adequate thermal hours for optimal productivity (Khodarahmpour, 2011; Hu *et al.*, 2017). This agricultural management technique has also been successfully used to escape effects of climate change on corn (Otegui *et al.*, 1995; Zhao *et al.*, 2015) and wheat (Spink *et al.*, 2000) farming, but in slightly controlled environments in China. Competent implementation of sowing date adjustment strategy is facilitated by subsistence farmers' comprehensive understanding of climate variabilities of Umzimkulu and Lусisiki, borne from experimentation and long-time residency in the areas. For example, low winter rainfall frequency determines how soon after spring rainfall onset can subsistence farmers start sowing. This is efficient because increased rainfall seasonality has mostly been coupled with shorter summer rainfall duration (Roffe *et al.*, 2020a). Therefore, ensuring that sowing commences after rainfall onset reduces potential heat stress on corn. On the other hand, when rainfall seasonality is observed to be low in a particular year, farmers can commence sowing before spring rainfall onset in anticipation that rainfall frequency will be high throughout the growing season. Nevertheless, forecasts are still highly probabilistic because there a plethora of uncertainties in rainfall seasonality and duration, and have been observed in the study areas within the last two decades but the precise application of the knowledge can still result in reasonable adaptation level. These forecasting techniques harness the maximum capacity of natural resources in both study areas. Admittedly, in cases of extremely delayed rainfall onset, participants sow regardless of rainfall occurrence. This is a reactive strategy mostly based on cultural and religious beliefs in

the study areas, that God will provide rain anyway. Perhaps it is also facilitated by readily available seeds from the previous harvest and available time resources because most subsistence farmers in the study areas are unemployed. Therefore, it is low risk strategy because farmers can afford to replant if seeds are damaged by heat stress but they can also benefit if rain occurs soon after.

In both Umzimkulu and Lusikisiki, there are significant inopportune changes in rainfall seasonality and wet season duration, yet subsistence farmers are still producing food during each growing season. Although farmers actively employ adaptation measures, they attribute the continued agricultural success to God's favour. Farmers remark that if rainfall is extremely delayed, sowing regardless makes God recognise that they need rainfall and then he will provide it. Most rural areas with strong religious backgrounds believe that observed changes are just God's acts (Bankoff, 2004; Simatele and Simatele, 2014). Respectively, in Umzimkulu subsistence farmers believe that unfavourable weather conditions particularly prolonged dry spells and high temperatures are a manifestation of God's retaliation and punishment for their sins. In other communities where environmental changes are attributed to 'God's acts' such as in Zambia (Simatele and Simatele, 2014) and Senegal (Mertz *et al.*, 2009), farmers tend to dispute the influence of their actions towards the natural environmental change and declare changes inevitable. This is not the case in Umzimkulu, community members from this area believe that if they treat the natural environment with respect and are not lazy in always using the natural resources they have, God will reward them through 'fixing the environment' so they can continue farming. Although this displays a limited understanding of underlying scientific complexities that cause environmental change, it presents a good starting point for teaching more anthropogenic climate change-related information in these communities. Community members believe that

changes in their lifestyle influence the observed changes in the natural environment, particularly species disappearance and increasing temperatures. Similarly, in Lusikisiki participants stated that changes in their lifestyles and farming practices are the cause for observed changes in the natural environment. Furthermore, in Lusikisiki changes in lifestyles are linked to the neglect of farming in Umsikaba flood plains, which in addition to reducing the natural resource base for food, it also limits access to medicinal plants and wild vegetables that are argued to be currently more abundant in the forests. This understanding of environmental change illustrates the potential foundation for a more extensive integrated understanding of the natural environment that can further enhance the adaptability of IKS strategies by community members. Community members in the study areas already believe that their actions influence the natural environment, therefore they may be more receptive and understanding of the concept of anthropogenic climate change. Contrary to the farmers from Delta State in Nigeria who could not fathom that their actions can influence the natural environment because they consider God the only and the ultimate power (Ebhuoma and Simatele, 2017). Community members in Umzimkulu and Lusikisiki can benefit from the integration of knowledge systems to facilitate environmental learning, conservation and sustainability because they acknowledge one of the essential components for understanding anthropogenic climate change; the influence of human activities towards the natural environment (Parry *et al.*, 2007; Maslin, 2019). Therefore, integration of knowledge systems will expose them to more information and strengthen their asset portfolios through conservation of natural assets and advanced mobilisation of social assets (Mauser *et al.*, 2013; Ebhuoma and Simatele, 2017; Benyei *et al.*, 2020). This may also promote the inclusion of these local communities in the development of broader weather forecasting, environmental conservation, and management strategies. Intentional and articulate engagement of governments, scientific institutions with IKS

holders can increase uptake of climate and weather forecasting information in rural communities and maximise the agency of both knowledge systems in climate change adaptation. Integration of knowledge systems may facilitate IK uptake by the younger generation and facilitate IKS preservation and re-discovery (Alexander *et al.*, 2011; Goduka, 2012).

Custodians in Umzimkulu and Lusikski lament that the youth associate IK with poverty and some younger participants view education as an escape from IKS. The resistance to adopting this tacit knowledge in favour of westernized education threatens the social capital of Umzimkulu and Lusiksiki and can be detrimental to food security and livelihoods. In South Africa, the graduate unemployment rate is continuously increasing (Oluwajodi *et al.*, 2015). Therefore, acquiring skills through formal education does not directly translate to secure livelihoods either (Van der Berg and Broekhuizen, 2012; Oluwajodi *et al.*, 2015). Community members acknowledge the aid of government remittances in diversifying incomes, household economic development and thus promoting access to more food sources. However, Chakona and Shecklton (2019) found that households that receive social grants are predominantly food insecure and have lower mean monthly expenditure and wealth index. Furthermore, social grants are not a sustainable income (Waidler and Devereux, 2019). Involvement of science institutions and government bodies may offer the required support and resources to disseminate IK in avenues that are more appealing to the youth (Simatele and Ebhuoma, 2017). In addition to increasing the adaptive capacity of communities, integration of knowledge systems can also motivate the youth to explore alternative and sustainable forms of livelihoods and deviate from the status quo that is mostly dependent on western education alternatives (Cassidy *et al.*, 2011; Benyei *et al.*, 2020). This will also promote the preservation of cultural identity and environmental management in these areas (Schenck and Louw, 2002; Goduka, 2012).

6.6 Storing and Sharing Traditional Knowledge

Methods of communicating IKS in Umzimkulu and Lusikisiki are threatened by the distance between custodians and intended youth, weak social networks between the custodians and younger subsistence farmers in the rural areas and largely western focused developments. Subsistence farmers from all age groups have significant similarities in their farming strategies and methods of adaptation in Umzimkulu and Lusikisiki. However, the perception of custodians towards younger farmers is misrepresentative of the actual beliefs and methods used by the youth in farming. This displays the need for mutually advantageous intergenerational engagement in these communities to facilitate IKS transmission and overall knowledge sharing between age groups. Bridging the gap between custodians and the youth will facilitate IKS dissemination and promote further knowledge adaptation and implementation for farmers (Christanch and Vining 2009; Forrest, 2018). This is important because custodians are growing up and dying with the knowledge, the social networking across age groups will ensure preservation and progress of IKS (Goduka, 2012). Age is inversely proportional to farm output, but it is the most important attribute for IKS expertise (Goduka, 2012; Ebhuoma, 2017). Furthermore, younger farmers in both study areas already highlight the advantages of integrated knowledge systems in farming, which is significant for subsistence farmers to continue producing food in the face of climate change (Fernández Llamazares Onrubia, 2015; Parsons *et al.*, 2016; Magni *et al.*, 2017). Therefore intentional communication between age groups will provide an opportunity for community members to develop strong social asserts and ensure human capital through assisting each other with the expertise that each has more experience and informed about.

One important component of farming that is still considered reliable after generations of use, across all age groups, is the use of manures for soil fertility. Climate variables are considered the most essential factor of agricultural productivity, therefore, remarkably reduced yields are attributed to climate change. However, decreasing soil fertility is also a challenge. Community members in both Umzimkulu and Lusiksiki commend kraal manure for boosting soil fertility. Manures are still considered more effective than commercial fertilisers in these areas. The continued use of manures in the study areas is also promoted by the easy economic access to this resource. Nonetheless, animal manures do adjust soil mineral cycles and ensure fertility (Loss *et al.*, 2019). Apart from economic efficiency and promoting yield success which is significant aspects of food production in these rural areas, animal manure is more environmentally and economically sustainable (Bayu *et al.*, 2005; Loss *et al.*, 2019; White *et al.*, 2018). Furthermore, because manures ensure holistic soil fertility, community members argue that they also promote the growth of traditional vegetables, further contributing to food availability and IKS conservation. Intergenerational programmes are necessary to ensure that there is more sharing of IKS, continued existence of IKS, strengthen its dissemination in the study areas, and therefore effectively mobilise resources. Moreover, articulate intergenerational transmission of IK will promote maintenance of the knowledge in a way that continuously promotes natural resource conservation and climate change adaptation (Forrest, 2018). This will enhance the social capital of Umzimkulu and Lusiksiki through maintaining natural asset portfolios and open communication with communities while allowing assistance from external western avenues thus effectively reducing vulnerability to the effects of climate change (Benyei *et al.*, 2020).

Subsistence farmers from the study areas acknowledge that traditional modes of communicating IK are not as efficient, and suggest digitalisation of the information to improve access and appeal

to the younger generation. The suggestion to store IK on digital platforms coupled with the appraisal of decontextualised western education in both Umzimkulu and Lusiksiki (Section 4.1.2) displays a possibility for increased intellectual access to IKS of these areas by indigenous outsiders. Dlamini and Ocholla (2018) also state that information and community technology provides a good platform for IKS management. This can be advantageous for creating a corpus of the knowledge thus, facilitate the synthesis of information and promote the integration of knowledge systems. However, the obscure intellectual property rights for community-owned knowledge in South Africa may render the IKS of Umzimkulu and Lusiksiki vulnerable to exploitation (Masango, 2010; Chambers *et al.*, 2017; Tong, 2017). Furthermore, most studies do not maintain communication with knowledge holders post data collection, thus excluding community members to other important parts of the research (Bisong and Andrew-Essein, 2010; Chambers *et al.*, 2017; Benyei *et al.*, 2020). Benyei *et al.* (2020) state that the exclusion of custodians in phases of documenting and storing IKS limits access and agency of the developed conservation initiatives to the creators and users of IK, thus illuminating the exploitative nature of western education for using IKS to validate science arguments (Popova, 2014; Tong, 2017). Moreover, this exclusion may lead to misinterpretation of custodians' narratives because IKS is constantly adjusted and changing to facilitate its practicality, especially knowledge related to weather and agricultural management, because of climate change (Bohensky and Maru, 2011; Mapfumo *et al.*, 2016; Dlamini and Ocholla, 2018; Benyei *et al.*, 2020). Some community members in Umzimkulu and Lusikisiki expressed concerns about the validity of the information over time because of constantly changing environment and access to the documented information about their strategies. This demonstrates the extent of the rate of climate change and high temporal adaptation of these communities, which displays a somewhat high degree of adaptive capacity in

the study areas. More research is necessary to investigate the level inclusion of IKS holders in systematic documentation of IKS strategies to enhance the credibility of the information and ensure relationality (Altieri and Nicholls, 2017; Benyei *et al.*, 2020). Moreover, because IKS is particularly contextual, cultural and not static, continuous inclusion of knowledge holders reduce the chances for the information to be distorted, or imposition of incorrect assumptions (Chambers *et al.*, 2017; Tong, 2017; Kramer *et al.*, 2019).

6.7 Limitations

This study encountered limitations associated with the chosen research design, data collection methods used and researcher's positionality, addressed in (Section 4.1). My positionality as a community member of both Umzimkulu and Lusikisiki, to some extent influenced the interpretation of the results. Although my subjectivities are detailed in (Section 4.1), they still were part of the research process. For example, although participants in Lusiksiki stated that home fencing can limit crop productivity. The interpretation of how livestock rearing influences crop farming activities were aided by my familiarity with the culture and beliefs of both study areas. Furthermore, the amount of time I spend between study areas, in general, might have affected the amount of attention and detail given to each area in the data reporting and analysis. Moreover, although pictures were useful in describing some components of the results, collecting data through taking pictures was not part of the research methodology (Chapter 3). However, pictures were taken during the data collection process out of respect to the participants who insisted that I take pictures because photos will be important for the research. Therefore, since I made sure to emphasise that the data collection process was an environment of co-production of knowledge

(Section 4.1.2), I valued the input from the respondents and used the photos in (Chapter 5, 6) without compromising the results of the study.

One of the most prominent limitations in qualitative research is that the results cannot be extended to broader populations with the same degree of certainty (Ochieng, 2009). Therefore, findings of this study, although consistent with findings found in other parts of the country and the world regarding the use of phenological indicators in weather forecasting and preferred weather forecast methods, their validity is mostly restricted to Umzimkulu and Lusiksiki. This is also because IKS cues and methods are innately developed through largely subjective perceptions of the natural environment in context to a particular community (Mafongoya and Ajani, 2009; Lefale, 2010; Chand *et al.*, 2014). Additionally, IKS is constantly progressing in response to observed changes in climate and ecological variables essential for farming productivity (Nyong *et al.*, 2007; Fernández Llamazares Onrubia, 2015). Participants also indicated that traditional knowledge is developed in a continuum of practices. Therefore, the data in this research is mostly representative of methods and indicators that were effectively used before the 2019-2020 growing season in Umzimkulu and Lusikisiki.

This study used individual interviews as a data collection method. This method is based on collecting data in an environment that fosters attribution of only one participants' views on the phenomena under study at a time (Marshall, 1996; Dworkin, 2012). Unlike focus groups where participants from one area can converse and express different perceptions of events and interpretation of observed changes (Ebhuoma, 2017). For example, a participant in Emause indicated that floods in 1976 had positive impacts on farming because she received great yields. Floods are generally associated with extensive soil erosion, livestock mortality and property damage, particularly in rural areas (Fabiya and Oloukoi, 2013; Hlahla and Hill,

2018). Therefore, the perception that floods were positive for agriculture in the area is based on the agency of the event to her individual farming productivity. Furthermore, (Section 6.4) illustrates that community members can recall events correctly but assign them to a wrong date. Perhaps this could have been prevented in a focus group setting, maybe community members could have reminded each other of the correct year based on the level of damage or productivity the event caused.

6.8 Synopsis

Most of the results in this study are consistent with the theories and arguments regarding the use of IKS in rural subsistence farming. Furthermore, community members in Umzimkulu and Lusikisiki displayed an understanding of the threats of climate change to both their IKS strategies and agricultural productivity. Nonetheless, some of their methods still could not be aligned with research (ie. using salt to retain soil moisture). However, they provided a synopsis of the value and practicality of IKS in their communities. These communities could be viable locations for IKS pedagogy and may be receptive to integration of knowledge systems which is different from other religious rural communities. Farmers in these areas display ingenuity in their agricultural methods and have a reasonable adaptive capacity.

7. Conclusion

Resource-constrained rural areas are practicing subsistence farming to supplement food sources and secure livelihoods (Dasgupta *et al.*, 2014; Kassam *et al.*, 2017; Sibhatu and Qaim, 2017). The agricultural sector, particularly subsistence agriculture is highly vulnerable to the effects of climate change. Farmer sector needs to develop and implement pragmatic adaptative measures to facilitate productivity and ensure food availability (Kassam *et al.*, 2017; Ebhuoma *et al.*, 2020). Subsistence farmers from rural areas mostly have limited access to mechanical and financial resources that may improve the resilience of their agricultural activities to climate stressors (Mafongoya and Ajani, 2009; Radeny *et al.*, 2019). However, these farmers are not passive actors (Orlove *et al.*, 2010; Ebhuoma, 2017). They have been using their knowledge of environmental variables borne from experience and long-time residence in the communities to forecast weather and inform agricultural decision making (Gadzirayi *et al.*, 2006; Armatas *et al.*, 2016; Fitchett and Ebhuoma, 2018). IK is informed by community member's perceptions and interpretations of the natural environment thus, the knowledge system is localised and broadly linked to cultural values in an area (Chand *et al.*, 2014; Chambers *et al.*, 2019). The main aim of this study was to investigate IKS cues essential in agricultural management in KwaZulu-Natal and the Eastern Cape Provinces in South Africa. The research objectives, highlighted in (Section 1.2) address the primary aim through discussing subsets of IKS that are important in agricultural management, which include TPK, meteorological indicators and astronomical indicators.

The data used to address the objectives of this study was obtained through semi-structured interviews with subsistence farmers from Umzimkulu, in KwaZulu-Natal and Lusikisiki, in the Eastern Cape Province. It is noteworthy that there were limitations associated with research design, data collection methods and researcher's positionality, they are addressed in (Section 6.7).

However, these limitations did not compromise the credibility and validity of the results presented in (Chapter 5). The results were informed by the data obtained from Umzimkulu and Lusikisiki that facilitated the achievement of the set objectives for this dissertation.

7.1 Achievement of the Study Objectives

One of the objectives of this study was to determine IKS indicators used for timing the tilling, sowing and harvesting onset in Umzimkulu and Lusikisiki. Through extensive experience and attentive observation of the natural environment that is borne from dependence on environmental viability for agricultural success, community members in Umzimkulu and Lusikisiki have several IKS cues that are used to forecast short and medium-term weather forecasts. The information deduced from the weather forecasts is used to facilitate the management of household gardens and ensure optimal productivity. Subsistence farmers in Umzimkulu and Lusikisiki are more attentive to rainfall seasonality and patterns because their agricultural activities are mainly rain-fed. Therefore, most noted IK indicators are rainfall related. Community members displayed an awareness of climate changes in their areas and the influence of household socio-economic changes on food availability and IKS. The most common indicators in both communities are indicators that are used to track the start of the sowing season, and the tilling and sowing date within the season. Community members in both Umzimkulu and Lusikisiki are less attentive to harvest dates, therefore do not have prominent indicators for the start of the harvest season. Community members within these communities display an ability to adapt to the observed environmental changes through employing locally based expertise and experiences as farmers. A recurring theme in literature and the results of this study is that climate variability and change influence the abundance and reliability of indicator species, which causes concerns over the use

of IKS in climate change adaptation. Results of this study indicate that community members in both Umzimkulu and Lusikisiki are aware of high climate change vulnerability in the areas. Furthermore, they demonstrate that they are also aware that IKS methods are becoming less reliable and are threatened by household economic development and climate change. However, farmers in Umzimkulu and Lusikisiki also highlight that IKS is not static. Although most custodians do not view this a viable reason to document and formally store IKS since they associate IKS with respect and cultural values. This displays a possibility that community members in rural areas may be able to notice new indicators and maintain a reasonable adaptive capacity.

A second objective was:

To explore the perceived reliability of the indicators for sowing dates in each town.

a. Are these indicators reliable?

All participants of this study indicated that IKS weather forecasting methods are becoming less reliable. Community members in Umzimkulu and Lusikisiki do not explicitly associate this change in reliability with anthropogenic climate change. However, they note that changes in their lifestyles is responsible for the observed environmental change. This demonstrates a threat to IK, which may lead to significant agricultural losses and food insecurity in the study areas.

To explore the perceived reliability of the indicators for sowing dates in each town.

b. Do they prefer these IK methods to the national meteorology forecast?

Weather forecasts by national weather services are available through radio and television for both Umzimkulu and Lusikisiki. Admittedly, these reports are based on coarse spatial scale forecasts (Kgakatsi and Rautenbach, 2014), but they are still reported to be useful for daily domestic activities and rainwater harvesting. Community members in both Umzimkulu and Lusikisiki do

not use SAWS reports to inform agricultural management because they argue that these forecasts lack contextual relevance. Furthermore, there is a limited understanding of the metrics used when reporting climatic variables, particularly for rainfall, in both study areas. This informs most of the community member's perception on national weather services reports. On the other hand, IKS forecasting methods are commended for the high spatial resolution and the contextual relevance of the information inferred from the used environmental variables, in both Umzimkulu and Lusikisiki. The preference by community members for IKS cue over national meteorology reports is due to lack of trust by farmers on SAWS reports to inform their agricultural decisions.

The results of this study indicate that rainfall and rainfall seasonality are fundamental to subsistence agriculture productivity. They also demonstrate that despite limited financial and mechanical resources, rural communities still manage to successfully adapt to the effects of climate change and continue producing food and maintaining livelihoods. These results are consistent with several arguments in the literature that emphasise that rural communities, though highly vulnerable to the effects of climate change are not passive actors. A different concept in Umzimkulu and Lusikisiki, from the data that has been recorded in other rural areas, is that although community members associate changes in the environment with a higher power (God), they also believe that their actions either directly or indirectly influence the natural environment. This displays a high likelihood for the reception on the concept of anthropogenic climate change and can facilitate the integration of knowledge systems. These communities have observed changes in abundance and distribution of species, which in literature is linked to changes in species phenology due to climate change. In Umzimkulu and Lusikisiki, this is mostly associated with land-use change and altered farming practices. Overall, this study displays the ingenuity of

subsistence to use IKS and western methods to facilitate food production. It also demonstrates the progressive characteristics of IKS and highlights the observed threats to this knowledge system.

7.2 Recommendations for Future Research

This research highlights the important indicators in two rural areas, in the Eastern Cape and KwaZulu-Natal Provinces, in South Africa. There is still a lot of research needed to extensively explore IKS, particularly in the context of South Africa. Perhaps future research can ensure to conduct data collection during a sowing/ growing season or adopt a longitudinal method that will clearly demonstrate the change and development of new IKS adaptive methods for at least two sowing/growing season. Future studies can also incorporate a quantitative component to increase the contribution of results to broader climate change knowledge in South Africa. In which the research can indicate the differences and/or similarities between perceived climate change by community members and the weather patterns and climate recorded by weather stations close to the study areas. More IKS research can facilitate understanding of community perceptions on complex seasonality metrics and contribute to the development of bottom-up climate change adaptation strategies. There are diverse avenues to traditional knowledge research that will help broaden the understanding of climate variability and various impacts in different locations within the country, ranging from understanding the impacts of contracting biomes to agriculture to the impacts of changing rainfall seasonality on subsistence farming. The research can also be extended to investigating the perceived limits of the broadly accepted rainfall zones and differences IK that informs agriculture in those areas.

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Appendices

Appendix 1: Ethics Clearance



Research Office

HUMAN RESEARCH ETHICS COMMITTEE (NON-MEDICAL)
R14/49 Magaya

CLEARANCE CERTIFICATE

PROTOCOL NUMBER: H19/04/10

PROJECT TITLE

Indigenous knowledge systems cues essential in agricultural management and tracking seasonality in KwaZulu-Natal and Eastern Cape, South Africa

INVESTIGATOR(S)

Ms S Magaya

SCHOOL/DEPARTMENT

Geography, Archaeology and Environmental Studies/

DATE CONSIDERED

26 April 2019

DECISION OF THE COMMITTEE

Approved

EXPIRY DATE

13 June 2020

DATE

14 June 2019

CHAIRPERSON

(Professor J Knight)

cc: Supervisor : Dr J Fitchett

DECLARATION OF INVESTIGATOR(S)

To be completed in duplicate and **ONE COPY** returned to the Secretary at Room 10004, 10th Floor, Senate House, University. Unreported changes to the application may invalidate the clearance given by the HREC (Non-Medical)

I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee. **I agree to completion of a yearly progress report.**

Signature

17 1 06 1 2019
Date

PLEASE QUOTE THE PROTOCOL NUMBER ON ALL ENQUIRIES

Appendix 2: Consent form

This consent form was provided for the participants of the study after the purpose of the study was explained to them. Respondents were given the form to sign and give their permission for their participation. It also provided options for anonymity and for community members to choose between being audio recorded or no. The consent form was written in both IsiXhosa and English to ensure that participants understood clearly.

I..... (Name and surname)
from..... (Name of the area) agree to take part in this research project. The research and all the terms and conditions have been explained to me and I clearly understand what my participation entails.

Circle the appropriate answer:

I agree that my participation will remain anonymous YES NO

I agree that the researcher may use anonymous quotes in her report YES NO

I agree that the interview may be audio recorded YES NO

Print Name.....

Signature.....

Date.....

Appendix 2a: Consent form in IsiXhosa

Mna..... (igama nesbongo)
osuka.....(ilali) ndiyavuma ukuthata inxaxheba kule
projekthi. Iprojekthi nemiqathango ehambisana nayo ndiyichazeliwe kwaye ndiyayi qonda
indima yam kuyo.

Ndiyavuma ukuba igama lam ngeke lidalulwe Ewe Cha

Ndiyavuma ukuba uminkazi we projekthi

angasebenzisa amazwi am enjongokuba ngaphandle kokubhala igama lam Ewe Cha

Ndiyavuma ukuba aqophe amazwi am kunomathotholo wakhe Ewe Cha

Igama.....

Sayina.....

Umhla.....

Appendix 3: Guiding Question

The participants were asked prompting questions to guide the interview sessions and make sure that the researcher obtains valuable information. The questions below are examples of some of the questions that were asked during interviews. The questions were also presented in both English (for the Ethics committee) and Isixhosa. All interviews were conducted in IsiXhosa.

Type of Questions:

1. Were you born in this area? If not, how many years have you been living here for?
2. Do you like the weather conditions here?

a. If yes:

Have the conditions always been this pleasant

b. If no:

Was there a time where they were better than this?

3. Are the weather conditions advantageous to your farming activities?
4. How do you know when it is time to start sowing?
5. What animal/plant behaviour indicates that it is going to be a productive season?
6. What climatic factors are good for sowing?
7. Where do you get the weather information from?
8. Do you believe in radio or television weather reports are accurate?
9. Have you always depended on those reports to inform decision making in your farming activities?
10. Have you ever been misled by television (TV)/radio weather reports? Tell me more about that.

Appendix 3a: Interview Questions outline in IsiXhosa

Uphando lwale projekthi luzawuthatha ingyanga ezimbini (kusuka 20/06/2019 kuya20/08/2019), luzakwenziwa eLusikisiki nase Mzimkulu.

Uhlobo lwemibuzo ezawbuzwa:

1. Wazalelwa apha? Ewe okanye Cha. Ukuba ngaba awzalelwanga apha, wazalelwa phi?
2. Uyaythanda imozulu kulendawo?
 - a. Ukuba ewe: Yayihleli inje?
 - b. Uba hayi: Kwakukho ixesha yayi bhetele kunoku?
3. Imozulu yalapha iyancedisana nokulima kwakho?
4. Wazi njani xa sekulixesha loku lima?
5. Zikhona izityalo, ukhula okanye izilwanyana obona ngalo uba sekulixesha lokulima?
6. Yeyiphi imozulu ebhetele ukuze uqale ukutyala?
7. Ulwazi ngemozulu yemihla ngemihla ulufumana phi?
8. Uyakholelwa kwimozulu emenyezelwa kunomathotholo?
9. Wawuhleli uncediswa ile mozulu kano mathotholo kwaku dala?
10. Apha eminyakeni, ike yakulahlekisa lemozulu kanoma thotholo okanye umabona kude?