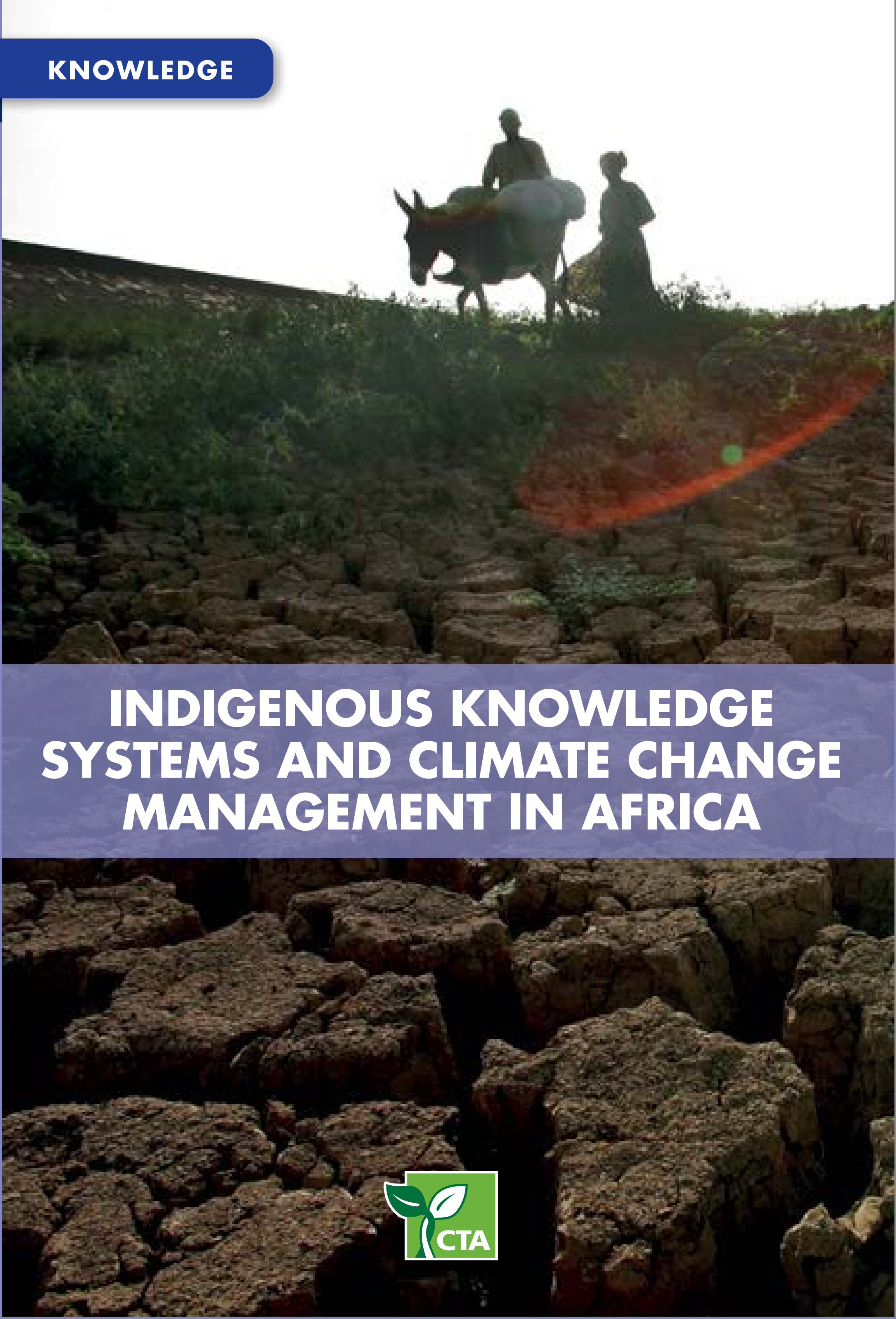
KNOWLEDGE



INDIGENOUS KNOWLEDGE SYSTEMS AND CLIMATE CHANGE MANAGEMENT IN AFRICA

CTA

ABOUT CTA

The Technical Centre for Agricultural and Rural Cooperation (CTA) is a joint international institution of the African, Caribbean and Pacific (ACP) Group of States and the European Union (EU). Its mission is to advance food security, resilience and inclusive economic growth in Africa, the Caribbean and the Pacific through innovations in sustainable agriculture.

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INDIGENOUS KNOWLEDGE SYSTEMS AND CLIMATE CHANGE MANAGEMENT IN AFRICA

Edited by P.L. Mafongoya and O.C. Ajayi

Contents

Acronyms

ACP	African, Caribbean and Pacific
BBMFS	Butha Bothe Machobane Farming System
BBNMFS	Butha Bothe non-Machobane Farming System
CAF	Cancun Adaptation Framework
CBD	Central Business District
CCAA	Climate Change Adaptation in Africa
COF	Climate Outlook Forums
CRCM	Community Reconciliation and Conflict Management
CTA	Technical Centre for Agricultural and Rural Cooperation
CVCA	Climate Vulnerability and Capacity Analysis
DRM	Disaster Risk Management
EPAs	Extension Planning Areas
EWS	Early Warning Systems
FAO	Food and Agriculture Organization
FGD	Focus Group Discussion
GCMs	Global Climate Models
GHG	Greenhouse Gas
GIS	Geographic Information System
GoK	Government of Kenya
GoU	Government of Uganda
HADO	Hifadhi Ardhi Dodoma
ICT	Information and Communication Technology
IFAD	International Fund for Agricultural Development
IFOAM	International Federation of Organic Agriculture Movement
IFRCRCS	International Federation of the Red Cross and Red Crescent Society
IK	Indigenous Knowledge
IKFs	Indigenous Knowledge-based weather forecast system
IKS	Indigenous Knowledge Systems
IPCC	Intergovernmental Panel on Climate Change
ITCZ	Intertropical Convergence Zone
KII	Key Informant Interview
LGAs	Local Government Areas
MFS	Machobane Farming System
MGDS	Malawi Growth and Development Strategy
MGLSD	Ministry of Gender, Labour and Social Development
MHMFS	Mohale's Hoek Machobane Farming System
MoFPED	Ministry of Finance, Planning and Economic Development
MoHEST	Ministry of Higher Education, Science and Technology

NAPA	National Adaptation Programmes of Action
NARO	National Agricultural Research Organization
NF	Nitrogen Fixing
NFB	Nitrogen Fixing Bacteria
NGOs	Non-Governmental Organisations
NUSAF	Northern Uganda Social Action Fund
OPM	Office of the Prime Minister
PEAP	Poverty Eradication Action Plan
PGPR	Plant Growth Promoting Rhizobacteria
PMFS	Pitseng Machobane Farming System
PNMFS	Pitseng non-Machobane Farming System
QMFS	Quthing Machobane Farming System
QNMFS	Quthing non-Machobane Farming System
SSA	Sub-Saharan Africa
SITC	Swinomish Indian Tribal Community
SWaCAP	Soil and Water Conservation and Agroforestry Programme
TEK	Traditional Ecological Knowledge
TLVs	Traditional Leafy Vegetables
TMFS	ThabaTseka Machobane Farming System
TNMFS	ThabaTseka Non-Machobane Farming System
UNCST	Uganda National Council for Science and Technology
UNEP	United Nations Environment Programme
UNESCO	United Nations Education, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UNICEF	United Nations Children's Fund
UNMA	Uganda National Meteorological Authority
UNU	United Nations University
WHO	World Health Organisation

Keywords

Indigenous knowledge, adaptation, weather forecast, climate risks, resilience, food security, underutilised crops, livestock, mitigation, preservation, indigenous communities, natural resources, indigenous farming, agro-pastoralism.

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A woman harvesting corn (maize) in Kamilombe, 20km outside of Lubumbashi.

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Foreword

Climate change presents a profound challenge to food security and sustainable development in Africa. Its negative impacts are likely to be greatest in the African region, which is already food insecure. In the face of global climate change and its emerging challenges and unknowns, it is essential that decision makers base policies on the best available knowledge. In recent years, the knowledge of local and indigenous people, often referred to as indigenous knowledge (IK) has been increasingly recognised as an important source of climate knowledge and adaptation strategies.

Over the millennia, local communities have relied heavily upon their IK to conserve their environment and deal with natural disasters. The communities, particularly those in hazard-prone areas, have developed a good understanding and knowledge of disaster prevention and mitigation, early warning, preparedness and response, and post disaster recovery. This knowledge is based on facts that are known or learnt from experience or acquired through observation and practice, and is handed down from generation to generation. Communities identify easily with IK systems, which are imbedded in their culture to enable them to live in harmony with the environment. These systems are important resources for adaption to climate change.

IK is still important among local communities in many parts of Africa and the global scientific community acknowledges its value, but it is not well documented and is in danger of being lost as its custodian pass away. This is one of the reasons why CTA and its partners decided to publish this book. It is essential that policy makers and development practitioners endeavor to understand IK and the practices of the communities in which they are working. At present, many are either relatively familiar with the notion of IK or at least understand its worth.

With good understanding of IK, policy planners and climate specialists would be better able to integrate IK with scientific knowledge and in doing so, would instigate development initiatives that are both environmentally and socially appropriate and hence, more sustainable. This is the conclusion the reader inevitably reaches after digesting this volume. Any development initiative aiming to improve and enrich the lives of smallholder farmers in Africa should incorporate IK and involve local peoples' 'participation at all stages of intervention'.

The book is an addition to previous efforts by CTA to document and share proven practices, tools or policies that promote resilience and help farmers to address the challenges posed by climate change. The efforts have helped to identify specific climate solutions that work for smallholder farmers in the ACP region. CTA has been working with a consortium of partners to scale up these climate solutions to the benefit of smallholder farmers.

The present book represents CTA's commitment to highlighting the contribution of IK to building climate resilience. It should be considered an essential read for all those who wish to pursue further studies in this exciting field. I congratulate the editors and all the contributors of this book.

Michael Hailu
Director, CTA

CHAPTER 1 - Indigenous knowledge and climate change: Overview and basic propositions

P.L. Mafongoya and O.C. Ajayi

Abstract

This book explores the role for indigenous knowledge (IK) in climate change management in Africa. In the face of global climate change and its emerging challenges and unknowns, it is essential that decision makers base policies and actions on the best available knowledge. Biophysical and social sciences contribute significantly to the collective understanding of earth systems, social systems and their interactions. In recent years there has been a growing awareness that scientific knowledge alone is not adequate for solving climate crises, whilst the knowledge of local and indigenous people is increasingly recognised as an important source of climate knowledge and adaptation strategies. This book explores the use of IK practices for the prediction of agricultural seasons and climate change adaptation and mitigation strategies. The 15 chapters in this book examine case studies on the different uses of IK in the seasonal prediction of climate, based on tree phenology, animal behaviour and astronomical observations, to facilitate decision-making in managing and adapting to climate risks. Since some IK indicators, such as tree phenology, are losing their value in the face of climate change, the integration of IK in scientific seasonal forecasting for more robust decision-making is discussed. With IK at risk of extinction, the conservation of IK in situ and *ex-situ* is also discussed.

Introduction : What is indigenous knowledge (IK)?

The terms indigenous, traditional and/or local knowledge make reference to knowledge and know-how that is accumulated over generations and guides human societies in their innumerable interactions with their surrounding environment. Berkes (2012) defines such traditional, ecological knowledge as “a cumulative body of knowledge, practice and belief, evolving by adaptation processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with their environment." An abundance of labels for IK co-exist in the literature. Common names include, but are not limited to: indigenous knowledge, traditional knowledge, traditional ecological knowledge, local knowledge, farmers' knowledge, ethnoscience, folk knowledge and indigenous science or ethnoscience (see Box 1 on page 30). Although these terms have different connotations, they share sufficiently consistent meanings that are utilised interchangeably throughout this book.

Valuable local knowledge of relevance to climate change assessment and adaptation is held by rural societies (Jiri, 2015). These knowledge systems are transmitted and renewed by each succeeding generation, ensuring the wellbeing of people by providing food security, environmental conservation, and early warning systems for disaster risk management. IK is considered as social capital for the poor and is relied upon for food production and to ensure survival. However, IK is gradually disappearing due to the invasion of development concepts, which promise development goals or solutions, but are not sustainable. The tragedy of the disappearance of this knowledge is obvious to the local indigenous communities, and the implications for others can be detrimental when local skills, teachings and expertise are lost.

V A crop of vegetables raised using drip irrigation tubing. The tubing is low-cost, low-maintenance and very effective.

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The Intergovernmental Panel on Climate Change (IPCC), an international scientific body mandated to provide the world with a clear understanding of climate change and its potential environmental and socio-economic impacts, publishes assessment reports relevant to the implementation of the UN Framework Convention on Climate Change (UNFCCC). The reports are based primarily on published and peer reviewed scientific literature and are among the most widely cited sources in debates related to climate change. IPCC's fourth assessment report noted that "indigenous knowledge is an invaluable basis for developing adaptation and natural resource management strategies in respect to environment and other forms of change." (Parry *et al.*, 2007).

This recognition was reaffirmed at the 32nd Session of the IPCC in 2010, where it was stated that, "Indigenous and traditional knowledge may prove useful for understanding the potential for certain adaptation strategies that are cost-effective, participatory and sustainable" (IPCC, 2010). The indigenous observations and interpretations of meteorological phenomena have guided seasonal and inter-annual activities of local communities for millennia. This knowledge contributes to climate science by offering observations and interpretation at a much smaller spatial scale with considerable temporal depth, and by highlighting aspects that may not be considered by climate scientists.

The Cancun Adaptation Framework (CAF) adopted at the 2010 UNFCCC conference, the Cancun Climate Change Conference, has a guiding principle – the need for adaptation to be based on and guided by the best available science and, as appropriate, IK. Up until this conference, observations and assessments by indigenous peoples and local communities had remained outside the IPCC process, in part due to exclusive focus on scientific documentation and peer reviewed publications. In accordance with CAF principles, an assessment report published in 2014 included a chapter on human security, which discussed the benefits of local knowledge and IK.

In recent years, climate change, local communities and IK have become a rapidly expanding area of investigation, and the collaborative research bringing together indigenous peoples, and natural and social scientists has led to a growing volume of published papers and materials on IK. Roncoli *et al.* (2009) lists 192 published papers in a recent review on epistemological and methodological approaches to climate in cultural anthropology. Crate

(2011) references 136 sources on climate change and culture in an article for the *Annual Review of Anthropology*. Roncoli (2006) surveyed 154 references that examined indigenous communities' responses to climate predictions. The United Nations Education, Scientific and Cultural Organization (UNESCO) and the United Nation University (UNU) (Nakashima *et al.*, 2012) cited over 300 references in the 2012 report *Weathering Uncertainty: Traditional Knowledge for Climate Change Assessment and Adaptation*, which provides an overview of key issues and areas of research on IK. UNFCCC (2011) recognises the importance of IK conservation as key to the benefits of an ecosystems-based approach to climate adaptation. The expanding volume of scientific and grey literature around IK, primarily documents the system as community-based observations of climate change impacts, whose traditional practices and mechanisms may provide a robust basis for effective responses to climate change. Box 1 provides a list of UN knowledge platforms and resources where IK relevant to climate change impact assessment and adaption can be found.

Documentation and research is uncovering the early efforts of indigenous communities to respond to climate change impacts. Nyong *et al.* (2007) found that in the Sahel region, pastoralists integrate

Box 1: Platforms and resources on indigenous and traditional knowledge and climate change

- The UN's Food and Agriculture Organization technology for agriculture platform, available at http://teca.fao.org, provides an online platform for practical information on agricultural technologies and practices to help smallholders in the field.
- The Local Coping Strategies Database of the UNFCCC, available at http://maindb.unfccc.int/public/adaptation/, provides examples of knowledge related to coping with weather hazards, including shifting seasons, drought, erratic rainfall, floods, sea level rise, storms, and extreme heat and cold.
- Climate Frontlines of UNESCO, available at www.cliamtefrontlines.org, is an interagency platform for IK and climate change and provides a repository of indigenous observations and knowledge on climate change, including discussions on early impacts, coping with change, rituals and spirituality, and impacts of climate mitigation action.
- *Advance Guard*, available at www.ias.unu.edu/resource_centre/UNU_Advance_Guard_Compendium_2010_final_web.pdf, is a publication by the UNU Traditional Knowledge initiative that provides a compendium of case studies on climate change adaptation, mitigation and indigenous peoples.
- *Weathering Uncertainty: Traditional Knowledge for Climate Change Assessment and Adaptation*, available at www.ipmpcc.org, is a publication by UNESCO and UNU that reviews scientific and grey literature on traditional knowledge and analyses key issues and emerging trends in IK.

mobility with the active management of their herds to survive droughts. Their responses to disasters, hazards and other extreme events may also be of relevance to climate change adaptation techniques. Ongoing research relates to the action local communities are taking on their own initiative. The challenge for governments, organisations and institutions, therefore, is to identify policy decisions and action that might support those communities in their efforts to enhance climate change assessment and adaptation through mobilisation of their IK.

IK therefore contributes to the co-creation of farmer-led knowledge on climate change adaptation. For centuries farmers and communities have been transmitting this body of knowledge from generation to generation. However, these knowledge systems are threatened because, in most cases, the disseminated information is not properly appraised or documented, leading to a potential loss of knowledge.

Mobilising IK for climate change adaptation

The examination of support for climate change adaptation provides interesting insights into increasing trends, such as the erosion of IK, but it is important to note there has been effort to show evidence of the use of IK in adaptation action. The global research policy agenda is only just starting to investigate the role of IK in adaptation, as evidenced by the introduction of a section on IK for the first time in the IPCC fifth assessment report (2015). The practices and tools proposed for the incorporation of IK into adaptation are often the same tools that seek to build community development or participation into decision-making. Such practices and tools are embedded in participatory development work. The review of practices and tools to implement the use of IK in climate adaptation, assess IK mobilisation within each of the following steps of adaptation: observation of climate change and its impacts; assessment of impacts of vulnerability and adaptation to climate change; adaptation response, planning, implementation and monitoring and evaluation.

In understanding how IK for adaptation can be fostered, it is equally important to highlight policy decisions that facilitate the fullest expression of indigenous adaptive capacity (Ford *et al.*, 2010). Such policies may include those that maintain the integrity of and access to traditional societies, reinforce local practices for sustaining crop or herd diversity, and enhance transmission of IK values, attitudes and worldviews. Good policy decision processes should be coupled with local capacity building, strengthening of local institutions, the inclusion of IK holders as key partners in the development of climate change research and adaptation plans, and promoting the continued transmission of IK.

While global and regional systematic observation systems do not incorporate IK when forecasting weather and climate patterns, the integration of science and IK to improve forecasting is of interest to agricultural scientists. In West Africa, an initiative bringing together the forecasting knowledge of M'bororo pastoralists with scientific long-term and seasonal weather information, is being piloted by the Association for Indigenous Women and Peoples of Chad, the Indigenous Peoples of Africa coordinating committee, and UNESCO. The initiative builds upon a series of dialogue and exchanges between indigenous people and scientists with the support of IK experts. Climate Change Adaptation in Africa (CCAA) supported eight projects in 2009 to investigate how seasonal climate forecasting, developed by the national meteorological services, might be better integrated into agricultural and pastoral decision-making to strengthen livelihoods and food security (Ziervogel and Opere, 2010). While such projects demonstrated potential in bringing together seasonal climate forecasters with indigenous forecasters, the CCAA programme recommended more exploration to improve forecasting, including the use of local predictors. This should be explored in relation to climate change in order to help IK practitioners determine whether such indicators are altered by climate change. Meteorological services could start integrating IK systems (IKS), such as phenological data, into their advisories to provide users with more broadly-based information.

With appropriate design and planning, geographic information systems and mapping tools can facilitate the inclusion of specific sets of IK, such as the distribution of specific trees used for tree phenology indicators, in climate observation schemes. Such information and communication technology (ICT) based projects are typically designed to include a specific factor of IK. The information gathered can then be applied to understand the options in relation to that specific factor or variable. In addition to being used to combine data from science and IK for climate observation, ICT tools can be harnessed to document and promote the transmission of IK for adaptation.

There is a growing awareness that IK has significant contributions to make within climate change adaptation processes, from observation and assessment to planning and implementation. Since climate change adaptation itself is a rich and rapidly developing field of theories and practices, this entire area of work is new, and because the articulation of IK and adaptation was only initiated some 10 or so years ago, work in this area has only begun in earnest in the last 5 years. The domain of IK and climate change adaptation holds great promise, but as yet, requires considerable investigation, experimentation and negotiation.

On to the emerging nature of the work, major gaps persist and need to be addressed in order to benefit from the added value of bringing IK into climate change adaptation processes in an appropriate and mutually agreed upon manner. The initial development of guidelines on mobilisation of IK across all components of adaptation, could provide decision makers and practitioners with modalities and tools for linking IK with scientific knowledge and using IK in adaptation decision-making. These will recognise the role of relevant international policies and best practices. Such guidelines could also include development based indicators that contribute to measuring the progress made towards adaptation goals, including those of the UNFCCC. The guidelines could be developed through an ad hoc transdisciplinary process that includes the knowledge of indigenous peoples and local communities.

A herder among his cattle, Sudan.

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The main objectives of the book are to:

- Identify the different IK initiatives that are practiced by smallholder farmers, and any scientific support for their use.
- Assess the trend over time of the extent to which IKS are being used by farmers, including an explanation of the trend.
- Determine the extent to which IK actions are still relevant in contemporary situations, taking into account population growth and climate change.
- Identify the threats to IK and the policies and actions that conserve them.
- Evaluate potential synergies for IK with existing scientific climate approaches, and identify where IK can be adapted in current efforts addressing climate challenges facing smallholder farmers.

The book outline is as follows:

Chapter overview

Introduction

There are three introductory chapters. Chapter one introduces the scope of the book and the main objectives of publishing a book. It also defines IKS. Chapter two looks at the history of IK, its role in development and natural resource management. The characteristics of IK are discussed and the critical issues involved in conducting research on IK are explored. The differences between IK and western science are also explored and the importance of integrating IK with scientific knowledge is elaborated. The use of IK in management of biodiversity, environmental conservation, climate risks and disasters in terms of early warning and preparedness is also discussed.

Chapter three gives an overview of the use of IK for seasonal prediction and managing climate risks across Africa. This chapter acts as a basis for the chapters which deal with the use of IK indicators for seasonal prediction and IK practices for climate change adaptation. Issues of IK transmission, dissemination and conservation are discussed. IK indicators based on tree phenology, animal behaviour and astronomical observations are drawn from west, east and southern Africa. This chapter clearly shows that certain indicators are commonly used across the continent and can be scaled up.

The use of IK in seasonal forecasting

A number of chapters concentrate on the use of IK indicators in Malawi, South Africa, Tanzania, Uganda, Zambia and Zimbabwe. These chapters clearly show that in all these countries, tree phenology, animal behaviour and astronomical observation are the basis of seasonal forecasting. Some of the indicators are specific to a particular country or location. However, there are some indicators which are commonly used across the countries, hence this can be scaled up across the continent. Most of the chapters also show that IK indicators are not as reliable as they used to be due to changing climate. Hence, these chapters emphasise the need to integrate IK forecasts and scientific seasonal forecasts. In many African countries, between 60%-70% of farmers still rely on IK indicators for seasonal forecasting and are anxious to integrate scientific forecasts for better decision-making.

The use of IKS in climate change management

A number of chapters discuss various IK practices for climate change adaptation and mitigation. A prominent chapter raises the issue of under-utilised and neglected crop and livestock species for climate change adaptation. These crops/animals are adapted to cope better with high temperatures, heat stress, low rainfall and diseases, and provide farmers with food and nutritional security during droughts and climatic shocks. Indigenous fruits and edible insects play a major role in terms of nutrition and livelihood provision for farmers during climate shocks. The use of indigenous social capital, such as the *Zunde Ramambo* programme in Zimbabwe, for example – where the traditional chief collectively stores food crops ready to distribute to community members during periods of drought – underscores the importance of social capital and traditional practices for climate change adaptation and mitigation. Other IK practices by agro-pastoralists in East Africa show that IK practices are underpinned by ecological principles in rangeland management.

Conclusion

There are two concluding chapters at the end of the book; the first discusses the challenges of documentation, dissemination and conservation of IK. This chapter clearly shows that IK is at high risk of being lost and hence the need to document and conserve it. Various means of documenting IK are discussed in terms of databases, archives and libraries, and the establishment of national and regional resource centres of IK. Inclusion of IK in the curriculum of schools and tertiary education is also discussed. The issues of access to IK by farmers when it is conserved ex-situ is highlighted; and the use of ICT to blend modern science with IK is also suggested. More research on IK is recommended if increased funding is made available from the national government and international donors. Governments are also encouraged to have a national IK policy as demonstrated by, among others across the continent, the governments of Kenya and South Africa.

The final concluding chapter starts by emphasising co-knowledge production with various biophysical scientists, social scientists and IK information holders in communities. The challenges brought by global climate change are beyond the level of experience of all knowledge holders whether scientific or indigenous. Effective adaptation planning requires access to the best knowledge available, hence the importance of core knowledge production. IK is in danger of being lost and should be documented and conserved both *in-situ* and *ex-situ*. There must be mechanisms to guarantee access to IK by communities when it is conserved *ex-situ*. The major recommendations are that IK should be documented and databases should be established for this, it should be incorporated in national policies and integrated with western science. IK should also be part of school and university curriculums and popularised amongst various stakeholders and the general public.

One important question that readers may ask is: Why the book? What has it got to do with climate smart agriculture? How will it help farmers cope with the problems that they face on a daily basis with climate change?

Below is some useful information taken from the terms of reference of the book to outline the practical value of the publication.

ANNEX 1 : TERMS OF REFERENCE

1. Background of the project

Climate change is a crucial topic with critical implications in the agricultural sector of ACP countries, which are already greatly exposed to climate variability and extremes. Due to these emerging challenges, it is essential that decision makers base their policies and actions on the best available knowledge.

CTA is helping to promote the upscaling of climate resilient solutions that work for family farming in ACP regions. An achievable option is the inclusion of IKS in addition to scientific knowledge. In the context of this activity, IKS are defined as a collection of knowledge, beliefs, skills, innovations, experiences and insights of individuals and communities concerning the management of their natural and cultural environments.

Family farmers and local communities have gone through a series of bad weather situations in the past; they have acquired some experiences and developed home grown methods to address these challenges. Over time, they have accumulated a wealth of traditional knowledge on a wide variety of agro-ecological solutions to prevent food crises, on fostering their resilience to climatic shocks and on capacities to adapt to natural emergencies. There is an increasing acknowledgement by various stakeholders, including scientists and researchers, that knowledge, lessons learned and best practices acquired by farmers can be useful in planning climate adaptation and resilience strategies. Furthermore, they contribute to the much needed solutions to contemporary challenges, if properly harnessed. IKS therefore contribute to the promotion of farmer-led knowledge in the co-creation of adaptation policies and practices to address climate change. Farmers and communities have been transmitting this body of knowledge from generation to generation. However, these knowledge systems are threatened as, in most cases, IK methods are not properly appraised and documented; leading to a potential loss of knowledge and a reduced number of available options for addressing climate change.

CTA is collaborating with partners in ACP regions on this topic, to establish a thorough understanding of the role of IKS in the agricultural sector within the context of the growing challenges linked to climate change.

2. Objectives

Through a team of authors that have been assembled to prepare manuscripts that focus on different aspects of IKS, the overall objective is to produce a book that provides the following insights:

Identify the different IKS initiatives practiced by smallholder farmers and any existing scientific support for their use.

Assess the trend over time of the extent to which IKS are being used by farmers including an explanation of the trend.

Determine the extent to which IKS actions are still relevant in contemporary situations taking into account population growth and climate change.

Identify the threats to the use of IKS and policies and actions to conserve them.

Evaluate potential synergies for IKS with existing scientific climate approaches and identify options for adapting IKS to current efforts to address the climatic challenges facing smallholder farmers.

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Bwindi, Uganda - A woman harvesting Sorghum.

CHAPTER 2 - Indigenous knowledge systems: Their history, development over time and role in sustainable development and climate change management

P.L. Mafongoya and O.C. Ajayi

Abstract

Indigenous knowledge (IK) systems are considered as social capital for the poor. They are the main asset to ensure survival, to produce food and secure livelihoods. Most IK disappears due to the invasion of foreign teachings and development concepts that promise development goals or solutions, but are not sustainable. The tragedy of the disappearance of this knowledge is obvious to those who developed it. The implications can be detrimental to others when skills, teachings and expertise are lost. This review will look at the characteristics of IK systems (IKS), the research issues when conducting research on IKS, and evaluate the role of IKS in sustainable development and climate change management in Africa. The role of IKS in biodiversity and environmental conservation, disaster preparedness and management, poverty alleviation and food security will also be discussed. The integration of IKS with scientific methods will be evaluated and the threats to IKS and their conservation deliberated.

Introduction

In the face of global climate change and its emerging challenges, unknowns and uncertainties, it is essential that decision-making for policies and actions be based on the best available knowledge. The biophysical and social sciences contribute significantly to the collective understanding of earth systems, social systems and their interactions in what is commonly known as socio-ecological systems. In recent years, there has been a growing awareness that formal scientific knowledge alone is inadequate in solving the climate crisis (Finuccare, 2009). The knowledge of local and indigenous people, often referred to as local, indigenous or traditional knowledge, is increasingly recognised as an important source of climate knowledge and adaptation strategies. Indigenous knowledge (IK) is already seen as pivotal in fields such as sustainable development, agroforestry, traditional medicine, biodiversity conservation, soil science, ethnoveterinary science, applied anthropology and natural resource management. Many are expecting this knowledge to play a primary role in climate science and in facilitating adaptation to climate change and variability.

Box 1: Definitions of indigenous and traditional knowledge applied by UN bodies and agencies

Convention on Biological Diversity

Traditional knowledge refers to the knowledge, innovations and practices of indigenous and local communities around the world. Developed from experience gained over centuries and adapted to local culture and environment, traditional knowledge is transmitted orally from generation to generation. It tends to be collectively owned and takes the form of stories, songs, folklore, proverbs, cultural values, beliefs, rituals, community laws, local language and agricultural practices, including the development of plant species and animal breeds. Sometimes it is referred to as an oral tradition for it is practiced, sung, danced, painted, carved, chanted and performed down though millennia. Traditional knowledge is mainly of a practical nature, particularly in such fields as agriculture, fisheries, health, horticulture, forestry and environmental management.

United Nations, Educational, Scientific, and Cultural Organization

Local and IKS refer to the understandings, skills and philosophies developed by societies with long histories of interaction with their natural surroundings. For rural and indigenous peoples, local knowledge informs decision-making about fundamental aspects of day-to-day life. This knowledge is integral to a cultural complex that also encompasses language, systems of classification, resource use practices, social interactions, rituals and spirituality. These unique ways of knowing are important facets of the world's cultural diversity and provide a foundation for locally-appropriate sustainable development.

World Intellectual Property Organization

Traditional knowledge is the knowledge, know-how, skills, innovations or practices that are passed between generations in a traditional context and that form part of the traditional lifestyle of indigenous and local communities who act as their guardian or custodian.

Intergovernmental Panel on Biodiversity and Ecosystem Services

Indigenous and local knowledge refers to the multi-faceted arrays of knowledge, know-how, practices and representations that guide societies in their innumerable interactions with their natural surroundings. This interplay between people and place has given rise to a diversity of knowledge systems that are at once empirical and symbolic, pragmatic and intellectual, traditional and adaptive.

These knowledge systems are transmitted and renewed by each succeeding generation, and ensure the wellbeing of people by providing food security, environmental conservation and management and early warning systems for disaster risk management.

History of IK: Colonial science borrows from IK

Traditional knowledge is as ancient as humankind, and the origins of science is rooted in traditional knowledge. With European expansion in the 17^{th} and 18^{th} centuries, the newly established scientific disciplines of ethnobotany and ethnozoology threw an influx of new knowledge from traditional knowledge holders across the globe. However, the primary concern of European settlers was not to understand other knowledge systems *per se*, but rather to glean from this knowledge information for the development of colonial science. Their major efforts focused on compiling a list of useful plants and animals unknown to European science. During the colonial period, European scientists did not limit their reliance on local experts to the simple identification of species of interest, they also adopted from local people entire classification systems that interpreted ecological systems according to indigenous logic. IK was hence transferred to western taxonomic knowledge and practices. Throughout the colonial

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A handful of cowpea seeds, Ouagadougou.

period, western scientific understanding expanded the appropriation of traditional ecological knowledge, with little acknowledgement of the intellectual origins of their borrowed discoveries.

A shift in attitudes of western scientists towards IKS began in the mid-20th century. This was triggered by iconoclastic worker, Conklin, whilst working in the Philippines in 1954. He observed that in the Hamunoo society, the understanding of characteristics which differentiate plant types and often indicate significant features of medicinal and nutritional value, were the topic of everyday conservation (Conklin, 1954, box 2).

The work of Conklin dissects indigenous ways of understanding and surviving the world. This challenged and raised questions about the supposedly superior intellect and training of scientists by demonstrating the complexity, detail and accuracy of IK and its value to the scientific community (Schultes, 1994; Zent, 2009).

In his widely cited work *The Savage Mind*, Claude Levi-Strauss (1962) argued that IK is first and foremost an intellectual pursuit, debunking prevailing stereotypes of traditional knowledge merely suiting a practical purpose.

Box 2: Indigenous ecologies of tropical plants

The Hamunoo culture's relationship with the plant world

Conklin observed that in the Hamunoo society, 'the hundreds of characteristics which differentiate plant types and often indicate significant features of medicinal or nutritional value', were a major topic of everyday conversation. This empirical interest in plants is acquired very young in the community, as demonstrated by Conklin's account of his exchange with a 7-year-old Hamunoo girl. She systematically examined Brown's authoritative three-volume guide to useful plants of the Philippines, and for each image, she either assigned a Hamunoo name or solemnly declared to have 'not seen that plant before'. Out of 75 plants, she identified 51 with only two errors.

Source: Conklin (1954).

Integrating IK with scientific knowledge

The contemporary study of IK and its interface with science dates back many decades. Scientists' efforts to conform climate observations by indigenous people have not all been met with success. However, reports from Africa in this volume show convergence of IK system forecasts with scientific forecasts, climate change and seasonal predictions. However, parameters observed by scientists are different in meaning to those observed by traditional sources (Mafongoya *et al.*, this volume).

Faced with the climate challenges ahead, efforts to create a constructive dialogue between indigenous peoples and scientists constitute an important step towards decision-making based on the best available knowledge. In this, efforts to compare indigenous and scientific knowledge of a phenomenon should not amount to comparing apples and oranges.

Western science and IK

IK is considered as social capital for the poor, relied upon for food production and livelihood security. The use and abundance of western scientific knowledge and teachings in pushing the development agenda has eroded the use of IKS. This could be disastrous for proponents and users of IKS, particularly in the absence of certainty in scientific climate change prediction models.

Some scientists have expressed concerns that the promotion of IK is tantamount to promoting pseudoscience and anti-science. Even in Africa, one of the strongholds of IK, it has until recently been regarded as being backward, static and a hindrance to modernisation Pseudoscience constitutes an attempt to be perceived as scientific, whilst anti-science constitutes an opposition to science. IK is neither of those. It is developed with a different intent and context to pseudoscience and anti-science in that it is neither attempting to masquerade as science, nor sees itself in opposition to science.

Western science and IKS are presented as two competing knowledge systems, characterised by a binary divide. This divide has arguably evolved out of the epistemological foundation of the two knowledge systems. Hence, they may be treated as discreet entities separable from each other in space, which precludes dialogue and learning between them (Mohan and Stokke, 2000). Western science is seen to be open, systematic, objective and very much dependent on a detached centre of rationality and intelligence. IK is seen to be closed, parochial, unintellectual, primitive and emotional (Ellen and Harris, 2000). Consequently, western knowledge systems are part of the whole notion of modernity, whilst IKS are perceived as part of a residual, traditional and backward way of life.

However, IKS have become central to sustainable development. This is because of the way in which IK has evidently allowed people to live in harmony with nature for generations. The privileging of IKS in development is welcomed because it also presents a shift away from the preoccupation with centralised, technically oriented solutions, which have failed to alter the life prospects for the majority of peasants and smallholder farmers worldwide (Agrawal, 1955).

Characteristics of IK

Ellen and Harris (1990) provided characteristics of IK as follows: IK is local; it is rooted to a particular place and a set of experiences; and is generated by people living in those places. The result of such factors is that transferring IK from one place to another runs the risk of dislocating it.

- IK is orally transmitted or transmitted through intrinsic dramatisation. As a consequence, writing it down changes some of its fundamental properties, but also makes it more portable and permanent.
- IK is a consequence of practical engagement in everyday life, and is constantly refined by experience, trial and error. This experience is a product of many generations of intelligent reasoning and its failure has undesirable consequences for the lives of its practitioners. Its success is very often a good measure of a combination of factors. It is tested in the rigorous laboratory of survival.
- IK is imperial rather than theoretical knowledge. To some extent, its oral character hinders the kind of agonisation necessary for the development of theoretical knowledge.
- Repetition is an essential characteristic of tradition, even when new knowledge is added. Repetition aids retention and reinforces ideas.
- IK is constantly changing, being produced as well as reproduced, discovered and lost, though it is often portrayed as being static.
- IK is characteristically much further ahead than other forms of knowledge. Therefore, it is called the people's science. However, its distribution is still segregated and socially clustered. It is usually asymmetrically distributed within a population by gender and age and is preserved through the memories of individuals.

A farmer measuring growth rates of a rice crop while his colleague records the data as part of an exercise at a Farmer Field School.

- IK may be focused on particular individuals and may achieve a degree of coherence in rituals and other symbolic occurrences, however its distribution is always fragmented. It does not exist in totality at any one point or within any one individual.
- IK is characteristically solicited within oral cultural traditions and therefore, separation of the technical from the non-technical and the rational from the non-rational, is problematic.

Modern scientific knowledge is centralised and associated with the machinery of state, and those who are its bearers believe in its superiority. In contrast, IK is scattered and associated with low prestige rural life and even those who are its bearers may believe it to be inferior to scientific knowledge. IK differs from western scientific knowledge on the following grounds (Table 1)

- Substantive grounds – there are differences in subject matter between IK and western knowledge.
- Methodological and epistemological grounds – the forms of knowledge employ different methods to investigate reality.
- Contextual grounds – IK is more deeply rooted in its environment (Agrawal, 1995).

IK is essential to development and it is often suggested in the literature that such knowledge must be gathered and advanced in a coherent and systematic fashion. As more studies of IK become available, its relevant to development will be self-explanatory. Such studies should be archived in national and international centres in the form of data bases, and the information should be systematically classified. The collection and storage of IK should be supported with adequate dissemination and exchange among interested parties using newsletters, journals and other media.

Researching IK

Researching IKS from the perspective of the demands of formal science throws up a number of challenging issues. Firstly, IK is difficult to categorise since it is holistic in nature and not disciplinary like conventional science. It is specific in relation to a place, having evolved in response to local conditions, yet it is diverse in content, with concepts that may combine agroecology with social relations of production (Faihead, 1991).

Table 1: Comparison between formal science and IK

Major differences	Western/formal science	IK
Mode of transmission	Written, formally documented	Oral, repetitive
Substantive differences	To construct general explanations; is removed from people`s daily lives	Concerned with immediate and concrete necessities of people`s daily livelihoods
Methodological and epistemological differences	It is open, systematic, objective and analytical. It advances by building rigorously on prior achievements	It is closed, non-systematic and holistic rather than analytical. It advances on the basis of new experiences, not on the basis of deductive logic
Contextual differences	It is divorced from epistemic framework in search for universal validity	It exists in a local context anchored to a particular social group, in a particular setting at a particular time

Secondly, IKS have mostly been studied by anthropologists who have utilised them in order to comprehend the knowledge and values of those societies (Conklin, 1954). The universal IK approach is arguably non-scientific having no predominant structure or theory. It can reduce the collection of large amounts of field data that is difficult to assess. Anthropologists who are experts in their field of study, can often have difficulty in communicating their knowledge to others in a non-technical and comprehensible manner (Chambers, 1983). This is to the detriment of rural development, since the insights and weather knowledge gained through their experiences remain inaccessible and offer little practical guidance without appropriate explanation. Such knowledge must be made more accessible to rural development policy makers (Selltoe, 1998).

Thirdly, there is a danger that local knowledge may be interpreted in terms of formal scientific concepts regarding agriculture and economics. This is grossly disturbing and what anthropologists call 'ethnocompression'. This results in some researchers portraying local practices in terms of their own external perspective and technical expertise without having a contextual understanding of the cultural conditions that have informed the evaluation of the idea.

Further, informants from local communities may find it hard to provide formal access to their traditional knowledge and uses of it. The process of a researcher questioning an informant or 'knowledge provider' can interfere with his or her perception of what is being discussed. In modern science, understanding is generally constrained to written or spoken word, but indigenous peoples are not necessarily familiar with expressing everything they know in words. Much traditional knowledge is learnt and communicated between generations through practical experience. IK is transferred via informal and practical demonstrations as opposed to articulation. In this sense, it is a skill as much as it is a concept.

Knowledge that is learnt through experience may applied without conscious awareness of the detail, and even conscious knowledge may not always be expressed in terms of rules and procedures. This has implications not only for the elicitation process but also for subsequent representation of the knowledge for use by others. Moreover, the knowledge provider may be unwilling to impart information because he/she recognises that holding on to this knowledge provides power or status. Problems of communication are central to IK research. The familiarity and skill with which words are used to express concepts and procedures will affect the quality of the knowledge elicited through interview. Although people identified for interviews may be experts, it is unlikely that they have previously been required to describe their knowledge and decision-making procedures. They are not familiar with communicating them in this way.

Finally, the status assumed by the researcher when studying the community will influence the data collection process. Attempts to reduce social and intellectual barriers and improve understanding will enhance cooperation and knowledge elicitation. If a researcher assumes the role of a learner, informants are more likely to be responsive than if he or she presents themselves as a scientist, policy maker or planner.

Use of IK in sustainable development

Most development practitioners have now recognised the value of participatory approaches in decision-making for sustainable development. IK provides the basis for decision-making. IKS for ecological zones, agriculture, aquaculture, forests, grassland and game management, to mention a few areas, are far more complicated than previously assumed (Posey, 1995). Furthermore, this knowledge offers new models for development that are both ecologically and socially sound. Hence, it is a well-known fact that development projects that work with, and through IK, have advantages over projects that operate outside them.

One classic example is that of reverting back to 'non-scientific' polyculture (mixed cropping, intercropping, and multiple cropping) from the 'scientific' monoculture. With the introduction of the green revolution, the characteristics of traditional polycultures that make them desirable were ignored by researchers in developing agricultural models. Polyculture has many sustainable characteristics such as diet diversification, diversified income generation, production stability, minimisation of risk, low pest and disease prevalence, efficient use of labour and resources, and intensification of production with reduced natural resource degradation. Local people have learnt these lessons over millennia and their accumulated experiences and survival techniques are invaluable in designing modern development plans. Therefore, greater attention should be paid to IKS are their uses at the policy level of the development process.

The critical strength of IK is its ability to see the interrelations of disciplines, and integrate them meaningfully. This holistic perspective and the resultant synergies show higher levels of developmental impact, adaptability and sustainability than western, modern knowledge. IK is a very good source of readily available practices that are useful for identifying appropriate policies to respond to climate change.

The value of IK is not only limited to agriculture, environment and biodiversity, it also has an immense value in education, medicine, soil science and other natural resource disciplines.

IK and biological diversity

Biological diversity is now threatened by extinction. Biological diversity and cultural diversity are two sides of the same coin. Living diversity in nature corresponds to a living cultural diversity. With cultural and environmental change, both biodiversity and IK vital to sustainability, are lost at an incredible rate (Haverkant and Miller, 1994). Poverty is one of the main reasons for loss of biodiversity and IKS. Poverty increases the pressure on natural resources and directs people away from complex IKS to more simple and easy technologies, such as chemical agriculture. This has led to a tremendous loss of landraces and their wild relatives of food crops, which are used in plant breeding for various abiotic and biotic stresses caused by climate change and variability (see Jiri *et al.*, this volume).

The concept of biodiversity as a form of biological capital has been highlighted by several authors (Ajayi, 2005; Ajayi, 2000; Hueth and Regey, 1974). Altieri (1993, p 257) describes biodiversity as a "salient feature of traditional farming systems in developing countries and (it) performs a variety of renewal processes and ecological services in agro-ecosystems". The introduction of modern commercial agricultural technology from western disciplines, or even elements of the local indigenous practices, in favour of modern practices such as monocropping, has caused the subsequent loss of many plant and animal species. This has also led to the degradation of natural resources, poor nutrition and a loss of informal chemicals used by communities (Larson, 1998).

Potential of IK in environmental conservation

Many IK approaches to environmental conservation include such technologies and practices as shifting cultivation, mixed cropping, intercropping, and minimum tillage and agroforestry systems. These technologies and practices are used in many parts of sub-Saharan Africa (SSA) in combination with various other farm practices to promote higher yields, while at the same time conserve the environment. Intercropping or mixed cropping of maize with legumes and other crops promotes the efficient use of labour and environmental resources such as water, light, nutrients and land, whilst reducing the risk of complete crop failure, soil erosion and susceptibility to pests and diseases.

V **Harvesting rice crop, Malawi.**

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Disaster management

Many communities in SSA face natural hazards, the major ones being droughts and floods. Case studies in this volume show that communities are well aware of these disasters and that a well conserved environment helps them reduce associated problems with natural disasters. These disasters invariably cause famine, food insecurity and poverty. However, communities have developed a variety of measures that have helped them to survive climate changes with little or no help from the outside, such as growing drought tolerant and early maturing indigenous crops, gathering wild fruits and vegetables, cultivating wetlands, and diversifying and selling livestock.

Early preparedness

Most communities have an array of early warning indicators and well developed structures to which wisdom of the community is applied to interpret and deal with disasters quickly and efficiently. In Swaziland, where droughts and floods are common disasters, communities take precautions following indications of disaster. They look at the nest heights of emahloko birds (*Ploceus* spp.) in trees to predict floods. When floods are likely to occur, the nests of the birds are high on the trees next to the river and when floods are unlikely to occur, nests are lower down. Other indigenous indicators used by the Swazis to predict natural hazards include wind direction, the shape of the crescent moon and the behaviour of certain animals.

Poverty alleviation and food security

Poverty in communities translates to food insecurity. Therefore the question is how to use IK to improve food security. The use and application of appropriate IK can promote environmental conservation (land, grasslands, forests, wetlands and biodiversity) and management of disasters in terms of prevention, mitigation, recovery, prediction or early warning, preparedness, response and rehabilitation. IK can promote poverty alleviation through traditional food production and preservation, and healing through traditional medicinal practices. Maasai pastoralists in Kenya rely on a system of land use and management that has assured them a stable livelihood for generations, enabling them to optimise their utilisation of rangeland resources for maximum meat and milk production.

Conclusion

IK is increasingly recognised as an underutilised resource in rural development. Scholars have pointed out that many technological solutions to problems in rural communities have failed because they did not take into account local knowledge and practices. The chapters in this volume will show several case studies that demonstrate how understanding the IK of a given group could greatly enhance participatory and sustainable approaches to developing appropriate strategies on climate change in particular, and rural development in general. Whilst this does not imply that IK is superior to formal scientific knowledge, it is important to know that understanding IK can help to determine whether or not external scientific alternatives are appropriate or how can they be adapted or integrated with IK for greater impact. It will be by comparing and integrating scientific knowledge and IKS that the most appropriate solutions will be found for developmental problems.

All academics, policy makers and practitioners should pay greater attention to this invaluable treasure of knowledge threatened by extinction. If we are to move away from the conventional technology transfer approach to an interactive technology development, we will need to learn from 'village level experts', who are the custodians of IK.

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CHAPTER 3 - Using indigenous knowledge for seasonal quality prediction in managing climate risk in sub-Saharan Africa

P.L. Mafongoya, O. Jiri, C.P. Mubaya, and O. Mafongoya

Introduction

Sub-Saharan Africa (SSA) is considered highly vulnerable to the impacts of climate change. This is due to its dependence on rain-fed agriculture and natural resources which are climate sensitive; the warmer baseline climate; highly variable precipitation; and limited adaptive capacity (Thornton *et al.*, 2008; Hassan and Nhemachena, 2008). This vulnerability is also due to the fact that current climate is already severe, climate information is poor and technological advance is less evolved in SSA. The impacts of climate change on agriculture could severely worsen livelihood conditions of the rural poor and increase food insecurity in the region.

Extreme climate events such as droughts and floods, as well as changes in the mean climate temperature, have direct effects on crops and livestock and thus, peoples' livelihoods. Food security is at risk, particularly in SSA where agricultural production is mostly rain-fed. The impact is already significant. The 2002 drought in Malawi meant more than 5 million people needed emergency food aid. Similar situations have since occurred in Nigeria in 2004-2005, when 2.5 million people needed food aid and in Kenya in 2009, when 3.8 million people required food aid because of prolonged droughts (UNDP, 2007).

Reducing the impact of climate variability and change on food production and livelihoods can be achieved. This is in part by using available climate information to anticipate and manage the impacts related to climate risks (Washington *et al.*, 2006). Climate information is available from two main sources: meteorological forecasts and indigenous knowledge (IK). This information can help farmers to manage their crops and livestock to

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reduce risk during unfavorable seasons and maximise opportunities during favourable conditions. There is scope in Africa to substantially increase the use of climate information and services in planning to reduce the threat of climate variability and change and achieve development goals. More effective use of climate information and services by both vulnerable groups and institutions charged with managing impacts of changing climate, will enable the climate-sensitive sectors of African societies to cope better with the natural variability of the climate system. This will allow better adaptation to the impacts of climate change. In southern Africa, approaches to harness the potential of climate information for increased food production and community resilience are common, and minimise the impacts of climate change.

^ On the way back to lilongwe from M'njolo Junior Farmer Field Life School.

The effectiveness of meteorological seasonal forecasts as a supportive decision-makingtool for small scale African farmers remains open to debate. This is so given the fact that scientific forecasts are still not easily available to farmers in a timely manner. The challenge, therefore, is for researchers to respond to the needs expressed by farmers, relating to forecasts, with scientific tools, IK-based forecasts or a combination of the two approaches.

The concept of IK has become increasingly topical and embraced by academics and development practitioners as integral to addressing multiple livelihood challenges faced by rural communities in developing countries, and as a basis for locally driven adaptation strategies that transcend the planning stage and can begin to be implemented (Mapfumo *et al.*, 2015; Moonga and Chitambo, 2010; Saitabau, 2014). In Botswana, more recent studies have shown that resilience building for smallholder farmers is a process that starts with the ability to anticipate change and adjust farming practices accordingly - this creates the basis for sound food security, particularly in the context of climate variability and change (Kolawole *et al.*, 2014).

Interest in IK systems (IKS) started decades ago (Posey, 1986). This interest has since expanded to the areas of agricultural development and natural resource management (Chambers, 1994; Alston, 2006; Thompson and Scoones, 1994). There are also studies which document the effectiveness of IKS in land management (Vermulen *et al.*, 2006).

What are IKS?

The term 'IK system' is well established in literature. Other terms such as local, traditional, vernacular or folk knowledge are also used (Ellen and Harris, 2000). The term indigenous, traditional or local knowledge is associated with knowledge and knowhow accumulated across generations. This knowledge guides societies in the incredible interactions with their surrounding environment (Berkes, 2012). An abundance of information exists in literature on IKS. Other names for IKS include farmers' knowledge, traditional ecological knowledge, local knowledge, folk knowledge and indigenous science, to mention a few. This paper will use IKS. IKS encompass empirical understanding and dedicated thought, community know-how, practices and technology, social organisations and institutions, and spiritual rituals. IKS are often community generated (Berkes, 2012). Men and women help disseminate knowledge and have differing and complimentary roles in society. In this chapter, we use IKS to refer to 'a cumulative body of knowledge, practice and belief, working by adaptive processes and handed down through generations by cultural transmission, about the relationships of living beings (including humans) with one another and with their environment' (Berkes, 2012).

IK should not be seen as static, rigid, or repetitive of traditions that are unable to incorporate innovations (Guchteneire *et al.*, 2010). It is a flexible entity due to its diverse and experimental nature and can easily integrate skills and insights from other knowledge systems. The relevance of IKS for climate change adaptation is a new and rapidly expanding area of collaborative research involving indigenous people, local communities and scientists. A literature review by Roncoli *et al.* (2009) lists 192 papers published on IKS. Crate (2011) references 136 sources on climate and culture. Recently, Nakashima *et al.* (2012) cited over 300 references in Weather Uncertainty: *Traditional Knowledge for Climate Change Assessment and Adaptation*. This expanding body of scientific and grey literature discusses IKS as a basis for community-based observations of climate change impacts and traditional practices, and mechanisms that provide a robust basis for climate response.

There has been a great deal of research on IKS in agriculture, forestry, biodiversity, soils, land and water management. However, little knowledge from IKS has been applied to climate change adaptation strategies (Vermeulen *et al.*, 2008). This could be due to the fact that climate organisations operate at national, regional and international levels, making it difficult to incorporate IKS. Orlove *et al.* (2000 and 2002) look at the indicators used to forecast weather or season variables, whilst Roncoli (2006) looks at the integration of these indicators with agricultural practices. These studies have shown the potential of drawing on IKS for program ordered forecast dissemination (Rancoli *et al.*, 2002, 2009).

Seasonal climate forecasting

Climate forecast predictions relate to seasonal precipitation and other aspects of seasonal climate such as the level of rainfall, temperature changes and extreme weather events. Climate prediction is one of many sources of information that can be used by decision makers to reduce risk and optimise gains. The agricultural sector stands specifically to benefit from climate information because of the link between climatic patterns and production outcomes. This potential has generated hope that seasonal rainfall forecasts may boost food security for highly vulnerable groups in SSA. Forecast interpretation depends on the way people think about climate variability and productivity; how they assess their vulnerability to climate risk; the options and trade-offs they face, and the potential consequences of their decisions.

Scientific forecasts

Seasonal climate forecasts have the potential to significantly bolster climate risk management capabilities in agriculture. This is of particular importance for environments where high climate variability at seasonal and inter-annual scales depresses crop productivity. Prospects of further incorporating probability forecasting over the next decades are good given recent advances in crop and climate models, and improvement in remote sensing technologies and access to spatial environmental databases. However, despite both realised and potential progress in seasonal climate forecasting skills, significant uncertainties remain in relation to intra-seasonal rainfall variability.

Regional climate outlook forums (COFs) are an important means through which seasonal climate forecasting is developed in Africa. COFs are held on an annual or biannual basis and in advance of the rainy season, with the forecast developed for a 90-day climate window at national or regional scales. The forecasts are expressed in terms of probability, reflecting the likelihood of below-normal, normal or above-normal rainfall. The Southern Africa Regional COF held in 1997-98 was the first regional COF. There were 12 participating countries. Subsequent COFs have been developed for other regions in Africa.

The timely dissemination of accurate climate forecasts has the potential to improve climate risk management on a seasonal basis through mitigating risk during unfavorable seasons, and generating benefits during optimal seasons. Seasonal climate forecasts contribute to foundations for adaptation through:

- Coordination of formal and informal institutions around a central task
- Building communication structures to support forecast dissemination
- Educating the public about forecasts and climate risk
- Better management of seasonal climate variability risk
- Empowering rural communities through participation in forecasting workshops

The capacity of end-users such as agricultural extension workers, farmers, non-governmental organisations and policy makers to understand and respond to seasonal climate forecasts is low. However, work in Zimbabwe (Patt *et al.*, 2005), Mali (Hellmuth *et al.*, 2007), Nigeria (Isaac *et al.*, 2009) and Burkina Faso (Roncoli *et al.*, 2008) has shown that efforts to translate and localise the information can influence farmers' decision-making processes. However, results from a paper by Luseno *et al.* (2003), in Ethiopia and Kenya show the contrary. COFs as vehicles for seasonal forecast dissemination to smallholder farmers are inadequate. The main reasons for this are:

- Forecasts are not specific enough to the needs of end users. This includes issues of poor spatial resolution and response to local scale agricultural decision-making needs, and a lack of information on intra-seasonal rainfall distribution (Archer *et al.*, 2007).
- Poor interpretation and communication of forecasts, which leads to misunderstanding and low dissemination rates.
- Farmers' inability to respond to forecasts due to their lack of access to seed, implements, fertiliser, labour and credit, which would allow them to make adjustments in relation to the expected seasonal climate.

One way to enhance access to climate information is through the use of participatory farmer workshops designed to help farmers better understand and use seasonal forecasts. These workshops can improve trust and credibility of forecasts among local people and provide an opportunity for farmers to experience repeated exposure to, and familiarity with, the concepts behind probability forecasting. This will allow better comprehension of what forecasts can and cannot do. Further, farmers can use their indigenous forecasting methods to compliment scientific forecasts.

Indigenous local forecasting knowledge

Indigenous or local predictions provide clues about aspects of climate that are most salient for farmers, and about the kinds of climate information farmers seek to mitigate agricultural risk. At the same time, they can help enhance the relevance of scientific forecasts by integrating them with locally specific observations. Ethnographic and participatory methods have been deployed to identify local sources and indicators of climate prediction used by farmers.

Farmers' seasonal forecasts offer an alternative to scientific forecasts. Environmental indicators that farmers use to predict the coming season become available for observation at different times of the year, beginning immediately after harvest and continuing into the new season. The indicators farmers mostly rely on include fruit production of certain trees, temperature during the dry season, intensity and distribution of winds, and behaviour of birds and insects throughout the year.

Farmers' forecasts diverge from scientific ones in important ways, especially in regards to the parameters and scales they address. Local forecasts focus on rainfall characteristics relevant to farmers such as the time of onset, duration and distribution (Roncoli *et al.*, 2003). Farmers' forecasts concentrate on number, type and timing of rainfall rather than total quantity, which is key in scientific forecasting. Currently, scientific forecasting is unable to predict duration, amount or distribution of rainfall. Hence, integration of scientific knowledge with local knowledge might allow some inferences in this regard. Farmer forecasts address local rather than regional scale crop-climate interactions; and local farmers recognise that rainfall patterns have different impacts on each crop depending on when and how they occur. Therefore, combining the knowledge of local resource-dependent people with evidence provided by formal climatology analysis, holds the potential to reduce uncertainty and increase the relevance of future assessments of vulnerability and climate change adaptation.

However, IKS face some risks. As the world warms, traditional weather indicators may become less and less valuable. Individual species will adapt to local climatic impacts in idiosyncratic and unpredictable ways. Animals may change their behaviour or their range, while plants may begin flowering at different times. These changes will make traditional knowledge less reliable. Whether this is already happening, and in what direction, needs to be documented.

V **A herd of cattle, Mali.**

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Indigenous and traditional peoples develop adaptation measures based on their own observations and interpretation of climate variability and change. Their own observations and weather forecasting systems in future may become less meaningful, affecting their decisions. This is due to more rapid and complex global change. Facilitating access to scientific knowledge and technologies such as early warning systems may help decrease indigenous peoples' vulnerability to change.

Given the significant gaps in scientific knowledge, ethno-meteorological knowledge plays a key role in farmers' ability to devise climate variability and update adaptation measures. There is evidence to show that farmers have a natural inclination towards reliance on indigenous forecasts as opposed to scientific forecasts, because they value their own experiences above scientific data (Kolawole *et al.*, 2014; Roudier *et al.*, 2012). Farmers rely on historical patterns, weather observations and signs to formulate their own expectations on weather and climate (Orlove *et al.*, 2010).

IK indicators of seasonal forecasting

The diversified nature of rural livelihoods, farmers' knowledge sources, and their needs, are likely to encompass a mix of parameters which may be significant for different types of producers and production systems. Field research targeting African farmers shows that they do not generally use a single forecasting indicator, rather, they consider signs, indicators and chaos that arise at various times and in multiple settings (Roncoli, 2002; Luseno *et al.*, 2003). The significance of forecast indicators also varies for different crop activities.

Early warning systems have proved to be indispensable in preparing for climate events such as the onset of rainfall, floods, cyclones and droughts. In West Africa, Tall *et al.* (2008) and Braman *et al.* (2013) demonstrate how seasonal rainfall forecast information is used to reduce the loss of lives, property and infrastructure caused by floods.

The knowledge of indigenous peoples should be included when designing climate change adaptation strategies in SSA. Local communities and farmers have developed a new knowledge base for predicting climatic and weather events based on observations of animals, plants and oceanic bodies (Roncoli *et al.*, 2003). Understanding how local communities perceive and predict rainfall variability is key to communicating scientific weather forecasts. To predict the future, indigenous people rely on traditional divines and prophesies using Christian and Islamic scriptures as well as spiritual rituals for rainmaking.

Indicators used by farmers to predict the quality of the rainy season are available throughout the year (Roncoli *et al.* 2009). Just like scientific forecasts, indigenous forecasts rely on observation and interpretation of specific phenomena. The indicators farmers mostly rely on include fruit production and tree phenology, animal behaviour, wind and atmospheric phenomena, and spiritual manifestations in the form of divinations, visions and dreams. Elderly male farmers generally have more knowledge than younger male and female farmers. However, indicators are usually gender specific, with men relying more on certain indicators than women, and vice versa.

Flower and fruit production of local trees

Most local trees that farmers use to forecast rainfall begin flowering before the onset of the rainy season. The phenology of these trees signals good rainfall or drought (Table 1). The variation of fruit or flower production also influences farmers' expectations. The abundance of fruits on one side of a tree, for example, may indicate in which area the rains will come first. Trees which are located near houses or fields and are observed over a long period are normally used to predict rainfall.

Astronomy, star and moon movements

There is a strong relationship between astronomy and rainfall (Table 2). The visible phases of the moon are associated with rainfall, drought or a dry spell. The full moon is expected to indicate dry weather. Star constellations and the time of their appearance indicate rainfall patterns and hence, when farmers should plant their crops. Changes in the appearances of stars and the moon provide a framework of sequences for expected rain events and mark key points in relation to cropping calendars.

Temperatures and winds

During the year and within seasons, farmers expect natural phenomena such as temperature, winds, clouds and rain to conform to certain patterns that they define as the norm (Roncoli *et al.*, 2009). The beginning of the cold season and its end follow certain rainfall patterns. Increasing hot temperatures indicate a good rainy season (Isaac *et al.*, 2009), whilst violent winds during the dry season may predict a bad rainy season. The direction of winds is also associated with particular rainfall patterns (Table 2).

Table 1: Indigenous indicators for weather and climate in SSA – tree phenology

Indicator	Country	Significance	Reference
Onset of the rains			
Flowering of the peach tree (*Prunus persica*), apricot (*Prunus armeniaca*), budding of acacia species	Botswana Zimbabwe South Africa Tanzania Mali Nigeria	Beginning of rainy season	Kolawole *et al.*, 2014; Risiro et al., 2012; Mapfumo *et al.*, 2015; Zuma-Netshiukhwi *et al.*, 2013; Kangalawe *et al.*, 2011; Elia *et al.*, 2014; Kiptot, 2007;
Flowering coffee, delonix (*Christmas*) and mango trees; and other trees	Uganda Tanzania Kenya Burkina Faso	Rains are not far	Orlove *et al.*, 2010; Kangalawe *et al.*, 2011; Elia *et al.* 2014; Roudier *et al.*, 2012; Roncoli *et al.*, 2002;
Season quality			
Behaviour of certain plants: sprouting of Aloe ferox; germination of new leaves on baobab and tamarind trees	Ethiopia South Africa Zimbabwe Zambia Burkina Faso	Indication of good rains	Saitabau 2014; Speranza *et al.*, 2009; Zuma-Netshiukhwi *et al.*, 2013;
Mango tree (*Mangifera indica*)	Tanzania Zimbabwe Burkina Faso	Heavy flowering of the mango trees indicates a potential drought season	Kijazi *et al.*, 2013; Elia *et al.*, 2014; Roncoli *et al.*, 2002;
Muchakata tree (*Parinari curatellifolia*), gan'acha tree (*Lannea discolor*), mushuku tree (*Uapaca kirkiana*)	Zimbabwe Mali Nigeria	Heavy flowering of the trees indicates a potential drought season	Muguti and Maposa, 2012; Risiro *et al.*, 2012;
Dormancy breaking in certain trees species e.g. mupfuti (*Brachystegia boehmii*)	Zimbabwe	Indicates plenty of rain in a few days	Muguti and Maposa, 2012;
Profuse fruiting of certain tree species	Burkina Faso Ethiopia Kenya Nigeria	More fruiting of certain trees indicates a challenging rainy season ahead	Roncoli *et al.*, 2002; Kiptot, 2007; Davis, 2010;

Animal behaviour

The behaviour of animals such as livestock, birds, insects and amphibians is also used by farmers to predict the onset of the rainy season. The songs and movements of different birds to signal the onset of rains has been reported in Ethiopia, Mali, Nigeria, Swaziland, Tanzania and Zimbabwe, among other countries in SSA (Table 3). Farmers predict the amount of rainfall depending on whether the bird is singing with happiness or not.

When the bird sings with a clear, sharp voice it means the bird is happy and indicates to farmers that a lot of rain that will fall, and vice versa (Luseno *et al.*, 2003).

Table 2: Indigenous indicators for weather and climate in SSA – atmospheric circulation

Indicator	Country	Significance	Reference
Onset of the rains			
Moon phases	Uganda South Africa Zimbabwe Kenya, Mali Burkina Faso	Moon crescent facing upwards indicates upholding water and when facing downwards is releasing water in the next 3 days	Zuma-Netshiukhwi *et al.*, 2013; Shoko and Shoko, 2013; Roncoli *et al.*, 2002;
Star constellation	Zimbabwe South Africa Burkina Faso Botswana	Star pattern and movement from west to east at night under clear skies means rain will fall in 3 days	Shoko and Shoko, 2013; Zuma-Netshiukhwi *et al.*, 2013; Roncoli *et al.*, 2002;
Winds movement	Uganda Zimbabwe South Africa Burkina Faso Kenya Nigeria Botswana Ethiopia	Winds moving from west to east indicate onset of the rain season	Okonya *et al.*, 2013; Kiptot, 2007; Davis, 2010; Roncoli *et al.*, 2002; Zuma-Netshiukhwi *et al.*, 2013;
Season quality			
Moon profuse halo	Uganda South Africa Zimbabwe Kenya, Mali Burkina Faso	Good rains Disposition of the new moon indicates more disease and erratic rainfall	Zuma-Netshiukhwi *et al.*, 2013; Kijazi *et al.*, 2013; Elia *et al.*, 2014; Shoko and Shoko, 2013; Risiro *et al.*, 2012;
Wind swirls	Zimbabwe South Africa Uganda Mali	Frequent appearance is a sign of good rains	Muguti and Maposa, 2012; Zuma-Netshiukhwi *et al.*, 2013; Risiro *et al.*, 2012;
Mist-covered mountains	South Africa	Signal of good rains	Muguti and Maposa, 2012; Risiro *et al.*, 2012;
Temperature	Tanzania Zimbabwe Burkina Faso Uganda Kenya Nigeria	Heat in low areas in August indicate there will be more rainfall in the coming season; high temperature in October and November signifies near onset and a good rain season	Kijazi *et al.*, 2013; Elia *et al.*, 2014; Shoko and Shoko, 2013; Risiro *et al.*, 2012;
Strong winds	Tanzania Ethiopia Mali	Strong winds in the July through October indicates less rainfall in the coming season	Kijazi *et al.*, 2013; Elia *et al.*, 2014;
Appearance of many nimbus clouds; appearance of red clouds in the morning	Uganda Zimbabwe	Indicators for rain in 1-3 days	Okonya *et al.*, 2013; Risiro *et al.*, 2012;
Appearance of fog/haze in the morning	Uganda Zimbabwe Kenya Ethiopia Botswana Nigeria	Indicator for no rain	Okonya *et al.*, 2013; Risiro *et al.*, 2012;

Table 3: Indigenous indicators for weather and climate in SSA – animal behaviour

Indicator	Country	Significance	Reference
Onset of the rains			
Appearance of red ants, rapidly increasing size of anthills	South Africa Zimbabwe	Good rains are coming	Zuma-Netshiukhwi *et al.*, 2013; Risiro *et al.*, 2012;
First appearance of sparrows; flock of swallows preceding dark clouds	South Africa Tanzania Uganda Zimbabwe Nigeria Mali	Rain is at hand and farmers should prepare for above normal rains	Orlove *et al.*, 2010; Kangalawe *et al.*, 2011; Elia *et al.* 2014; Roudier *et al.*, 2012; Roncoli *et al.*, 2002;
Appearance of certain birds e.g. stock Singing, nesting and chirping of certain birds	Uganda Tanzania Zimbabwe Burkina Faso Botswana Nigeria Mali Ethiopia	Rain is at hand and farmers should prepare for above normal rains	Kangalawe *et al.*, 2011; Orlove *et al.*, 2010; Elia *et al.*, 2014; Okonya *et al.*, 2013; Muguti and Maposa, 2012; Risiro *et al.*, 2012; Roncoli *et al.*, 2003; Roudier, 2012; Kolawole *et al.*, 2014;
Termite appearance (*Ancistrotermes spp*)	Tanzania Uganda Zimbabwe	Appearance of many termites indicate near rainfall onset	Kijazi et al., 2013; Elia et al., 2014; Okonya *et al.*, 2013; Muguti and Maposa, 2012;
Bee eater (*Merops hirundineus*)	Tanzania Nigeria Mali Botswana	Appearance in October indicate imminent rainfall and/or onset	Kijazi *et al.*, 2013; Elia *et al.*, 2014;
Frogs in swampy areas croaking at night	Uganda Zimbabwe	Indicator for onset of rains	Okonya *et al.*, 2013; Muguti and Maposa, 2012;
Rock rabbit	Zimbabwe	Its unusual squeaking indicates imminent rainfall	Muguti and Maposa, 2012; Risiro *et al.*, 2012;
Cicadas (nyenze), day flying chafers (mandere), dragon flies (mikonikoni)	Zimbabwe	Appearance of these signifies imminent rainfall	Muguti and Maposa, 2012; Risiro *et al.*, 2012;
Season quality			
Grunting pigs indicate low humidity	South Africa	Rains are near	Zuma-Netshiukhwi *et al.*, 2013;
Calves jumping happily	Uganda South Africa	Good rain season	Okonya *et al.*, 2013; Zuma-Netshiukhwi *et al.*, 2013;
Certain snakes moving down the mountain	South Africa	Good rain season	Zuma-Netshiukhwi *et al.*, 2013;

Indicator	Country	Significance	Reference
Frequent appearance of tortoises	South Africa	Good rain season	Zuma-Netshiukhwi *et al.*, 2013;
Appearance of certain insects e.g. millipedes, spiders	Tanzania Zimbabwe Burkina Faso	Indicates coming of heavy rains	Kangalawe *et al.*, 2011; Elia *et al.*, 2014; Risiro *et al.*, 2012; Mapfumo *et al.*, 2015; Roncoli *et al.*, 2002;
Butterfly movement from west to east	Tanzania Burkina Faso	Rainfall is approaching	Kangalawe *et al.*, 2011; Elia *et al.*, 2014;
Armyworms (*Spodoptera exempta*)	Tanzania Burkina Faso Zimbabwe	Appearance of army worms on trees during the month of October signifies abundant rainfall in the coming season	Kijazi *et al.*, 2013; Elia *et al.*, 2014;
Grass hopper (*Hesperotettix speciosus*)	Tanzania Zimbabwe Uganda	Occurrence of more grasshoppers indicate less rainfall and hunger	Kijazi *et al.*, 2013; Elia *et al.*, 2014
Scorpion (*Arachnida spp*)	Tanzania Burkina Faso	When black or dark scorpions are seen in the month of October it indicates possibility of a good rainy season	Kijazi *et al.*, 2013; Elia *et al.*, 2014
Cattle egret birds (*Bubulcus ibis*)	Tanzania Burkina Faso Ethiopia	Occurrence of these birds in October indicates onset of rains and a good rain season	Kijazi *et al.*, 2013; Elia *et al.*, 2014;
Coucal bird (*Centropus spp*)		Singing of these birds early in the morning in October indicates the onset of the rains and a good rainy season	Okonya *et al.*, 2013;
Pangolin (*scaly ant-eaters*)	Tanzania Burkina Faso Zimbabwe	Appearance indicates imminent rainfall occurrence	Kijazi *et al.*, 2013; Elia *et al.*, 2014;

Other indigenous indicators

Table 4: Other indigenous indicators for weather and climate in SSA

Indicator	Country	Significance	Reference
Body feels increased or excessive heat during the night and day; a feeling of body pain (headache, flu, backaches)	Uganda Burkina Faso Mali Kenya Zimbabwe Nigeria	Indicator for rain in 1-3 days	Okonya *et al.*, 2013; Risiro *et al.*, 2012;
Asthmatic attack, increased pain from past body wounds e.g. from surgical operations	Zimbabwe South Africa Nigeria	Imminent cold weather and humid conditions	Risiro *et al.*, 2012
High water levels in water bodies	Burkina Faso Uganda Ethiopia Kenya	Maintenance of high water levels in water bodies after the first rains indicate a good rain season ahead	Roncoli *et al.*, 2002

Integrating IK forecast and scientific forecasts

The challenges caused by global climate change and extreme weather events are beyond the local experiences of knowledge holders, whether scientific or indigenous (Huntington *et al.*, 2005). Effective adaptation to climate change requires the best knowledge, regardless of the source. Given the high risks of climate change and the associated impacts, there is urgent need for policies and actions that foster the co-production of new knowledge. Such knowledge is based on collaborative research and regards community knowledge holders, natural and social scientists. Armitage *et al.* (2011) define knowledge co-production as "the collaborative process of bringing a plurality of knowledge sources and types together to address a defined problem and build an integrated or systems oriented understanding of the problem."

The previous section on indigenous and scientific seasonal forecasts emphasised both the potential value and the pitfalls of both IK forecasting and scientific forecasting methods. There is the potential for scientific and indigenous forecasts to play complementary roles in improving seasonal forecast use and decision-making (Table 5).

These cross-scale and cross-cultural methodologies provide impartiality for adaptation to climate change on the ground (Berkes, 2012). In the Arctic, remote sensing and other scientific methods such as meteorology and

Table 5: Complementarity between science and traditional seasonal climate forecasts (adapted from Moller *et al.*, 2004)

Principle	Explanation
Diachronic vs systematic complementarity	Science collects dynamic data in a time series over a large area e.g. the use of COFs in Africa. IKS focus on diachronic data and long term series' in small areas e.g. the use of indigenous indicators of forecasting in African villages or districts.
Focus on averages vs extremes	Science is based on the numerical data analysis of averages. IKS observe extreme weather events and unusual patterns, which is critical in climate change adaptation.
Quantitative vs qualitative information	Science demands quantitative data. IKS demand qualitative understanding of the system. Understanding complex systems like climate change requires both. Qualitative measures are rapid and inexpensive but they lack precision.
Hypothesis vs mechanisms	IKS rely on hypotheses for problem solving. Science has powerful tools to explain the reasons for mechanisms. The use of both IKS and science takes advantage of their relative strengths.
Objectivity vs subjectivity	Science is objective and excludes people's feelings. IKS include people's feelings, relationships and sacredness. The combination of both methods produces science with a heart.

modeling are being used with IK of Sanic and Nerdic reindeer herders to co-produce data series for improved decision making, herd management and adaptation strategies (Maynard *et al.*, 2005). In Africa, rainmakers in the Nganyi communities of western Kenya (Ogallo, 2010) and farmers in the Messa village of southern Malawi (Kalanda-Joshua *et al.*, 2011), collaborate with meteorological scientists to produce integrated forecasts that are being disseminated by both indigenous and conventional methods to enhance community resilience. In Tanzania, to predict whether a season will have good rainfall or early rains, farmers use a combination of local indicators such as the flowering of peaches and plums, and the appearance of swarms of butterflies, frogs, ants and grasshoppers. Meteorological forecasts were similar to indigenous forecasts for the 2012 season.

These studies suggest that farmers' trust and willingness to pay for scientific forecasts is increased when local, traditional methods of forecasting are combined with modern scientific methods. As such, scientific forecasting may be able to compliment indigenous forecasting to help mitigate the loss of traditional weather and climate indicators. These results, which point to the beneficial association of indigenous and scientific observation systems, may provide insights for climate change effects.

The emergence of adaptive management or ecosystem-based management to climate change impacts through learning-by-doing methods of understanding ecosystems, may be considered an indirect acknowledgement of the similarities between IKS management and scientific management. However, there are incidences where indigenous forecasts have contradicted meteorological assertions. Marin (2010) concluded that the indigenous observations of nomadic pastoralists in Mongolia were divergent and contradictory of meteorological records and predictions. Similar observations were made by Gearheard *et al.* (2011) in the Arctic. These studies offer interesting insights into the value of both indigenous and scientific knowledge. Even when indigenous people and scientists observe the same phenomenon in the same environment, the nature of their observations may differ quite profoundly (Nicholas *et al.*, 2010; Tables 1, 2, 3 and 4).

The conclusions of indigenous observations are based on multiple environmental and social factors that they consider in an integrated manner e.g. rainfall patterns, wind speed, wind direction and the variability of temperature (Tables 1, 2, 3 and 4). In contrast, scientists may use a range of parameters e.g. temperature, wind speed or rainfall, but base their conclusions on the extrapolation of data from a narrow data set (Gearheard *et al.*, 2010). In this sense, comparing indigenous and scientific knowledge of a phenomenon may amount to comparing mangoes and pawpaw.

These studies also illustrate the inherent difficulties of corroborating the observations of indigenous people with scientists. Faced with the challenges of climate change and numerous unknowns ahead, efforts to create a constructive dialogue between indigenous people and scientists constitutes an important step towards decision-making based on the best knowledge available. The integration of scientific knowledge with IKS methods of seasonal forecasting is needed to increase the utility of knowledge in managing climate change adaptation. IKS alone cannot solve all the problems of climate change. The problems of ecological scale and consequent difficulties in sampling and experimentation limit the predicting power of science, and there is growing evidence that conventional scientific approaches may be insufficient in the face of climate change complexity. Problems of complex adaptive capacity involving people cannot be separated from issues of value, equality and social justice – they require participatory approaches where scientists and local people work together (Participatory Extension Approaches, 2010).

V **A Maasai tribesman cutting bark off a mkunde kunde tree.**

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The reduction of experimentation complexities to a few simple rules of thumb can produce remarkably robust outcomes (Gadgil *et al.*, 1993). Complex problems, such as those occasioned by climate change, can be addressed to some extent by a few simple and often intuitive decision-making rules (Mackinson, 2001).

Cultural and spiritual significance in indigenous forecasting

The role of the chief and other traditional stakeholders in indigenous forecasting remains important for smallholder farmers. Farmers have confidence in and act upon advice provided by the chief as it is believed that the chief and the elders of the community, including ritual specialists, have connections with spiritual beings who give instructions in line with the approaching season (Kolawole *et al.*, 2014; Roncoli *et al.*, 2005; Roudier *et al.*, 2014). The advice that the chief gives can include the specific crops and crop varieties to be grown within a season. But there is evidence to show that the major predictions of community elders mainly concern the onset of rains, with their estimations ranging from days to weeks (Roudier *et al.*, 2014). Orlove *et al.* (2010) highlight that there is in fact a strong connection between a belief in God and spirits and a reliance on IK. Smallholder farmers take indigenous forecasting into account because they believe that rain has a cultural and religious significance; scant rainfall therefore symbolises that God and the spirits are displeased with the community and the inverse is true for abundant rains.

Cosmology in turmoil: what went wrong with the indigenes on rituals and indicators?

Whilst individuals from the elderly generation still believe IKS represent a good source of climatic information for adaptation and disaster preparedness, challenges emanate from the inter-generational gap with the youth. For example, regarding indicators like birds, the youth question the symbolic relationship between birds' songs and the coming of rains. Their doubts are driven by a number of factors. Birds like *dendera* (*Bucorvus leadbeateri*, southern ground hornbill) and *kohwera* (*Cuculus canorus*, rain bird) are rarely heard making any sounds, even just prior to rainfall. The youth argue that perhaps these birds have already adapted to the severe climate variability (IPCC, 2007). There are also times when the birds are heard making calls when there is no sign of rainfall. This, therefore, strengthens the argument of youths that signals which were reliable traditionally, are undergoing serious change. These confused signals increase youths' doubts in birds as reliable climate indicators. In contrast, the elderly confidently praise birds as reliable indicators, yet the results on the ground are not satisfactory to all smallholder farmers.

Another noted aspect is that numbers of these symbolic birds has drastically reduced. Competition over finite natural resources like land, forests and water is increasing and hence, the birds' habitat options are depleting. Such disturbances on ecosystems and biodiversity pose severe threats to IKS indicators. With time, the value of ethno-metrological indicators will disappear. This is exacerbated by the fact that the educated younger generation are vouching for science in seasonal planning and reacting to climate change, and therefore don't see the need to conserve certain types of birds or naturals resources for seasonal and weather information.

IKS and climate change adaptation

IKS greatly contribute to climate science by providing observations from a much lower spatial scale than scientific methods, with higher temporal depth.

Recognition of the significance of IKS for climate change adaptation, at the international level, has only emerged in the last few years. The fourth assessment of the IPCC (2007) triggered an enhanced focus on climate change adaptation, which was accompanied by increased attention on impacts and responses at the national, subnational and local levels, and on the contribution of IKS.

It is important to note that in the IPCC reports (2001 and 2007), the main emphasis has predominantly been on the theories of indigenous communities from developed countries (Australia, Europe, New Zealand, North America and the Polar regions). However, the majority of indigenous farmers who live in developing countries got little or no such consideration, even from their own governments. Until 2010, observations and assessments by indigenous people and local communities have remained outside the IPCC process due to strict requirements regarding the types of documentation that will be considered.

Challenges to IKS transmission

This chapter has shown considerable potential for IKS to contribute to climate change adaptation strategies in SSA. However, it must be noted that IKS in SSA are rapidly eroding and being lost. This is mainly attributed to the interruption of intergenerational knowledge transmission. The factors that contribute to this are the absence of IKS in formal school curricula, globalisation (integration of SSA within the global economy), internal and external migration to urban cities, and relatively easy access to imported food and popular culture (Adger *et al.*, 2011).

Bridges and McClatchey (2009) attribute the erosion of IKS to the widespread abandonment of oral record keeping in the forms of dance and song, which are able to codify complex pieces of information and successfully transfer them across multiple generations. This breach in intergenerational traditional knowledge transmission needs immediate attention.

Other factors contributing to the gradual loss of IKS in SSA include the dominant uptake of the English language; the dissent of youths towards traditional ecological knowledge; and the replacement of many traditional agricultural production strategies and food culture with western processed foods.

Children can learn traditional knowledge at a very young age and from this, they are able to develop the skills of indigenous people in weather forecasting, food preservation and risk reduction strategies. Blending IKS with modern science will allow development of hybrid skills. An education system that rejects traditional knowledge is one that produces a generation ignorant to their historical roots.

In many countries formal education contributes to the erosion of IK. Schooling removes children from the family and community setting, and presents children with external values that may clash with or undermine traditional teachings. This loss of IKS and IK language reduces the social capital of younger generations. Policies that promote 'brothering' education and nurturing IKS and IK language alongside mainstream education, will provide generations with sources of innovation to strengthen community resilience in the face of change.

Conclusion

Indigenous people and rural communities are vulnerable to the impacts of climate change and have low adaptive capacity. They depend almost exclusively on the climate-sensitive resources of their environment for their livelihoods. By engaging with their natural environment on a day-to-day basis, indigenous communities have accumulated bodies of knowledge regarding its variability. This knowledge can be of societal benefit, providing important insights into the process of climate variability adaptation.

These communities have developed a wide variety of technical, social and economic responses that constitute the basis of their resilience in the face of climate change. A strong case can be made for revamping indigenous resilience as a basis for indigenous adaptation.

Government policies and activities need to be formulated on the basis of multidisciplinary action research that brings together IK holders and scientists (both natural and social), to build a mutual understanding and reinforce the need for change. Recent work on IKS provides new knowledge on responses to climate change challenges. The co-knowledge of IKS and scientific knowledge might be the way forward in countering impacts of climate change.

Facets of IKS such as their social nature, practicability and dynamism, provide scores of information at spatial and temporal scales that could provide scientists and meteorologists with useful information to support the production and dissemination of reliable forecasts. Scientists can produce meta-predictions at a large scale, whilst IKS specialise in location-specific prediction.

Future research and needs

Traditional societies in many places in Africa, and worldwide, have built knowledge over time about changes in their environment. They have developed elaborate and sophisticated strategies, practices and technologies to cope with changes and challenges. However, IKS in climate change adaptation and mitigation have been neglected in climate change observation, planning, implementation, monitoring and evaluation, and policy formulation, and have not been taken up in the climate change discourse. Traditional and indigenous people who have survived many kinds of environmental changes, including climate change, have valuable lessons to offer about successful and unsuccessful adaptation strategies. The following have been identified as key future research needs:

- Investigate the synergies and trade-offs between various traditional and new indigenous adaptation and mitigation measures.
- Explore the economic and social costs and benefits of these adaptation measures.
- Mainstream IKS into primary, secondary and tertiary education systems.
- Identify local predictors, what they predict, and the equivalent in meteorological terms.
- Determine whether such indicators are triggered by climate change.
- Integrate IKS into climate change observation using GIS (geographic information system) and mapping tools.
- Identify the major causes of IKS erosion and the key areas to conserve.
- Investigate how best to triangulate scientific and IK with development processes of climate change adaptation and mitigation strategies.
- Understand the scientific mechanisms behind indigenous indicators for seasonal forecasting.
- Calibrate indigenous indicators for seasonal forecasting with quantitative data e.g. rainfall amount.
- Determine which indigenous indicators are resilient in the face of rapid and complex climate change.
- Promote collaboration of research and action between IK holders and scientists.

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CHAPTER 4 - Indigenous-based climate science from the Zimbabwean experience: From impact identification, mitigation and adaptation

N. Chanza and P.L. Mafongoya

Abstract

The boundaries of science in climate change are increasingly being perforated to incorporate indigenous ways of understanding the phenomenon and responding to climatic events. This paradigm is stemming from the acknowledgement of both the growing threats of climate change and the value that indigenous science has for impact identification, mitigation and adaptation. Critical in this development is the understanding that climate change effects – noticeable in extreme weather and climatic events, such as violent storms, floods and droughts – pose serious risks, particularly to poor indigenous communities. The paradox of these phenomena in Africa is that the communities most vulnerable to climatic events have a very minimal contribution to the anthropogenic greenhouse gases (GHGs), largely blamed for destabilising the global climate system. Of particular note, is the fact that indigenous people are trapped as innocent victims of climate change, since their contribution to the anthropogenic causes behind global climate disturbances is very insignificant. For indigenous Africans, their religious attention to environmental management principles, shaped by their indigenous knowledge systems (IKS), is what has perpetuated their livelihoods. The fear however, is that indigenous people's resilience and adaptive capacities to these environmental shocks are increasingly being eroded. This situation is exacerbated by both the disregarding of IKS in mainstream development planning, and the importation of extraneous development interventions that ignore co-values and indigenous philosophies of surviving in a changing environment. In order to advance this discourse on climate science, this chapter draws

heavily on scholarly work on IKS that is relevant to climate change in Zimbabwe. It argues that indigenous communities, which have long-existed by relying on climate-sensitive and ecosystem-based livelihoods, are highly attentive to environmental change and variability. As such, they are not passive observers of the climate system. Their knowledge, survival strategies, experimentations, technologies and practices can be exploited by development organisations for a range of purposes, from enhancing impact identification and disaster risk reduction to framing successful climate adaptation and mitigation strategies.

Introduction

In its quest to adequately understand climate change, and in seeking solutions to the problem, the climate science knowledge community is now increasingly drawing on the lived experiences of indigenous communities, who are witnessing changes in their climate system. In particular, the latest fifth assessment reports by the Intergovernmental Panel on Climate Change (IPCC), include the topic of indigenous knowledge (IK) in producing more effective solutions to deal with the effects of climate change (IPCC, 2014a; b). The IPCC is a global think tank that gives credible information on the science of climate change. It defines climate change as: "A change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties that persists for an extended period,

V A seed physiologist inspects an eucalyptus plant in the quarantine room at the Forestry Commission head office in Harare.

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typically decades or longer. Scientific evidence projects that the effects of climate change, particularly on developing countries, will worsen (World Bank, 2013; IPCC, 2014a; FAO, 2016).

Alongside this acknowledgement, IK is now an increasingly sought after concept, both to enhance understanding of climate change and for developing mitigation and adaptation strategies that are pragmatic for indigenous people. Chanza (2014) coined a climate-based definition of IK as the collection of knowledge, skills, technologies and practices of local indigenous populations, which they have developed from observing and experiencing changes in climatic phenomena. He argues that this concept creates some space for the recognition of IK at the front of climate science, against a backdrop of the common dismissal of this knowledge form as archaic, rudimentary, primitive and unscientific. Arguments for the incorporation of IK in climate change discourses also stem from the realisation that indigenous communities tend to be vulnerable victims of extreme climatic events (Boko *et al.*, 2007; Nyong *et al.*, 2007), yet they have a minimal contribution to climatic destabilisation (IUCN, 2008). Accordingly, Chanza and de Wit (2016) advocate that climate governance as a concept, to embrace inclusivity in designing mitigation and adaptation strategies by all climate stakeholders, should include indigenous communities that are affected by climate change. Other scholars, like King *et al.* (2008), Peloquin and Berkes (2009), Turner and Clifton (2009) and Green *et al.* (2010), are of the view that communities that have long-existed by relying on climate-sensitive and ecosystem-based livelihoods are highly attentive to environmental change and variability.

This chapter is justified in reflecting on the Zimbabwean situation using an empirical analysis of the knowledge that should inform the upscaling of climate resilient solutions, particularly among indigenous farmers whose livelihoods are highly sensitive to climatic vagaries. The primary reasons for this focus relate both to the country's risk and vulnerability to climate change and the value given to IK in Zimbabwe. Zimbabwe is one of the countries highly vulnerable to climate change (IPCC, 2014b; GoZ, 2015), the depletion in the volume of water in major reservoirs and the increased desiccation of wetlands, are largely blamed on climate change (Unganai and Murwira, 2010; GoZ, 2015). In the 2015/16 agricultural season, the country experienced devastating El Niño induced drought, which had disastrous consequences that left over 33% of the population lacking food security. The hardest hit victims of the drought were the rural communities, constituting 67% of the country's population (ZIMSTAT, 2013) and largely consisting of subsistence farmers relying on rain-fed agriculture.

The effects of climate change are also noticeable in other sectors, such as energy (e.g., low water volumes in Kariba Dam, which is a major source of hydro-electrical energy), health (owing to the increased geographic spread of vectors and pathogens) and human settlements (where an increased frequency of floods pose a serious risk to low lying communities). Essentially, in this discussion, it is important to understand the paucity of knowledge in impact identification and climate policy responses. Adaptation gaps in the country's response system are raised by Chanza *et al.* (2015). Against this background, most researchers and policymakers are developing an interest in tapping into the experiences of local people, their knowledge and practices, to frame climatic activities and strategies. However, it is disturbing to learn that IK practices in Zimbabwe, and indeed in many parts of the African continent, have largely remained as undocumented paraphernalia. The implications of this development have been raised by Odora-Hoppers (2002) and Chanza and de Wit (2013), as leading to a natural erosion of IK systems (IKS), with serious insinuations for the capacity of African communities to cope with climate change (Chanza, 2015).

Drawing heavily on the Zimbabwean experience, this chapter is a collection of indigenous ways of understanding and responding to climate change, with a view of climate-proofing the communities at risk. It documents knowledge related to impact identification and the indigenous ways of predicting weather and climatic phenomena that are mainly used by local farmers. Equally essential to note in this chapter, is the realisation that local communities are not simply passive observers of the changes happening in their environment, but responsive actors, employing various ways of coping and adapting to climatic stimuli. A range of IK belief systems and practices that are relevant in climate mitigation, are also documented in this chapter. This collection is informed by a conceptual analysis of the scholarship that addresses the topics of IK and climate change, backed up by an empirical synthesis of cases, and complemented with expert knowledge on the research around the local knowledge that is relevant to climate science.

This introduction section is followed by a conceptualisation of IK and climate change. Ideally, this is intended to ground the discussion within a theoretical focus. The chapter then collects evidence of IK practices that can be useful in identifying the impacts of climate change and how such knowledge is used for predicting weather patterns and climatic trends, particularly by local farmers whose livelihoods are largely climate-dependent. Thereafter, the chapter documents how IK is used in the management of climatic risks and disasters. Attention is given to how the local communities use traditional knowledge to secure their crops and livestock against such hazards as floods, violent storms, droughts and dry spells. Thereafter, the analysis focuses on IK and climate change mitigation. The chapter later discusses the various strands of IK-based adaptation and its potential in enhancing the coping and adaptive capacity of local communities. In conclusion, the discussion highlights some policy directions for tapping into locally-based solutions for climate-proofing farmers and addressing climate change.

Conceptualising IKS and climate change

In this section, an attempt is made to show how the concept of IK has been treated in climate science. Notwithstanding the phenomenal interest in IK in climate change debate and literature, there are continuity challenges faced by the concept that are also discussed here. Evidently, the wave of interest in climate change and IK has gathered momentum. Although the chapter is a collection of evidence of IK's utility from the Zimbabwean experience, cases are also drawn from many other places, both within and outside of Africa, to show the universal application of IK practices.

Definitions and terminologies of IK are heterogeneous. Among the commonly used terms for IK are: local knowledge, IKS, traditional knowledge, traditional ecological knowledge, local people's knowledge, farmer's knowledge etc. Chanza and de Wit (2015) prefer the term indigenous climate knowledge to define this knowledge form as it relates to climate change. This chapter adopts fluidity in the use of these terms. Despite this variety in treatment, scholars agree that this knowledge is developed by local people through studying environmental phenomena and by experimenting with appropriate ideas, practices and strategies for survival (Nyong *et al.*, 2007; Mapara, 2009; Berkes, 2009; Turner and Clifton, 2009; Orlove *et al.*, 2010; Nakashima *et al.*, 2012; Mawere, 2013). Conceptual linkages between IKS and climate change have been given significant attention in studies conducted widely in many countries. Berkes and Jolly (2001) study the adaptive capacity to climate change of the Inuvialuit in the Canadian western Arctic community. Nyong *et al.* (2007) focus on the value of IK in climate change mitigation and adaptation in the African Sahel. Gearheard *et al.* (2009) investigate knowledge and meteorological data to understand changing wind patterns of the Inuit Nunavat in Canada. Thorough examinations of the topics are also carried out by Lefale (2009), whose studies focus on traditional ecological knowledge of weather and climate of the Samoa, a Polynesian community in the South Pacific; Peloquin and Berkes (2009), in dealing with the ecological complexity of hunters in James Bay, Subarctic Canada; and Green *et al.* (2010), through investigating the IK of weather and climate of the Aboriginal and Torres Strait Islanders in Western Australia. In Kwazulu-Natal in South Africa, Jlyane and Ngulube (2012) explored IK applications in weather forecasting. In Zimbabwe, attention to the topic of IK has largely been on its deployment in agriculture and disaster management (for example, Patt and Gwata, 2002; Gwimbi, 2009; Mubaya, 2010), with insignificant attention to IK applications in climate studies. However, attempts to focus IK in climate change science are made by Chanza (2014). This chapter broadly aims to understand the range of IKS applications in climate change, which local farmers have accumulated as solutions to manage food security and for building resilience to climatic shocks.

Evidence of the utility of IK in climate change has been significantly advanced. Nyong *et al.* (2007) show that local knowledge is capable of giving practical solutions for mitigating against and adapting to global change. According to Duerden (2004) this is likely made easier by the fact that the knowledge is well understood by the local people. Berkes (2009) notes that IK builds ecological resilience at the community level, while Bollig and Schulte (1999) point out that oral accounts by the elders can be useful for unearthing evidence of changes in the climate and associated disasters as they are understood by the locals. In a similar view, Salick and Byg (2007) indicate that local people can devise appropriate adaptive mechanisms for coping with climate irregularities since they are keen observers of their changing environment. Chanza (2014) argues that indigenous communities tend to develop more confidence and faith in their own local knowledge practices given the irregularities and inaccessibility of mainstream climate information services in many remote areas of Zimbabwe. Similarly, Patt and Gwata (2002) point out that the situation is worsened by limitations in official climate assessments and the poor dissemination of scientific seasonal forecast information among local farmers.

Despite growing enthusiasm for IKS in climate studies there is still a void in terms of the documentation of empirical evidence of IK's utility.

Consequently, the vulnerability of this knowledge form is indisputable. Threats to the continuation of IK practices largely emanate from the fact that this knowledge system is stored in people's minds and orally transferred. Other factors contributing to the loss in IK are related to population migration and displacement, technology and modernisation (Mapara, 2009; Mawere, 2013), and the failure of mainstream science to treat IK as scientifically legitimate (Chanza and de Wit, 2013). Although the IK-science debate remains highly volatile (Mawere, 2013), the limitations of science's ability to address the growing challenges of climate change are being narrowed by technocrats' work with local communities on climate mitigation and adaptation. In this report, the authors argue that aside from enhancing understandings of climate impacts, promoting the co-creation of farmer-led knowledge can enhance the effectiveness of locally-based climate mitigation and adaptation practices, and help build the resilience of local communities.

IKS' relevance in impact identification

Given their direct interaction with the environment, and their natural resource-based livelihoods, communities in many parts of rural Zimbabwe are keen observers of changes in their environment. Chanza (2014) documents various indicators that are useful for enhancing the proper understanding of climate change impacts at local levels. These include different elements of the climate system, notably, rainfall,

Women harvesting water for household use.

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temperature, wind, cloud, thunderstorms and lightning. In this section, we show that the use of environmental indicators by locals can serve as evidence of the direction and severity of change in the climate system.

Many rural communities also use local languages to understand changes happening in their environment. For instance, attention to seasonal changes is crucial in defining the agricultural livelihoods of farming communities. In Muzarabani, an agro-based rural community in the far north bordering Mozambique, Chanza (2014) documents evidence of a gradual shift towards shorter seasons that is indicated by the crop varieties adopted by the peasant farmers. Before the noted seasonal changes, farmers would grow long season crop varieties that would take up to 6 months to mature. For example, there was a sorghum variety called *Mudyandararama*, whose growth would take 6 full months under rain-fed conditions. Another late season maize variety they planted was called *Machingamvura*. These local Shona names have a deeper meaning that can shed more light on the climatic conditions under which the crops were grown. *Mudyandararama*, when loosely translated relates to the longer time required before the farmer can harvest the crop. *Machingamvura* denotes a crop that should be planted late in February, but is guaranteed to complete its life cycle and give the farmer good yields, provided it receives quality rainfall throughout the season. A normal rainfall season in Zimbabwe is usually experienced from mid-October to April. But in recent year, there is a progressive reduction in the length of growing season, which is punctuated by several dry spells (GoZ, 2015). Many local farmers use rainfall names to understand their climate system and seasons (see Table 1).

The local names used to describe the types of rainfall received and the months that they were expected are good indicators for understanding changes in the volume of rainfall and its distribution throughout the seasons. The first rain, usually received in October, called *bumharutsva*, is meant to clear the ash from the dry season fires. It is also referred to as *bvumiramutondo*, meaning that tree species, such as *Julbernardia globiflora*, start shooting their leaves. Gukurahundi was commonly received in mid-October. The name means that this rainfall type is capable of clearing away chaff from previous harvests, farmers use these rains to start land preparation. *Nhuruka*, usually received in November, used to signal the onset of the proper rainfall season and informed farmers that it was time to plant their crops. *Gumbura* would come later, around February, and was blamed for causing crop damage as most plants have matured by then. In

Table 1: Local rainfall typologies and their climate meanings

Rainfall Name	Period	Description
Bumharutsva	October	First rains for clearing burnt ash
Nhuruka	November	Signify the onset of the proper planting season
Gumbura	February	Devastating rains received late in the season
Tupfunhambuya	April	Light showers towards the end of the season
Mavhurachando	May/June	Usually the last rains marking the beginning of the winter season

(Source: Chanza, 2014)

April, the communities also received light showers called *tupfunhambuya*. In the local language, these showers are said to fall onto grannies while they are scouting the fields for some last produce to give to their grandchildren. Between February and April, locals also isolate *mubvumbi*, which describes rains lasting for several days and significantly filling streams, rivers and dams. In some places, *mubvumbi* would cause floods. The last rain to be received in some places is called *mavhurachando*. This would fall in May or early June, marking the start of the winter season. Through these descriptive names, it is clear that the local farmers relate rainfall to the seasonal calendar, both to forecast and manage the growing season. However, most elderly farmers in rural areas agree that the setting of the rains has changed drastically. For example, *bumharutsva* and *gukurahundi* are no longer definite and distinctive, and the duration of *mubvumbi* is increasingly being shortened, from an average of 10 days to just 3 days in some places. From the villagers account, *nhuruka* may still be seen, but *mavhurachando* is no more (Chanza, 2014).

An assessment of hydrological features, such as rivers, pools, ponds and vleis also serve as a good pointer of climate change in many rural places in Zimbabwe. These changes are variously noted through the desiccation of ponds, wells and vleis, intermittent river and stream flows, alterations in flow regularity and output over time, deeper water tables and diversions in river courses caused by channel flooding and silt deposition. The locals' knowledge about the location of these hydrological features, coupled with their constant study of the features' behaviours in response to aridity and temperature changes, can be useful in understanding how these features are impacted by changes in the climate system. A trend towards the desiccation of these water sources has been noted in some places. There are also changes in hydrological flow regularity. Rivers that used to be perennial have become intermittent. For example, through participatory interactions with respondents in Muzarabani, Chanza (2014) identifies big rivers, such as Musengezi, Hoya and Utete, which have become seasonal. In Musengezi alone, water is now confined to the pools during the dry season. Other rivers, like the Boore, which used to have permanent annual discharges, are now characterised by the disappearance and re-emergence of water along the course of their channels. The desiccation of vleis also affect river and stream flow. This is because the spongy-like nature of wetlands is known to hold water during the rainy season and slowly release it to continuously replenish rivers and streams, even during dry spells.

Given the existing voids in a comprehensive analysis of climate impacts in Zimbabwe, Chanza (2014) argues that IK is capable of filling knowledge gaps and validating current understandings about climate change, particularly at local levels. This view resonates with that of Nakashima *et al.* (2012), who claim that the climate observations of indigenous communities generate knowledge that contributes to climate science by offering detailed interpretations and explanations at a much finer spatial scale. To them, this focused level of analysis by local people has considerable temporal depths beyond the consideration of climate scientists. Evidently, climate impact assessments carried out in consultation with indigenous observers of climatic changes are useful for both refining current understandings of climate change, and giving clear indications of the magnitude of impact on local affected populations. This consideration is crucial in framing appropriate responses for climate adaptation and management of climatic risks and disasters.

IKS used in weather and seasonal forecasts

Many studies of IKS in Zimbabwe show that local weather and climate assessments, predictions and interpretations are carried out by observing a set of environmental variables. Such skills are also developed from studying the behaviour of plants, animals and insects, and through meteorological and astronomical indicators. It should be known here that these forecast indicators are not deployed haphazardly, but as a result of experimentation, a close understanding of nature, and the development of logical reasoning from daily life experiences and verified in an institutional setting, of what Odora-Hoppers (2002) refers to as an 'indigenous academy' of survival.

Chanza (2014) observes that indigenous people in Muzarabani keenly study the life cycle of certain trees and animals, which they use to predict events in the climate system, ranging from temperature and seasonal changes to drought, wind and floods. For example, they believe that if the *munanga* (*Acacia nigrescens*) tree blossoms in early September, then the rainy season should be expected to start earlier. An abundance of termite colonies seen collecting plant biomass into their mounds, the appearance of migratory birds and large numbers of the Christmas beetle (*Anoplognathus* spp.) are all associated with a normal or above normal rainfall season, with the potential to cause flooding in low lying areas. The application of this knowledge is highly valued in Muzarabani and can contribute towards enhancing the community's adaptive capacity, especially against a background of limitations in official climate assessments and the poor dissemination of seasonal forecast information cited by Patt and Gwata (2002).

In studies carried out in the Chimanimani, Mberengwa and Muzarabani districts by Risiro *et al.* (2012), Shoko (2012) and Chanza (2014), the authors noted a variety of biotic indicators used to predict weather changes. Certain plant species, such as *msasa* (*Brachystegia spiciforms*) and *mnondo* (*Julbernardia globiflora*), change their morphology with the season by shedding their leaves in the dry season and developing new leaves just before the setting of the rainy season. An abundance of fruit from certain trees, such as *mazhanje* (*Uapaca kirkiana*), *hacha* (*Parinari curatellifolia*) and *mango* (*Mangifera indica*), is associated with an impending drought. However, the physiological explanation behind this observation varies between communities. In many places, locals have observed that the windy conditions normally experienced prior to the rainfall period shake off flowers and young fruits. For example, elders in Muzarabani explained that these winds have a tendency of dispersing rainy clouds, preventing any rainfall being received. They refer to the winds coming from the east as *chisero chinopepeta mvura*, the meaning of which suggests that the winds dissipate the rain clouds. If the rain is accompanied by these winds it is always associated with violent thunderstorms and lightning (Chanza, 2014). Thus, it can be understood that an abundance of flowers is an adaptation feature to ensure that the trees remain with some fruits after excessive winds, and are better able to withstand the drier season. In Mberengwa district, Shoko (2012) ranked different species according to their significance as indicators in seasonal predictions. The highly ranked species were the ground hornbill, rain cuckoo, termites, cicadas and frogs.

Small animals, such as millipedes and frogs, are mostly seen at the beginning of the rainy season. Through their life long experiences of nature's movements in their community, the locals can predict the average onset dates for rainfall, and a delay in the onset of natural cycles, for them, is indicative of a drier season.

Other widely relied upon indicators are the timing, intensity and duration of periods of low temperatures and wind. Through studying wind patterns, local people in many parts of Zimbabwe have developed useful knowledge of environmental changes related to the frequency, pattern, and duration of wind. In Manicaland Province, the locals associate the start of the rainy season with a cool wind blowing from the eastern Mozambican side. If the wind is continuously blowing, they know that more rains will come (Risiro *et al.*, 2012). In Masvingo Province, Muguti and Maposa (2012) observe that people can predict rainfall patterns from the southern blowing winds. Table 2 reveals four types of winds identified by the locals in Muzarabani, which are useful in understanding the weather system. In many places the northerly flows, for example, are associated with significant rainfall. In the local Shona language, the northern direction is called *maodzanyemba*. Literally this term translates as a direction associated with heavy rains that can damage or spoil crops.

Aside from recording weather, plant and animal behaviour, locals in Zimbabwe also use indigenous astronomy to correlate movements and patterns of stars and planets with changes in weather. The science of weather prediction through studying the stars is well documented (Speranza *et al.*, 2010; Risiro *et al.*, 2012). People can predict weather by observing the visible spectrum, commonly referred to as the halo phenomenon around the sun or moon. If the spectrum around the sun has a greater diameter than that around the moon, rain is predicted to fall in a few days' time. Speranza *et al.* (2010) report that astrological constellations, such as the position of the sun and moon, are also interpreted as indicators for the upcoming season by agropastoralists. The appearance of certain stars in the sky is also used to predict seasons. For instance, the Milky Way changes its position in accordance with the seasons (Risiro *et al.*, 2012; Alvera, 2013). It is also important to report that indigenous people do not limit their knowledge application to understanding the changes happening in their environment. As explained in the next sections, they have devised various methods for promoting food security, mitigating against climate risks and adapting to climatic phenomena.

Table 2: Types and characteristics of winds in Muzarabani

Type	Description
Easterly flows	Dry violent winds from the east, mainly experienced from August to December.
Westerly flows	Often violent winds experienced during the rainy season. If they build in March, they become highly devastating leading to crop damage. They are often blamed for bringing diseases around the same period.
Northerly flows	Relatively calm and moist winds that are mainly associated with good rainfall.
Southerly flows	Triggered predominantly by the giant Mavhuradonha range, these winds can be highly destructive to villages situated along the foot of the mountain.

(Source: Chanza, 2014)

IKS and food security

The greatest climate change threat, particularly in Africa, is to food security systems (World Bank, 2013; FAO 2016). FAO (2016) states that by 2030 up to 122 million people, mainly in Africa and South Asia, could fall into extreme poverty owing to climate change. The report also states that farming is both a driver of climate change, responsible for about 21% of global greenhouse gas (GHG) production and a victim, with crops adversely affected by drought and floods. This makes agriculture a key sector in climate assessments. Local knowledge is part of a collection of time-tested survival strategies for food security, which consider the exploitation of locally available resources, indigenous skills and technologies over many years of exposure to different climatic conditions. Chanza (2014) identifies a range of strategies and practices used by rural communities to enhance their food security system. Strategies include: *Zunde raMambo, nhimbe* and rain petitioning ceremonies (see Table 3).

In Mararike's (2001) description, *Zunde raMambo* aims to ensure that a particular community has adequate food reserves to be used in times of a food shortage. A chief designates a piece of land for cultivation by his subjects. The yield from this land is stored in granaries (*Zunde raMambo*) at the chief's compound. According to local views gathered by Chanza (2014), the practice ensures that the community's food security is guaranteed at all times. It resonates well with conventional ideas of food security as relying on a strategic food reserve, which is readily available whenever required. A comprehensive definition given by the 1996 FAO World Food Summit

Table 3: Indigenous-based strategies for managing food security in Zimbabwe

Strategy	Description
Zunde raMambo	A rural project for enhancing social networks of disadvantaged members of a community, involving setting aside farming land under the supervision of a chief.
Rain petitioning ceremonies	These are meant to enlist the intercession of mhondoro to bring rainfall, especially used before the onset of the rainfall season or during mid-season dry spells. Various names, such as Huruwa, Mukwerera and Makoto, are given to these ceremonies in rural Zimbabwe.
Nhimbe	A term from the Shona people of Zimbabwe, meaning a collective community effort where people pull their resources together for field work or any other community task.

(Source: Chanza, 2014)

states that, food security is met when "all people, at all times, have physical and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (FAO, 1996). The indigenous philosophy of *Zunde raMambo* relies on the chief as critical to ensuring that all people in his village(s) have access to food at all times. Indeed, the strategy gives a sense of food governance through the collective action of community members, as a home-grown mechanism with merits in disaster risk reduction. Its significance in this regard deserves emphasis against the backdrop of climatic risks and the weakening of national social security schemes, attributed to resource constraints, erratic food relief supply chains and allegations of the politicisation of food aid reported by Mapfumo *et al.* (2010).

An interrogation of indigenous agricultural management systems for food security in traditional Zimbabwean society by Chirimuuta and Mapolisa (2011), reveals that local farmers are conscious of the acute problems of drought and rainfall scarcity and variability, and have developed comprehensive systems to counteract these threats. There are modes of cultivation and pastoralism from the farmers' management of micro-climates, which are designed to ensure food security. They identify the diversification of food security sources as critical to ensuring the adequate availability of food at a household level. Local farmers grow a mix of large (maize) and small grains (sorghum and millet), which are complemented by tuber crops (sweet potatoes, cassava and yams) and other crops (e.g., groundnuts, cowpeas, beans, pumpkins, watermelons and sweet reeds). Chanza (2014) identifies an assortment of drought adaptation crops, such as sorghum, bulrush millet, grain millet and cowpeas, which are used by farmers in dryland areas like Muzarabani. Notably, mixed cropping, or intercropping, in Zimbabwe has a gender dimension where women are primarily involved in carrying out such practices (Chirimuuta and Mapolisa, 2011). This gender bias is inarguably linked to ensuring household food security, since women are directly involved in food preparation in families. Mixed farming is also necessary for conserving soil moisture, promoting soil fertility, and for pest and disease control (Snapp *et al*., 1998; Giller *et al*., 2009).

Through the architectural designs of granaries used for storing grain, Chanza (2014) notes that local communities in Zimbabwe have strategies for keeping their grain and food stocks. The granaries are positioned about one metre above the ground so that the food is not spoiled by any dirt or water from the ground. They are neatly stacked on top of huge rocks or indigenous strong wood, which act as pillars, keeping the granaries away from the ground moisture or any other threats. The space beneath the store-house can also be used for ensuring an extension of the shelf-life of some food items: this space allows free air circulation, creating a naturally cold room where crops, such as sweet potatoes, pumpkins and watermelons, can be kept for some months beyond their expected seasonal lifespan. In some cases, fires are made beneath the stacks because the heat and smoke prevents pests and fungi from attacking the stored grain. In some places, Chirimuuta and Mapolisa (2011) discovered that the granaries are first cleaned and smeared with a cow-dung lining, before being filled with grain; cow-dung is then used to completely seal the granaries. The communities rely on local wisdom of the life cycles of pests and pest control systems. For example, sealing the granary ensures that pests already inside the granary are deprived of the oxygen necessary for respiration and reproduction, and soon suffocate to death. Therefore, reducing the risk of losing stored grain to pests and disease. Some families also keep a separate granary for the father of the family. This granary is more strategic and only used when the ordinary one is depleted.

Chirimuuta and Mapolisa (2011) also gathered that ashes collected from fire places are used to deter termites, weevils and other pests from attacking stored food. Numerous other indigenous skills are used for keeping food products longer. For instance, sweet potatoes can be kept fresh for a very long time in a pit away from moisture, or a jute sack filled with ordinary smooth ash. Weevils are prevented from attacking all kinds of grain by putting gum tree leaves, or other herbs, between layers of

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grain in the sacks or granary. Local communities continue enjoying the taste of fresh foods by boiling fresh mealies and groundnuts before drying them in the sun. These are then re-boiled in winter, summer or spring to meet the people's nutritional and dietary requirements. In addition, the practice of drying food, such as vegetables and fruits, is well known among the communities in Zimbabwe. For example, vegetables are boiled and dried so that they can be consumed during times when the products are out of season, or when there is no more water for irrigation.

^ Goats roaming in search of grazing pastures.

It has been illuminated here that, through their IK, local communities in Zimbabwe have developed long-term tried and tested strategies and practices for ensuring food security. There are evidently modes of agricultural practice that can meet the nutritional requirements of local families in a cost-effective manner. Crop diversification ensures food security within the communities through the strategic promotion of different foods to diversify food sources. There are various ways in which mixed cropping can enhance food security at a community level, e.g. the different crops mature at different times during the growing season thus minimising the risk of total crop failure. Several other strategies outlined above, are used to preserve food so that it does not spoil and is protected from pests and diseases. Related to these practices are a variety of methods deployed to withstand climatic risks and disasters, which are detailed in the next section.

IKS and management of climatic risks and disasters

A comprehensive definition of disaster risk management (DRM) related to climate risks is given by the IPCC (2012:558) as, "processes for designing, implementing, and evaluating strategies, policies, and measures to improve the understanding of disaster risk, foster disaster risk reduction and transfer, and promote continuous improvement in disaster preparedness, response, and recovery practices, with the explicit purpose of increasing human security, well-being, quality of life, and sustainable development." The intention, as explained by Wilbanks *et al.* (2007), is to keep climate change impacts as low as possible. In this conceptualisation therefore, the role of IK in DRM is explored. Through their IK, the local communities in many parts of Zimbabwe have devised a range of mitigation strategies against drought, violent storms and floods.

In a study to understand indigenous coping strategies against climate risks in Muzarabani, Chanza (2014) agrees with Gwimbi (2009) that local communities do not seriously consider conventional early warning alerts given by outsiders, especially if previous warnings are understood to be less serious or inaccurate. Instead, they seem undeterred by the frequent occurrence of floods as their main worry is food security, which they realise through farming in floodplains. They rely on local knowledge to exploit the attractiveness of the fertile and moist floodplains that have been supporting a dual cropping season for many years. In addition, the locals use their knowledge in the design of structures that can withstand violent storms and floods. Chanza (2014) reports that indigenous architecture is seen in the design of structures like houses, granaries and fodder racks. These are raised to a height of at least one metre above ground as a defence mechanism against floods. The tiers are made up of very strong wood, or supported by a combination of hard wood and large rocks, to enhance the durability of the structure. All household valuables like food, clothes and blankets are kept in this house, which they locally refer to as *hozi*.

It can be understood here that DRM entails a toolbox of interventions to enhance human security against disastrous events. Some of the indigenous drought risk management strategies are already stated in this report, including *Zunde raMambo*, *nhimbe* and rain-petitioning ceremonies. For example, when faced by a drought associated with delays in the start of the rains or dry spells during the growing season, a special group of elderly community members enlist the favour of the ancestral spirits whom they believe, if appeased, can influence the rains. This practice is linked to a sharp contrast behind understandings of the cause of drought between African indigenous communities and mainstream scientists reported by Chanza and de Wit (2015). The scholars learnt that indigenous communities understand the realities of climate change and the risks that its impacts pose to their survival. However, the understanding held by the local communities is that drought or climate change is inflicted by angry ancestors. Interestingly, their reasoning is that this punishment comes as a result of failing to prudently take care of the environment. This latter view resonates with scientific evidence that climatic risks are both caused and worsened by environmental ills.

Early warning systems (EWS) used by the indigenous people consist of indigenous seasonal forecasts, spiritual consultations, and information, education and communication strategies. It is important to note that EWS are also supported by early action involving seasonal migration and rescue operation plans. For example, Muzarabani ethnic group reported studying the behaviour of migratory birds (locally referred to as *Mashuramurove*) and certain tree species, such as *Hwakwa*, to predict events like floods (Chanza 2014). One respondent explained:

"If we see Mashuramurove hovering in the atmosphere around November/ December, or if there are many of the Hwakwa fruits that season, we can tell that there will be much rain with the potential of causing floods. So people are then warned to leave flood-prone areas as soon as we start to receive torrential rains".

In some places, information on EWS is also passed on to the villagers after consulting the spirits. There is a strong belief among the people that the *mhondoro* (spirit lions) have accurate forecasts on the occurrence of floods, droughts, or any other events like hailstorms and severe thunderstorms and lightning, they are seen as more reliable than conventional meteorologists. As such, special elders, including the *madunzvi* (spirit medium lead) and the *masvikiro* (spirit medium), routinely visit the holy shrines for advice before asking the villagers to take some appropriate action. In the event of anticipated flooding for example, early action would involve human migration to safer areas, shifting livestock grazing to less vulnerable places and stocking food coupled with the safekeeping of other assets (Chanza, 2014). Of particular mention in this analysis is that the strategies presented here exhibit a clear practical application of EWS and early action. The purpose of an EWS, from the viewpoint of the International Federation of the Red Cross and Red Crescent Society (IFRCRCS) (2014), is to put in place systems for action before the occurrence of the disastrous event. In this regard, the utility of the indigenous-based EWS presented here deserves emphasis against a backdrop of challenges in early warning communication and early action by responsible authorities in Zimbabwe, as reported by Gwimbi (2009).

Critical to the indigenous strategies for reducing disaster risks that are discussed in this chapter is the fact that they embrace the significance of community networking, participation, collective responsibility, response and continuous improvement, elements that commonly feature in disaster management scholarship (Gwimbi, 2009; IPCC, 2012; Lavell *et al.*, 2012; IFRCRCS, 2014). For instance, community networking through sharing experiences, knowledge and problem solving skills is an important aspect of the indigenous-based DRM strategies discussed here. These strategies have been treated by other scholars as social capital (Castle, 2002; Sekine *et al.*, 2009). Sekine *et al.* (2009) argue that social capital itself tends to influence the success of climate interventions targeting local communities. Similarly, the IFRCRCS (2014) advises on the need to consider cultural issues like religion and local beliefs as an entry point for disaster risk reduction.

Indigenous-based mitigation of climate change

In this discussion, two distinct definitions of mitigation are accommodated in order to adequately understand the scope of IK in climate interventions. One category, which relates to indigenous-based practices for minimising climatic risks has already been dealt with in the preceding section. Lavell *et al.* (2012) also view mitigation as a substantive action that can be used in different contexts where the reduction of damage in existing, specified conditions is required. This section concentrates on mitigation activities related both to reducing GHG emissions and enhancing GHG sinks from an IKS perspective. Nyong *et al.* (2007) indicate that employing mitigation strategies through indigenous natural resource conservation is an unstructured measure serving dual objectives: reducing GHG emissions from anthropogenic sources and enhancing carbon assimilation.

A discussion of environmental management in rural Zimbabwe can adequately be understood in terms of the customary governance system.

Within this traditional institutional arrangement, local people have a strong belief in their spiritual connection to the environment. They see it as a moral obligation to conserve environmental resources. The responsibility for ensuring compliance with local rules and customs rests with the chief. With support from advisors (*dare*) and immediate subordinates (headmen), the chief can monitor adherence to rules and enforce local sanctions when necessary. Guidance in decision-making can also be sought from the spirit mediums (*masvikiro*). In some instances, the chiefs also consult their wives before community meetings, reflecting gender sensitiveness in this governance system (Mohamed-Katerere, 2002; Mararike, 2011). Although the application of customary laws in natural resource management, in the view of Mohamed-Katerere (2002), is highly influenced by such factors as migration, western education, and the dependence of the locals on market economies, there are many places in Zimbabwe where locals are still regarding their environmental assets as sacred. Chanza and de Wit (2015) argue that the principle of sacredness is critical in forest resource management. In an examination of the role of traditional religious beliefs and traditional leaders in nature conservation in different communities in Zimbabwe, Byers *et al.* (2001) discovered that traditional spiritual norms have greatly influenced human behaviour in the protection of forests. They also found limited forest disturbance or damage in areas where traditional leaders remain empowered to exert their influences on nature conservation, as opposed to high rates of forestry loss in areas associated with the post-independence, relative disempowerment of the traditional political system. Chanza (2014) argues further that an interaction between ecology and traditional religion explains the existence of forests in Muzarabani. Accordingly, a conservation strategy, consisting of linkages between nature and culture shaped by traditional beliefs, values and institutions enshrined in the local customary governance system, has led to the existence of unique strands of forests in the area. In recognition of the sacredness of such places, thickets of unique dry forests that have been protected under traditional knowledge systems could be particularly useful in understanding the impact of long-term climate change on ecosystems. Box 1 gives a description of traditional knowledge systems relevant in environmental management, which have been in existence for numerous years in Zimbabwe.

Box 1: Typical indigenous knowledge systems related to forestry management

Traditionally, societies in Zimbabwe have practiced and enforced wildlife conservation through the timely hunting of animals and birds, avoiding indiscriminate killing and fostering selectivity. Societies believe that wanton killing is punishable by the spirits and, as a result, control mechanisms can be identified in traditional taboos, totems and customs. In some tribes, the customs or totems forbid people from eating certain animals, e.g., scavengers such as vultures and hyenas. Taboos forbid the killing of young animals and females during gestation. Hunting in scared places is also prohibited. The killing of rare species, such as the python and pangolin, is only allowed with permission from the chief. Trees are also protected through traditional taboos and customs. Certain trees are not cut because of their cultural importance, e.g., the Parinari spp. (Mutowo) under which ceremonies are held.

Chiefs play an important role in safeguarding their peoples' access and rights to resources. All land is held in communal tenure, and the headman or sub-chief is responsible for allocating each family grazing and arable land. Even though resources are held in common, there is a commitment to their protection because communities have real rights to manage the resources and benefit from them. However, with the intrinsic value of scarce resources, people overexploited resources for survival and individual gain. As colonialism entrenched itself, communities also lost their most important fundamental right – freedom. With that gone, the people lost all other rights and access to resources.

(Source: Ncube et al., 2002:115–117)

Indigenous-based adaptation to climate change

In climate theory and practice adaptation involves taking measures in response to climatic stimuli. IPCC (2014b:1758) refers to it as "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities." The 2012 IPCC report makes a distinction between adaptation in human systems and natural systems. In human systems adaptation is defined as "the process of adjustment to the actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities", while in natural systems it refers to "the process of adjustment to the actual climate and its effects,… [and only] human intervention may facilitate adjustment to [the] expected climate" (IPCC, 2012:36). To be indigenous-based, adaptation practices need to be developed locally by the communities observing climatic phenomena. This happens when the local people acknowledge the irregularities in elements of the climate system like rainfall, temperature, wind or clouds. It is clear from the preceding discussion that local communities are aware of the changes and variability in climate events. Given the threats posed by climate change, the locals in Zimbabwe have devised a toolbox of response mechanisms to save lives and livelihoods. Chapter 15 of the IPCC's Fifth

Assessment Report notes a marked transition from a phase of awareness to the construction of actual strategies and plans (IPCC, 2014a). This is also true in many rural areas of Zimbabwe, where the motivation behind designing responsive actions to climate change is largely driven by the knowledge that the local environment has been characterised by uncertainties and irregularities in recent years, which has compelled rural communities to adopt appropriate coping and adaptive strategies.

From an indigenous-based standpoint, Chanza (2015) observes that local responses to climatic stimuli fall into anticipatory and spontaneous categories. According to the IPCC (2014b), anticipatory adaptation is proactive in the sense that people take action before the stimulus is experienced, while spontaneous adaptation is passive as it does not constitute a conscious response. In the Zimbabwean case, empirical evidence shows that IK-based adaptation is a graduation from proactive to reactive actions. For example, Chanza (2014) gathers a portfolio of short-term coping practices (spontaneous adaptation), medium-term adaptive strategies (planned adaptation), and fairly long-term response strategies (proactive adaptation). Chanza (2015) later distinguishes these strategies according to the climate events experienced. As explained here, there are strategies used to cope with drought, floods, violent storms and lightning, and high temperatures, as well as responses to address food insecurity risks in the event of such climate problems. The latter has already been dealt with in the section on IK and food security. The present discussion therefore focuses on the use of drought tolerant crops, shifts towards livestock production and practices supporting it, the exploitation of ecosystem services (the value and benefits of ecosystems), barter trading, conservation farming and dry planting.

Local farmers in Zimbabwe have a set of responses that enable them to cope with drought or famine. Several scholars have written about farmers' preference of traditional crop varieties, such as sorghum, millet, beans, cowpeas, bambara groundnuts and other crops, as a drought adaptation practice (e.g., Mapara, 2009; Mubaya, 2010; Chanza, 2014). These varieties are known to be drought tolerant. It is essential to note here that many local farmers primarily choose local varieties of crop because modern crop seeds are not accessible. Indigenous strategies to manage famine in rural Zimbabwe abound. Depending on locality, communities' options include dual-season cropping, barter-trading, *Zunde raMambo* and *nhimbe*. Plans for barter-trading livestock with grain from other communities are put in place as soon as the villagers realise the impending threat to crop production posed by climatic events. The practice of barter-trading, apart from being a drought aversion measure, also serves to mitigate food security crises following crop failure. The locals use their networks to identify other places where they can exchange their livestock for grain. In some cases villagers also sell their cattle in order to raise money to buy food. The challenge with this practice is that it further disposes local people to poverty as they end up losing their most vital livelihood asset – livestock. On closer analysis, however, the benefit of this practice is that reducing the cattle herd to a sizeable number makes it easier to manage, given the lack of forage and drinking water caused by drought. The villagers do not just randomly cut down cattle numbers, but use their knowledge to selectively take out the weak, sick, thin or less productive animals. This practice is commonly referred to as 'culling'.

Knowledge of wild fruits and the procedure of processing them also serves as a coping mechanism in the event of drought or famine. Chanza (2014) records a range of tree species utilised by locals, which include: *maungu* (*Landolphia buchananii* fruits), *shumha* (*Diospyros mespiliformis* fruits), *masau* (*Ziziphus spp.* fruits) and *mauyu* (*Adansonia digitata* fruits) which are regarded as important food sources in drought situations. Knowledge about how to process these fruits for food is of higher importance than the fruits themselves, as this enables the people to realise more food value.

∨ Wild fruit from the Anona Senegalensis.

Some detailed descriptions of indigenous-based food processing techniques are given in Box 2. The major constraint, however, is the increasing pressure exerted on the availability of these fruits by both humans and wild animals. For example, *masau* fruits are increasingly harvested commercially to sell to people in the cities, depriving the locals who manage and conserve the fruits. The crisis is worsened by elephants and baboons competing with people over the berries. These challenges tend to weaken the local people's coping capacity.

Water scarcity caused by drought also demands that the locals devise appropriate coping mechanisms by planning cattle drinking schedules, for example. Farmers often take the herds to places where water is usually available during dry spells. Villagers also devise seasonal migration schedules where livestock are temporarily taken to suitable places for easily accessing drinking water. Thus, through their IK, farmers devise destocking arrangements in various ways. For example, if they have relatives such as in-laws in other, more hospitable places, they might relocate their cattle to such areas, perceived to have better climatic conditions (Chanza, 2014).

With regard to livestock production, many farmers are increasingly shifting much of their attention to this practice in the face of frequent droughts and crop failures. Animals like cattle, donkeys, goats and sheep are commonly domesticated. Rural Zimbabweans are confident that livestock rearing is a better option than crop farming, as it is more capable of withstanding the threats of drought. However, the threat of frequent or extended droughts to communities' adaptive capacity cannot be ruled out, since drought leads to the loss of grazing pastures and desiccation of water points. Nonetheless, most indigenous farmers have learnt mechanisms to preserve their livestock during times of drought, notably through devising cattle grazing and drinking schedules as explained earlier. The villagers prepare cattle fodder banks, which they use to feed the animals during the dry spell. This practice has a long history in the rural landscape and is being seriously considered as an additional adaptation strategy. The fodder is usually collected from crop residues soon after each harvest and given to the animals during critical times when pastures dry up (*ibid.*).

Conservation farming, known as *timbaugute* in the local language, is understood as a traditional practice used to cope with a drier climate. This practice, which entails digging planting holes with minimum soil disturbance, is associated with three main advantages: the conservation of

Box 2: Indigenous ecologies of tropical plants

Masau fruits are harvested between June and September. These can naturally be dried in the sun and carefully stored in granaries. In the event of famine or food scarcity, the fruits are pounded to prepare *masau maheu*, a liquid which is instantly made by mixing the pounded materials with water. Unlike the common *maheu* – a liquid made from fermented small grain (sorghum or millet) malt that is usually prepared overnight and drunk the following day – what is amazing about the *masau maheu* is its instant preparation. This makes the drink unique and a strategic food source that the locals can rely on in the event of famine.

Another fruit, *mauyu*, is used to make porridge. The white powder from the pounded fruits is briefly immersed in water to make it soft before being sieved. The collected powder is then mixed with water and heated to make porridge. *Magoma* fruits are also used to make porridge using a similar method of preparation to that used in the preparation of *mauyu* porridge.

(Source: Chanza, 2014)

soil against erosion and loss of nutrients; the retention of soil moisture; and the limited labour and time requirements. Mainstream agronomists also state that this strategy, alternatively referred to as minimum tillage or zero tillage, leverages natural ecological processes to conserve moisture, enhance soil fertility and improve soil structure (FAO, online). Local farmers also practice dry planting, locally known as *kuparira*. This practice is becoming increasingly popular with many small-scale farmers to suit the progressively dry climate. To locals, this practice holds several merits extending beyond drought cover to other benefits like early crop maturity, minimised labour challenges and reduced threats from pests. Under this method, farmers start sowing their seeds before the onset of rainfall so that by the time the rainy season starts, the seeds can fully utilise all the available moisture for fast germination and plant growth (Chanza, 2014; 2015).

Conclusion

An examination of the IK practices reported in this chapter illuminates that through their interaction with the surrounding environment for many years, the locals have developed a wealth of environmental knowledge that is useful for adapting to climate change. IKS involve practices that evolved through trial and experimentation, and such skills and experiences have proven to be flexible enough to cope with change. Collectively, this knowledge falls into the following categories: IK useful in weather and seasonal predictions; strategies critical in promoting food security; practices useful in managing extreme climatic events such as drought, dry spells, violent storms and floods; strategies useful for cutting carbon emissions and enhancing GHG reduction; and practices that help communities to adapt to environmental changes. Local knowledge is also expressed through the naming and classification of weather and climate phenomena in local languages, oral recordings of weather and climate-based events and trends, and the forecasting of weather and climate events using different environmental indicators. Various IK indicators of climate change and variability; namely animal, bird, insect and flora behaviour and signs, local weather conditions and signs, rainfall volumes and patterns, astrological constellations, and signs from the local environment are reported. These indicators are used to make seasonal climate projections and to understand changes in the local climate system. This makes indigenous communities key stakeholders in the design of climatic responses. For climate change mitigation, IK is potentially useful in the implementation of policies enhancing the management of GHGs in agriculture, ecosystems and other forestry management projects. The challenge, however, could be the limited scale at which such projects can be implemented to cause a significant reduction in the volume of atmospheric GHGs. In DRM practices IK can be harnessed to reduce community vulnerability to the hazards posed by extreme climatic events, such as drought, floods and thunderstorms. This knowledge is useful for making decisions about earning livelihoods from ecosystem services, as communities adapt to climate variability and change. The rural communities use their rich traditional knowledge for weather forecasting, vulnerability assessments and the implementation of adaptation measures. Essentially, current climate practice and policy can build on the local and traditional knowledge of farmers to create solutions based on farmers' needs.

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CHAPTER 5 - Seasonal climate prediction in Zimbabwe using indigenous knowledge systems

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Abstract

One of the key uses of indigenous knowledge (IK) includes using various forms of traditional indicators to predict weather and climate and also to respond to climate risks. Scientific knowledge has, over recent decades, increasingly taken priority over local knowledge and practice in agricultural systems' research and development. Early warning systems on disasters and climate-related shocks were traditionally channelled through religious and cultural methods such as oral literature, poems and songs, which had unfortunately lost recognition and utilisation in the context of climate change adaptation in the same period. However, in recent years, particularly in the past decade, there is an emerging and dominant view that places emphasis on local knowledge

∨ A stockfeed depot in Masvingo, Zimbabwe.

as a key component of an agricultural system and the view that scientific knowledge must enhance local knowledge, rather than displace it. This chapter uses secondary studies to compile important insights from Zimbabwe regarding indigenous knowledge systems (IKS) and historical, current and seasonal climate predictions. Findings point towards the understanding that, despite the shift towards recognition of IKS in climate change adaptation in agriculture systems, there is evidence to show that increased rainfall variability and temperatures have reduced smallholder farmers' confidence in IK, hence reducing farmers' adaptive capacity and increasing their vulnerability to climate change. In addition, skewed use of scientific knowledge and weather and climate predictions has proved to be a major constraint for farm level decision-making as they do not incorporate IK, which farmers already live with. In the same context, it is emerging that farmers are more willing to use scientific seasonal climate forecasts when these forecasts are presented with – and compared to – the local indigenous climate forecasts. In light of this background, this chapter concurs with studies that propose a framework of integration of IK forecasting with scientific forecasting for improved seasonal forecasts to in order to reduce climate risks and vulnerability.

Introduction

In Africa, agriculture is a complex and challenging operation due to a number of factors, including low soil fertility, changing social and political situations, an unfavourable economic environment and a variable climate (Osbahr and Allan, 2003). Farmers in semi-arid areas depend solely on rainfall, yet this is typically variable, both spatially and temporally. There is evidence to show linkages between droughts and development (or lack of it), given that rain-fed agriculture, which is very sensitive to weather, accounts for 70% of food production across Africa (UNISDR *et al.*, 2008; Hellmuth *et al.*, 2007). This ushers in the need for effective early warning systems that contribute to addressing the cycle of droughts and subsequently, reduce their negative impacts (Masinde, 2015). Literature highlights efforts by farmers to address these challenges and their use of indigenous knowledge systems (IKS) as a key component in this context. One of the key uses of IKS includes using various forms of traditional indicators to predict weather and climate and also to respond to climate risks (Joshua *et al.*, 2011). There is evidence to show that, as a result, farmers have developed and relied on traditional systems to adapt to variable rainfall. These traditional systems worked for centuries as they relate to local lifestyles, institutional patterns and social systems (Mbilinyi *et al.*, 2005).

There is wide consensus that IKS are key components of climate change adaptation in the agriculture sector, particularly in the development of locally relevant and sustainable adaptation strategies to mitigate the impacts of climate change. Scientific knowledge has, over recent decades, increasingly taken priority over local knowledge and practice in agricultural systems' research and development (Walker *et al.*, 1999). In the process, modern science has threatened the sustenance of local knowledge systems and transformed the nature of these systems, in some cases displacing local systems. Early warning systems on disasters and climate-related shocks were traditionally channelled through religious and cultural methods, such as oral literature, poems and songs, which had unfortunately lost recognition and utilisation in the context of climate change adaptation in the same period. However, in recent years, particularly in the past decade, there has been an emerging and dominant view that places emphasis on local knowledge as a key component of an agricultural system and the view that scientific knowledge must enhance local knowledge, rather than displace it (Jain, 2014; Joshua *et al.*, 2011; Maconachie, 2012; Osbahr and Allan, 2003; Walker *et al.*, 1999).

However, little attention has been paid to the connection between indigenous perspectives and observations to potential climate response or adaptation strategies (Andes and UNU-AIS, 2008). It is also disturbing that national adaptation plans in Africa, which act as frameworks for implementing adaptation programmes, place limited significance on IKS as shown by studies conducted across the continent (Nkomwa *et al.*, 2014). To date, little is known about specific details of farmers' physical and biological knowledge and how this knowledge is used to make farm management decisions (Osbahr and Allan, 2003). This chapter uses secondary studies to compile important insights from Zimbabwe regarding IKS and historical, current and seasonal climate predictions. The chapter specifically focuses on the; rationale for consideration of use of IKS for seasonal forecasts; characterisation of IKS indicators for weather and climate in the country; threats to existing IKS within the forecasting context; and, finally, a framework for consideration in ensuring improved seasonal forecasting in the country. This chapter is critical for the understanding of how, and the extent to which, smallholder farmers use forecasts.

Why seasonal forecasting for smallholder farmers?

One key point that emerges in the thinking around seasonal forecasting for smallholder agriculture is that of decision-making. In order for smallholder farmers to make various decisions for adaptation, they need climate information, regardless of the source (Gukurume, 2014). This is particularly important in the context of increasing variability and unpredictability of the rains, given that these farmers rely on rain-fed agriculture. There are already indications of sub-optimal uptake of scientific seasonal forecasts by farmers in southern Africa (Vogel and O'Brien, 2006 cited in Mberego and Sanga-Ngoie, 2014). This is of concern given that any form of response farming requires localised rainfall records in adequate time for sufficient levels of decision-making to optimise yields (Mberego and Sanga-Ngoie 2014; Stigter, 2010). The localised rainfall records have a critical role to play for smallholder farming system resilience and can be obtained from seasonal forecasts, which are either IKS or meteorologically based, or both. There is already empirical evidence of effective weather forecast data utilisation leading to reduced vulnerability to climate change (Jiri *et al.*, 2016; Mittal, 2012; Speranza, 2010). This evidence provides further testimony that a farmer with access to updated quality information, which they are able to use, is more able to deal with climate risks. Ziervogel (2004) makes the same assertion in an empirical study conducted in Lesotho, which claims that an increase in forecast accuracy to 60–70% or above is likely to guarantee positive impacts from using forecasts.

In Zimbabwe, more than 90% of smallholder farmers depend on rain-fed agriculture for their livelihoods, making seasonal forecasts critical in a context where only 37% of Zimbabwe receives adequate rainfall for agriculture (FAO, 2005). The dry conditions are compounded by droughts to form the highest source of production risk, driving the need for concrete and explicit steps in increasing smallholder farmers' use of forecasts (Unganai *et al.*, 2013). There is evidence of climate information contributing to the improvement of agricultural production and ultimately, dealing with food insecurity in Africa (Patt *et al.*, 2005; Roncoli *et al.*, 2009).

Conceptualising IKS for climate change adaptation

The term IKS is specifically used to refer to 'place-based' knowledge systems developed by communities as opposed to the scientific knowledge that generally refers to 'modern knowledge' (Ajibade, 2003; Mapfumo *et al.*, 2015; Orlove *et al.*, 2009). This is the definition that we apply to this chapter. In the context of seasonal forecasts, literature tends to focus on forecasts in the context of rainfall patterns as a basis, with interpretations of plants, animals, insects and bird behaviour mainly affirming rainy season indicators. This local knowledge is unique to a given culture and has the potential to form the basis of decision-making. The characteristics and types of IKS are also determined by the culture of the society and may, in most cases, vary from society to society and are likely to benefit locally-based adaptation plans (Nkomwa *et al.*, 2014; Rao, 2006). A study conducted in Zimbabwe indicates that IKS can be transferred and adapted by other communities, encourage participation and empowerment of farmers, improve interventions at the local level and are, to a large extent, close to reality given that they are beyond formal education (Mavhura et. al., 2013). This flexibility of IKS over cultures suggests an opportunity for tailored forecasts and corresponding adaptation strategies by smallholder farmers towards climate variability.

IKS have the potential to advance 'precision farming', and to use it to understand livelihood diversity and change over a period of time. High regard of IKS by farmers has the potential to improve the quality of farmers' lives through utilisation of their IKS (Soh and Omar, 2012). It is also important to take account of, and learn from, what local people already know and do, and to build on this. The role of women is important in the use of IKS as adaptation measures to climate change given that women have been shown to possess IK to maintain household food security in times of shocks, such as drought and famines, through reliance on drought tolerant plants (Easton and Roland, 2000; Eriksen, 2005; Ramphele, 2004). IKS have increasingly become topical and embraced by academics and practitioners alike, in part as a way to address a multiplicity of livelihood challenges that confront rural communities and as a basis for local level coping and adaptation mechanisms beyond the planning stage (Mapfumo *et al.*, 2015; Moonga and Chitambo, 2010; Saitabau, 2014). This conceptualisation appears to place emphasis on concerted efforts towards implementation of locally driven adaptation strategies at the lowest level.

For this chapter, we broaden this conceptualisation in an attempt to gather what literature highlights regarding the role of IK forecasting vis-a-vis modern scientific forecasting in Zimbabwe. In the next section, we present a possible basis for the consideration of IKS as an entry point to seasonal forecasting in the country.

Rationale for consideration of IKS for seasonal forecasting in Zimbabwe

A number of issues we raise in this section lend weight to the rationale for IKS considerations in seasonal forecasting, among them, existing agro-meteorology which appears to be ignorant about climate issues, farmers' limited access to climate information, inaccurate rainfall predictions, low uptake of climate information, the scale constraint, and limited alignment of climatic information with critical livelihood components. Further issues with dissemination channels and in some cases, political interference, also appear to limit meaningful uptake and engagement with climatic information for farmers.

Over the past two decades, the state of African, in general, and Zimbabwean agro-meteorology, in particular, appears to have been oblivious to the dynamics of changing local farming systems in the context of climate change (Olufayo *et al.*, 1998), yet the situation appears not to have changed much over the years. Farmers still have limited access to agro-meteorological information, inevitably making them rely on their memories of past climatic experiences and narratives for agricultural decisions. This problem raises an issue of: to what extent can these memories be sustained over time? Farmers have in the past two decades complained about misleading forecasts, a challenge which persists today. During this period, there is evidence of an increase in mismatches between seasonal rainfall patterns and maize yields, similarly leading to loss of confidence in scientific forecasts and subsequently relatively low yields, despite the abundant rains of 1999, 2003 and 2004, with political interference also contributing to the levels of inaccurate forecasts (Fontein, 2015; Manatsa *et al.*, 2012).

Low uptake of scientifically-derived climatic information appears to be another challenge that may warrant serious consideration for IK forecasting in Zimbabwe. For instance, in Chiredzi, there is evidence of a very low rate (17%) of utilisation of received information among local smallholder farmers, possibly emanating from incorrect, unintelligible, probabilistic and ill-timed earlier predictions that reportedly misguided farmers in their operations, resulting in losses (Manatsa *et al.*, 2012;

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^ **Farmers prepare to take their produce to market.**

Mapfumo *et al.*, 2015; Unganai *et al.*, 2013). It is common knowledge that uptake tends to be associated with perceptions regarding relevance and importance. In a study in southern Zimbabwe, 75% of farmers reported receiving seasonal forecasts and, of these, 57% reported changing planning and cultivar selection in response (Patt *et al.*, 2005). IKS come directly from the farmers themselves and information gathered in other ways that do not take these farmers into account, remain 'questionable' (Davis, 2005).

In Zimbabwe, the issue of the scale at which climate information is forecasted challenges scientific forecasting and lends credence to farmers' IK forecasting, especially in cases where climatic information covers a wide geographic area (Patt and Gwata, 2002). Climatic information of this nature is questionable given that response farming and rainfall parameters (onset dates, end of season) normally vary across districts and require precision for effective guidance in decision-making (Mberego and Sanga-Ngoie, 2014). This challenge is complicated by the limited integration of climate forecasts with farmers' agricultural operations, even with information originating from the southern African regional climate outlook forum process (Manatsa *et al.*, 2012). Smallholder farmers' livelihoods in Zimbabwe are agriculture based and any effort towards seasonal forecasting need to ensure alignment with agriculture-related operations for effective and timely risk management, or otherwise render the forecasting efforts less meaningful for these farmers.

Dissemination channels (radio, TV and newspapers) used for forecasting weather in Zimbabwe tend to be less effective than initially intended, as they are not easily accessible for poor farmers. Elite members among poor farmers tend to have access to these dissemination channels (which in most cases are not in vernacular), and therefore tend to use meteorological forecasts (Mapfumo *et al.*, 2015; Mugabe *et al.*, 2010). This issue brings to the fore social injustices and inequities that tend to pervade rural communities in Zimbabwe and calls for efforts towards levelling the playing field for farmers regardless of wealth, gender or any other criterion.

Capacity and skills in applied mechanisms in meteorology also limit the effectiveness of disseminated climatic information. For instance, while extension officers and workers in one district in the country had up to university and college level of agricultural education respectively, they lacked adequate capacity and skills in meteorological and climate change education to effectively organise and supervise farmers in relevant activities (Mberego and Sanga-Ngoie, 2014), yet extension remains the major enabler for adaptation decision-making (Mapfumo *et al.*, 2015).

The issues that we raise regarding seasonal climate forecasting generally, as a consequence, make farmers rely more on their IK and information from local social networks for decision-making on their farms. There is empirical evidence that, in Zimbabwe, adaptation is still situated within local experiential learning from previous climatic stresses in the form of 'strategic' (medium to long-term), 'tactical' (seasonal) and 'operational' (within season) decisions (Mapfumo *et al.*, 2015). For this reason, farmers in the country use less meteorological information than IK in their seasonal forecasting. A case in point is in a study where less than 25% of the farmers reported using the former, which in essence became complementary to the latter (Mapfumo *et al.*, 2015).

While the IK forecasting methods and indicators have their own limitations and are currently facing threats (see Section 6), IKS remain an entry point into understanding and strengthening seasonal climate forecasts for smallholder farmers (Jiri *et al.*, 2016; Mapfumo *et al.*, 2015). Advantages of IKS in this regard include their flexibility and acceptability by local communities, including a strong practical emphasis towards both planning and implementation and incorporation of new elements.

Characterisation of IK forecasting in Zimbabwe

This section outlines and profiles the nature of IK forecasting in Zimbabwe based on selected studies conducted across the country (Mapfumo *et al.*, 2015 in Manicaland; Mberego and Sanga-Ngoie, 2014 in Mashonaland West; Mugabe *et al.*, 2010 in Midlands and Matebeleland North; and a desk study by Jiri *et al.*, 2016). These studies provide a cross-section of geographic location that is somewhat representative of the country. For us to analyse the relevance and merit of IK forecasting, including suggesting a framework of operation for improved seasonal forecasts in the country, it is critical to build an understanding around the nature of IK forecasting in Zimbawe. More importantly, we need to further build an understanding of how these IK-based forecasts are used by smallholder farmers in Zimbabwe in the context of climate change.

Traditional forecasting indicators

A range of traditional forecasting indicators from across the country have been categorised in literature under tree phenology, biological (plant/ animal behaviour), atmospheric and other indicators not falling under any of these three sets of indicators (see Table 1). The main phenology-based indicator for the onset of the rainy season is the flowering of a type of tree, and for season quality it is the behaviour of plants during a drought or good season. Studies indicate that, traditionally, these indicators triggered the start of farming-related activities depending on the significance of the indicator (Mapfumo *et al.*, 2015). However, we suggest caution when considering these indicators given that these phenology-based indicators are themselves in a state of flux, with tree behaviour and flowering patterns also changing due to various factors (Curran *et al.*, 1999; Mugabe *et al.*, 2010).

In terms of animal behaviour, movement of migratory birds and sounds from insects signal a number of factors such as the start of a season or the abundance of rains for that season. These indicators traditionally contributed to the preservation of the animals concerned in Masvingo province (Jiri *et al.*, 2016), although some of these species are now endangered and may no longer provide good forecasting as was the case in the past. The changing seasons themselves are also shown to signify both the onset and quality of a coming season in Zimbabwe. Temperature changes and shifts in wind direction fall under this category. Farmers also use trend analyses of these changing seasons to come up with a pattern of forecasting indicators, potentially establishing the extent to which these indicators are reliable (Mapfumo *et al.*, 2015). In a similar fashion to phenology and animal behaviour, the atmospheric indicators have also shifted to an extent that they may also mislead farmers to erroneous decision-making and subsequently, affect livelihoods (Jiri *et al.*, 2016). Similarly, naturally-based indicators remain important for traditional forecasting, among them the nature and flow of rivers and streams in Zimbabwe, yet their unpredictability in terms of flow now makes it difficult to use them as reliable forecasting indicators (Kolawole *et al.*, 2014).

Indicators for seasonal changes and impacts on livelihoods

Traditional forecasting indicators in the country indicate changing seasonal patterns in various ways, with noticeable impacts on farmers' livelihoods. In a study conducted by Mapfumo *et al.* (2015) in the eastern parts of the country (see Table 2), changes in the traditionally recognised

V **Cabbage production.**

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Table 1: Farmer perceived categories of traditional indicators in Zimbabwe

Indicator	Significance
Phenology	
Onset of rains	
Flowering of the peach tree (*Prunus persica*), apricot (*Prunus armeniaca*), budding of acacia species	Beginning of rainy season
Season quality	
Behaviour of certain plants: sprouting of *Aloe ferox*; germination of new leaves on baobab and tamarind trees	Silver-leaf milkplum (Englerophytum natalense) and marula (*Sclerocarya Caffra*) during the months of December to February signify an imminent challenging farming season
Mango tree (*Mangifera indica*); Nandi flame tree (Delonix regia), muhacha (*Parinari curatellifolia*), gan'acha (Lannea discolor), mushuku (*Uapaca kirkiana*); *Boscia albitrunca; Adansonia digitata*	Heavy flowering of the mango trees indicates a potential drought season Heavy flowering of the trees indicates a potential drought season
Dormancy breaking in certain trees species e.g. mupfuti (*Brachystegia boehmii*)	Indicates plenty of rain in a few days
Animal behaviour	
Onset of rains	
Appearance of red ants, rapidly increasing size of ant hills, moist ant hills (October-November)	Good rains are coming
First appearance of sparrows; flock of swallows (*Psalidoprocne pristoptera*) preceding dark clouds	Rain is at hand and farmers should prepare for above normal rains
Appearance of certain birds e.g. stock, Quelia	
Termite appearance (*Ancistrotermes spp. and Macrotermes spp.*)	Abundance means near rainfall onset
Frogs in swampy areas croaking at night	Nearing onset of rains
Rock rabbit	Unusual squeaking for imminent rainfall
Cicadas or *nyenze*, day flying chafers or *mandere*, dragon flies or mikonikoni	Appearance signifies imminent rainfall
Season quality	
Appearance of certain insects e.g. millipedes, spiders	Coming of rains
Atmospheric indicators	
Onset of rains	
Moon phases	Moon crescent facing upwards indicates upholding water and when facing downwards is releasing water in the next 2 days
Star constellation	Star pattern and movement from west to east at night under clear skies means rain will fall in 3 days

Season quality	
Moon profuse halo	Good rains disposition of the new moon indicates more disease and erratic rainfall
Wind swirls	Frequent appearance is a sign of good rains
Temperature	Heat in low areas in August indicate there will be more rainfall in the coming season; high temperature in October and November signifies near onset and a good rain season.
Appearance of many nimbus clouds; appearance of red clouds in the morning	Indicators for rain in 1–3 days
Appearance of fog/haze in the morning	Indicator for no rain
Other natural indicators	
Rainmaking ceremonies	Praying and traditional healers consulting the gods
Body feels increased or excessive heat during the night and day; a feeling of body pain (headache, flu, backaches)	Indicator for rain in 1–3 days
Asthmatic attack, painful operations	Imminent cold weather and humid conditions

Sources : Jiri et al., 2016 Mugabe et al., 2010 ; Risiro et al., 2012; Mapfumo et al., 2015 ; Shoko and Shoko, 2013 ; Vijfhuizen, 1997

rainfall regime, common wind direction and onset of winter and summer periods indicate a number of impacts on farming communities' livelihoods. For instance, diminishing traditional rainfall regimes tend to reduce the opportunity for farmers to prepare their land in anticipation of the rainy season, and low temperatures between August and October delay the start of the rainy season and spell hunger for these farmers.

Adaptation to climate in response to IK forecasting

Following the IK forecasting indicators highlighted in preceding paragraphs, we have compiled the various agricultural adaptations that farmers from the study areas use for decision-making on their farms.

Among these adaptations are the shifting of planting dates and cultivars to suit the specific weather event, such as delays in the onset or impending onset of rains, among others. For instance, in Makonde, the changing of the maize crop to more drought resistant crops, such as sorghum and millet, is inevitable in situations where the rains are not promising to be

Table 2: Farmer perceived climatic indicators of changing seasonal patterns in eastern Zimbabwe

Climatic variable	Observed change(s)	Perceived impacts
Occurrence of traditionally recognised rainfall regimes	Traditionally known rainfall regimes diminishing	• Water scarcity: drying rivers due to lack of recharge • Diminishing opportunity to prepare fields during the dry season when there are no labour bottlenecks • Erratic showers confusing in terms of agricultural planning • Loss of opportunities for early cropping as soil is often very dry at depth • Dry season feed shortages • Food crisis and hunger through loss of food security crops associated with wetlands
Common wind direction	Traditional early warning systems failing as wind systems change	• Provides early warning, and used as trigger for major decisions on whether efforts should be directed towards: procurement of inputs • Off-farm employment/migration • The big search for food (kushuzha/kusunza). [involves special trips in search of working or barter trade terms for food that is subsequently transported to the family]
Onset of winter and summer temperatures	Apparent shifts in the start of winter and summer seasons	• Low temperatures between August and October increases delay in start of rainy season and spells hunger • Prolonged dry seasons cause social challenges including alcoholism and child delinquency – as there is little to do

Source: Mapfumo et al., 2015: 5

good. However, this kind of decision is not only made in relation to the forecast but also in relation to the availability of markets and good prices (Mberego and Sanga-Ngoie, 2014). This suggests that our thinking around decision-making is not entirely based on seasonal forecast, but rather, an intrinsic system that takes into account other factors that may not necessarily be tied to forecasts. Nevertheless, the shifting of planting dates and cultivars remains a major decision-making element based on forecasts (Mano and Nhemachena, 2007).

In eastern Zimbabwe, Mapfumo *et al.* (2015) highlight some of the decisions made following forecasts including allocation of land resources and investments, management of livestock and food stocks, and participation in trade, among others. Replanting, pest and disease control, and marketing of grain are also some of the strategies that were implemented following well thought out decision-making processes. However, Mapfumo *et al.* caution that some households in this community lacked capacity to make use of forecasts to respond to climatic risks.

Threats to IKS as seasonal forecasting mechanisms

Despite the rationale for IK forecasting and the arguably very rich profile of indigenous forecasting indicators, there remains a host of threats confronting the sustainability of IKS within this context. The threats that we outline in this section highlight the limitations of IKS in meeting new forms of challenges and adaptation to climate change and variability. There is an alarm bell that IK is slowly disappearing and being eroded, ultimately raising the question of how much longer the system can sustain itself. This is considered to be due to the waning source of knowledge as the elderly are replaced by the middle-aged and the youth, who appear to be more concerned with modernisation than taking up this knowledge (Mapfumo *et al.*, 2015; Shava *et al.*, 2009). Given this background, we suggest that there is immediate need for the institutionalisation of IKS into seasonal forecasting systems at national level. In addition, the documentation of existing IK forecasting indicators is required in the near future if these indicators are to be preserved as a basis for decision-making (Mapfumo *et al.*, 2015).

Other factors such as the unreliability of IK as the sole forecasting mechanism for smallholder farmers, human limitations due to short memories and the ambiguity of terminologies (in some cases 'abundant rainfall' may have more than one meaning) used in IK, all make IK forecasting difficult to sustain in the long term (Masinde, 2015; Mberego and Sanga-Ngoie, 2014). There is also evidence to show that increased rainfall variability and temperatures have reduced smallholder farmers' confidence in IK, hence reducing farmers' adaptive capacity and increasing their vulnerability to climate change (Mugabe *et al.*, 2010). Jiri *et al.* (2016) cite potential threats to IKS including negative perceptions that tend to view IK as backward; disruption by modernisation; and disruption of traditional indicators by changes in weather and climate, including the natural resource base upon which it is based. The school of thought that views IK as backward tends to extol scientific knowledge for climate forecasting as a superior form of knowledge. In addition, while the important role of IKS in climate risk reduction is now acknowledged (Jain, 2014), IKS have yet to be commonly used by communities, scientists, practitioners and policymakers (Hiwasaki *et al.*, 2014).

IKS or scientific forecasts? Towards a framework for improved seasonal forecasting in Zimbabwe

At this point, we hasten to say that our intention is not to entirely problematise scientific forecasting and romanticise IK forecasting. Rather, we demonstrate that scientific seasonal forecasts on their own have made little progress in terms of equitably empowering smallholder farmers in Zimbabwe (see sections 2, 3 and 4 of this chapter). In this section, we therefore address the question of whether this highlighted gap calls for farmers' total reliance on IK forecasting, which has been the traditional practice (see section 5). We explore literature on this question and concur with various studies suggesting a context for integrating scientific and IK seasonal forecasting for improved agricultural production, as opposed to sole use of each forecasting method independently.

The first justification for an integrated framework of seasonal forecasting methods is the skewed use of scientific knowledge and weather and climate predictions for farmers' decision-making that fails to incorporate IK indicators that farmers already live with. This is especially considering the evidence that these farmers are more willing to use scientific forecasts when they are presented and compared with local forecasts (Jiri *et al.*, 2016; Mugabe *et al.*, 2010). This assertion appears to back Osbahr and Allan (2003), who highlight the critical role that local perceptions play in decision-making implying that, unavoidably, external knowledge systems need to complement rather than displace IKS in order to get recognition and reach an optimal operational level by farmers. This framework emphasises reconsideration of decision-making mechanisms that are based solely on 'expert' knowledge that ignores IKS. This context provides an opportunity for a legacy of a society that protects its IKS. We find that this integration framework has started to take root with science and society beginning to blend and bond, providing potential to further mainstream IKS in adaptation systems (Jain, 2013).

Second, literature highlights that there are complementarities between scientific and IK forecasts (Mafongoya *et al.*, in Mugabe *et al.*, 2010; Ziervogel and Opere, 2010; Dondeyne *et al.*, 2003; Agrawal, 1995), Although IK forecasting lacks regulations and regimentation and encompasses spirituality, unlike scientific forecasts, both forms of forecasting are produced through observation, experimentation and validation (Kolawole *et al.*, 2014). A participatory approach has the potential to build the capacity of farmers and farmer groups to be able to measure daily rainfall on their own, recording these measurements and then using this information, with the guidance of scientist and extension, to make decisions for their day-to-day farm operations. This effort will address the limited availability of weather stations in districts around the country, leading to improved decision-making regarding pest outbreaks, crop diseases, droughts, and floods (Mberego and Sanga-Ngoie 2014). Similar efforts, which Zimbabwe can learn from, have been implemented in countries such as Mali and set up by the National Meteorological and Hydrological Service in Mali (Stigter, 2010).

Third, farmers are generally receptive to external information if it is provided in the right form and content and can integrate new information into their traditional forecasting methods (Orlove *et al.*,

V A farmer collects eggs from her chicken run, Dangarendove, Zimbabwe.

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2010). This openness provides an opportunity for scientists to engage these farmers and design forecasts that are congruent with farmers' expectations and practices. The onus remains on scientists to step out of their disciplinary confines and meet farmers in a 'third space' and co-design methods that improve on forecasts. Within this context, participatory learning and outreach programmes become key (Glantz, 2003, 2005; Goddard *et al.*, 2010; Mberego and Sanga-Ngoie, 2014). Elsewhere on the continent, tripartite arrangements with climate scientists, farmers and policymakers have begun to register success in terms of reaching a common ground and culturally relevant climate forecasts (Kolawole *et al.*, 2014; Ogallo, 2010; Phillips and Orlove, 2004), a model that has also started to be documented in Zimbabwe, albeit in its infancy (Mapfumo *et al.*, 2015; Mugabe *et al.*, 2010). One case in point in Zimbabwe is a study conducted in Chiredzi, where a participatory process led to the development of a tailored model for seasonal climate forecasts that meet the needs of the smallholder farmers concerned. In this case, the model embraced the fact that these farmers prefer 'binary' (which just tell them whether there will be a drought or not) to 'tercile' forecasts, which give no information regarding droughts (the most prevalent climate risk in the district) (Unganai *et al.*, 2013).

Among the methods suggested in the cited studies for the tripartite engagements are workshops, innovation platforms, public lectures, farmer field schools and media engagement. A suitable platform is therefore required for this process to take form in Zimbabwe and provide an opportunity for the improvement of climate forecasts in the country. In addition, it is important to bring on board extension in this process to allow for capacity building activities that empower extension, which has highlighted a gap in education efforts in particular. In this process, not only will scientists make recommendations to policymakers for improvement of forecasts as is normally the case, but rather, farmers and extension officers will also have an opportunity to suggest alternative ways of improving the quality of inclusive forecasts. This means that institutional strengthening is critical by ensuring that the participatory process is institutionalised within the national meteorological services and agricultural extension system.

Conclusions and recommendations

This chapter has outlined the importance of seasonal climate forecasts for smallholder farmers, who depend on rain-fed agriculture and the rationale for use of IK forecasting in decision-making for farm operations. A salient issue emanating from this exposition is that scientific forecasts, while helpful for smallholder farmers, are fraught with limitations that make it difficult for these farmers to access and use the forecasts for planning and implementing of farm activities, including a serious gap of inclusivity by these scientific forecasts. This underscores the need for IK forecasting, which has existed among farming communities in Zimbabwe for generations to play a more visible and formal role in climate risk management than is currently the case, given that this form of knowledge is more equitably distributed and seriously acknowledges existing strategies towards climate change adaptation.

However, this chapter also admits that IK forecasting is not without its limitations, and in light of this, concurs with studies that propose a framework for the integration of IK forecasting with scientific forecasting for improved seasonal predictions in order to reduce climate risks. This framework further underscores a platform of participatory learning in which farmers, multi-disciplinary scientists, extension workers and policymakers convene for concerted efforts towards instituting more robust seasonal forecasting systems.

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CHAPTER 6 - The use of underutilised crops and animal species in managing climate change risks

O. Jiri, P.L. Mafongoya and R. Musundire

Abstract

The vulnerability of smallholder farmers to climate change can be alleviated by the diversification of agricultural production and food systems through the promotion of underutilised species, which offer opportunities for strengthening adaption and resilience in the face of climate change. Smallholder farmers in southern Africa are among the most vulnerable to climate change because they rely heavily on rain-fed agriculture. A key strategy to adapt to a changing climate in this region would be the development and promotion of underutilised crops, livestock and edible insect species. Exploiting the large reservoir of minor and underutilised crop plants would provide a more diversified agricultural system and the food sources necessary to address food and nutrition security concerns in the face of climate change.

∨ Chad - Farmers checking the growth of a cassava crop.

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The genetic resources of indigenous livestock have traits of value for climate change adaptation, such as smaller body frames and lower feed requirements, the ability to utilise low quality feed, high fecundity and good mothering ability, tolerance to thermal and hydric stress, and disease and parasite tolerance and resistance.

Human consumption of edible insects could boost protein intake and increase resilience to climate risks, particularly in climate affected communities, through the diversification of food sources. The promotion and use of underutilised crops, livestock and insect resources provides adaptation opportunities, but generally these are not well quantified. There are clear opportunities for increasing productivity of such resources for enhanced climate change resilience through crop diversification and genetic variation.

In this chapter, we explore the potential for underutilised crops, livestock and edible insect resources to improve food and nutrition security, increase agricultural diversification and minimise the impacts of climate risks. We conclude that a key adaptation strategy will be through the research and development of underutilised crops, livestock and edible insect resources, which have proven their potential to cope with the adverse effects of climate change.

Introduction

The Intergovernmental Panel on Climate Change (IPCC) argue that about 30% of world biota is likely at very high risk of extinction as temperatures rise 2 degrees above that of the pre-industrial era (IPCC, 2013). Biodiversity loss will affect food and agriculture by causing losses of genetic diversity within species that are important to agriculture. Genetic resources are the living materials that local communities and scientists use to cope and adapt to changing socio-economic needs and ecological challenges (Kilroy, 2015). Utilisation of a wide basket of genetic diversity at a time of climate change will be an essential insurance policy for the food and agriculture sectors. With climate change, the value of underutilised genetic resources for food and agriculture will increase in the near future. Many of these underutilised resources will become more threatened as global climate change will erode genetic diversity and significantly destabilise food systems. Genetic diversity that is currently underutilised may become more attractive to farmers as a result of climate change.

Impact of climate change in agriculture and livelihoods

The Fourth Assessment of the IPCC provides an overview of recent scientific understanding on climate change (Klein *et al.*, 2014). Climate models are predictable means used to forecast global future climate, with 21 global climate models (GCM) giving different scenarios based upon atmospheric science, chemistry, physics, biology and astrology. As indicated by the GCMs, global temperatures will likely increase by 6.4 degrees by 2100 (IPCC, 2007). More critically for agriculture in southern Africa, water availability will decrease with the region receiving less and more erratic rains, therefore, the frequency of droughts will increase (Ericksen *et al.*, 2011). As temperature rises, the suitability of grains for production will decrease more rapidly in areas with sandy soils than in areas with heavier soils (Webb *et al.*, 2012). Furthermore, the frequency of extreme weather events such as cyclones, floods and prolonged droughts in southern Africa are likely to increase due to climate change and climate variability.

The implications of climate change in agriculture are still vague as such expectations are based upon modeling and predictions. Lobell *et al.* (2008) carried out an analysis of climate risks for crops in 12 food insecure regions to identify adaptation priorities based upon statistical crop models and climate projections for 2030 from the GCMs. The results indicated that southern Africa is one of the regions that, without sufficient adaptation measures, would suffer with negative impacts on several crops and animal species that are key to farmers. Southern Africa will be particularly hard hit by climate change as crop productivity of almost all crops is predicted to greatly decline (IPCC, 2007). Increased temperatures are expected to reduce yields of major crops whilst encouraging weed and pest proliferation (Speranza, 2010). These anticipated negative impacts of climate change threaten the food security of the region.

Climate change in southern Africa will also have an adverse effect on species biodiversity (Rao *et al.*, 2011). This will include changes to distribution patterns, reproduction timings, the duration of growing seasons, plant composition, and ecosystems. These factors would result in significant changes to farming practices and to genetic resources currently used. Coping and adapting to such developments would involve the innovative use of agricultural biodiversity to provide adaptability and resilience in the face of climate change and variability.

Role of underutilised biodiversity in the context of climate change

The role of conservation, farm management of agricultural biodiversity, and the use of underutilised crop and animal species is neglected in climate change debates. Various climate change predictions of the GMCs have made it clear that the southern African region will be adversely affected by climate change. It is therefore important to consider how climate change could affect the on-farm management of cultivated landraces and their wild relatives.

In a climate envelope species distribution model, Ramirez-Villegas *et al.* (2011) used current and projected climate data for the future, up to 2055, to predict the impact of climate change on the wild relatives of groundnut (*Arachis hypogea*), potato (*Solanum tuberosum*) and cowpea (*Vigna unguiculata*). They reported that wild groundnuts were the most affected group, with 24-31 species out of 51 projected to go extinct, and their distribution area expected to be reduced by 85-94%, (both factors dependent on migration scenario). In terms of species extinction, cowpea appeared to be the least affected by the climate projections although according to other studies, almost half of the natural distribution area of wild *Vigna* spp. is expected to be lost by the middle of this century due to climate change. These results suggest that there is an urgent need to identify and effectively conserve crop wild relatives that are at risk of extension due to climate change. There are many reports indicating that new strains of pathogens and pests are emerging, and landraces and wild relatives are needed as sources of resistant genes (Adamson, 2010). It is difficult to predict new pests that will develop due to climate change. To address the threat of new pests, access to a diversity of local crops is necessary for farming communities. Hence, on-farm conservation of genetic resources can play a critical role in solving the emerging problems of climate change.

Underutilised genetic resources may become more attractive to farmers as a result of climate change. Many neglected and underutilised species currently maintained through in situ conservation could be important crops for the future. Their adaptability, plasticity and resilience to stresses may provide farmers with a much needed coping strategy in the face of climate change. To increase adaptive capacity to changes in rainfall and temperature patterns, community based management of a wide portfolio of plant and animal genetic diversity is required. The suitability of current crop genotypes to local conditions will change in both positive and negative ways depending upon the crop and/or livestock species, but will undoubtedly affect future diversity. On-farm management processes of agricultural biodiversity carried out by smallholder farmers, have led to increased genetic diversity that helps to diversify incomes and livelihoods. The genetic diversity created through such practices has traditionally allowed farmers to cope and adapt to adverse climatic conditions, and this process will continue to serve that function in future.

Climate variability and risks have always been a part of agriculture, and farmers have developed many ways of managing these risks. From a farmer's perspective, climate change is not seen in terms of major disasters such as floods or droughts, but rather as increased uncertainty, for example, a shift in the onset of rain at planting time or at the end of the rainy season. Some years bring excessive rainfall while others are very dry, with a greater irregularity within and between rainy seasons. Such weather uncertainty directly affects crop production and farmer income.

The use of a wide diversity of crops and livestock is key to livelihoods and survival strategies of smallholder farming communities throughout the world. However, the speed of climate change is reported to be much higher than that required for underutilised species and landraces to evolve and adapt to changing climatic environments. Nicoglou (2011) defines phenotypic plasticity as a "property of a genotype to produce different phenotypes" in response to different environments. Scientists generally agree that phenotypic plasticity can be a useful framework to understand the interactions of genetics, development, ecology and evolution.

In order to understand the role of on-farm conservation of agricultural biodiversity in the presence of climate change, it is also important to understand how communities have been using diverse plant and animal species in integrated production systems to adapt and cope with climate change shocks.

Neglected and underutilised species as a buffer for climate change

Indigenous farming communities in southern Africa maintain portfolios of neglected and underutilised plant species and animal breeds, and farm trees as risk aversion strategies (Kalanda-Joshua *et al.*, 2011). Mixed farming and mixed cropping are common practices to address such uncertainties. In Zimbabwe, farmers grow a portfolio of emergency root crops in their gardens, (e.g. *Amorphophallus campanulatus* – elephant foot yam, *Colocasia* spp. – taro, *Dioscorea* spp. – yam and *Manihot* spp. – cassava) to buffer the food supply chain during climatic shocks. Many such examples were also reported in the indigenous communities of Botswana, Lesotho, Malawi and South Africa, (Mapira and Mazambara, 2013). Although policy makers and the media highlight the impact of extreme events such as floods and droughts, farmers are more worried about irregular rainfall and the divergence of temperatures from their typical ranges.

Despite the general notion that underutilised crops are neglected by indigenous farming communities for specific socioeconomic reasons, the role of these species becomes extremely important to reduce risks and adapt to shocks caused by climate changes. The use of such underutilised crop genetics will be vital for sustainable agriculture (IAC, 2004). Traditionally, neglected species contribute significantly to the well-being and livelihoods of rural households. Many of these species are well adapted to the stressful conditions of extreme environments and hence, are necessary in the adaptation of farming systems. Underutilised species

Nigeria - A woman peeling cassava for gari production

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occupy important niches, are adapted to risky and fragile conditions of rural communities, and have a comparative advantage in marginal lands as they can withstand stress. They also contribute to the diversity and stability of agro-ecosystems, often playing a strategic role in fragile ecosystems such as those of arid and semi-arid lands. In addition, most of these crops do not require high inputs and can be successfully grown in marginal and degraded areas. They can also contribute to increased agricultural production and have the potential to provide useful genes for crop breeding to develop varieties capable of tolerating climate shocks (Pye-Smith, 2011).

However, the genetic resources of many of these important species are being lost through the rapid destruction of their natural habitats, especially in the tropics. Jat *et al.* (2012) depicted a very worrying situation with regard to conservation and the use of agricultural biodiversity, highlighting that few efforts are on track to curb the genetic and cultural erosion that is taking place on-farm and severely affecting the sustenance of local crops and varieties. Hence, more concerted efforts are needed to support on-farm conservation and the sustainable use of neglected and underutilised species.

An integrated faming system for climate change adaptation

Agricultural biodiversity is an important part of the climate change management strategies being developed by indigenous people and rural communities. However, it is not adequately recognised and the knowledge of how, when and what agricultural biodiversity has been used in the past to cope with climate change is scattered and not well documented (Mapara, 2009). Most rural areas have always experienced climate variability, and farmers have always had to cope with a degree of uncertainty in relation to the local weather. Their production systems are integrated with crops, animals, fisheries, perennial fruits and trees around the homestead or in the vicinity of rivers and forests, and consist of portfolios of a variety of staple crops for managing risks. Farming systems incorporating perennial fruit trees such as mango, not only provide options for household food supply, but household nutritional diversity as well. Interdependence is incorporated within such systems, designed to spread risks and vulnerability in the face of unpredictable climatic events.

In the past, production systems with greater diversity or with successfully integrated livestock, were often less vulnerable to sudden changes and demonstrated higher levels of resilience. Livestock were never really mentioned in the climate change debate until 2007 when the Food and Agriculture Organization (FAO) reported that livestock produce 14.5% of all greenhouse gases (FAO, 2012). If livestock are effectively integrated into ecological farming by smallholder farmers, they have the potential to mitigate some of the adverse effects of climate change, and represent adaptation strategies for farmers.

Indigenous knowledge systems (IKS) and underutilised crops

Agrobiodiversity exists at two main levels – in the combination of species that make up an ecosystem, and in the number of different gene combinations within a species. The more diverse farming systems are, the more resilient they are in overcoming biotic and abiotic stresses and delivering food and nutrition security. Diet diversity is achieved from the consumption of a range of crops which deliver nutrition and health benefits. Agrobiodiversity will be essential to cope with the predicted impacts of climate change such as the prevalence of pests and diseases.

An important source of resilience for indigenous people is their ability to nurture and manage domestic and agrobiodiversity. Recognising that crops are subject to variable and unpredictable weather events and the occurrence of pests, indigenous communities have traditionally favoured the cultivation of diverse crop varieties/landraces. Traditional farmers have domesticated, improved and conserved thousands of crop species and varieties over time (Kalanda-Joshua *et al.*, 2011). There is abundant evidence that communities and smallholder farmers using indigenous knowledge (IK) are already involved in selecting new varieties/landraces and adopting new crops. In Botswana and Zambia, the level of intra-crop diversity of traditional varieties of pearl millet and sorghum have remained broadly similar throughout the dry periods for the last 30 years (Rohrbach and Mutiro, 1997). This suggests that these materials show sufficient adaptability to enable farmers to cope with periods of significant rainfall shortage (Pye-Smith, 2011). In both countries, there was a loss of pearl millet and sorghum landraces demonstrating slow maturing characteristics, and a preference for early maturing varieties.

The increasing importance of traditional crops is shown, for example, in northern India where there is dependence on finger millet. For the past 4 years, rainfall has been decreasing from around 550 mm to 300 mm and the finger millet varieties grown and conserved by farmers possess excellent drought resistance traits (Varadan and Kumar, 2014).

Maize farmers in Zimbabwe have fostered a diversity of crops in order to guarantee a harvest and also to fulfill social and cultural means (Mapfumo *et al.*, 2013). Such crops include early maturity maize varieties such as *mukadzi usaende* or *mukadzi dzoka* (these words literally translate as 'wife don't go' or 'wife come back'), and are suitable for short rain seasons with dry spells. The conservation of landraces also applies to sorghum, pearl millet, cowpea and bambara nut. The cultivation of different varieties or landraces of the same crop is reported by local farmers to better guarantee a harvest, regardless of seasonal variability, and to ensure dietary diversity with better nutrition (Rurinda *et al.*, 2014). These studies show the interlinkages between IK and genetic resource conservation, and their roles in adaptation to climate change and climate variability. Such findings illustrate the need to support initiatives that conserve and promote local landrace production, seed fairs, community seed banks and community based conservation and adaptation strategies.

The demands and expectations of modern supply chains lead farmers to concentrate on fewer and fewer crops. The result is the steady loss of agrobiodiversity and will lead to the disappearance of strategic underutilised crop resources necessary for the wellbeing of millions of people. The loss rate of 'new' and underutilised crops through extinction and genetic erosion is accelerating as a result of droughts, pests and diseases, over exploitation, overgrazing, land clearance and deforestation. Together with species loss, there is an accompanying and equally alarming wide spread erosion of local traditions and knowledge, which in turn contributes to reduced biodiversity, worldwide.

The role of underutilised crops in mitigating climate risk

Cereals

Although many cereal crops are grown in southern Africa, maize (*Zea mays* L.) is one of the staple foods. Maize ancestry comes from outside of Africa, however as a result of hundreds of years of farming the crop and natural selection, it has become ‘indigenised’. Smallholder farmers in most rural areas in southern African farming systems continue to cultivate maize landraces, which they have kept from generation to generation (Jones and Thornton, 2003). It has been reported that maize landraces are drought tolerant during the establishment stage and are well suited to low input agricultural systems. Awareness of these desirable characteristics exists in the IK of the communities that still cultivate them.

Other cereals such as millets are examples of indigenous cereals grown in the dry parts of southern Africa (Rohrbach and Mutiro, 1997). These crops may have been indigenised to the dry areas due to many years of cultivation, as well as natural and farmer selection. Across much of the region, cultivation of pearl millet is mainly practiced at a subsistence level by smallholder farmers. It is only grown commercially as animal fodder in some areas. Compared with other staple grains such as maize, wheat and sorghum, pearl millet is less susceptible to pests and diseases, in addition to being more drought tolerant. Due to such characteristics, millet is a suitable crop for climate change adaptation, withstanding variable rainfall and intermittent stress. Millets could therefore be promoted in areas experiencing huge rainfall variability. The case of millets reaffirms the need to incorporate IK into efforts to promote new and underutilised crops in southern Africa.

Traditional leguminous crops

Different types of legumes are grown and consumed in tropical regions of the world. Some legumes are commonly used as food crops – such as cowpea in West Africa – while some are lesser known, neglected or underutilised outside of their indigenous areas. Table 1 shows some of the legumes grown in Africa. Underutilisation can be due to the hard-to-cook phenomenon of legumes and lack of information on potential food uses. Pigeon pea (*Cajanus cajan*), African yam bean (*Stenostylis stenocarpa*), lima bean (*Phaseolus lunatus*) and bambara groundnut (*Vigna subterranean*) are neglected or underutilised crops in many parts of Africa, including southern Africa.

Food legumes represent a major crop group in the southern African region because of their role in human and animal nutrition, nitrogen fixation, adaptation to stress conditions and general suitability to various cropping and agricultural systems (Chivenge *et al.*, 2015). However, it is usually easier for countries to attain food sufficiency using staple cereal crop production and hence, the production and availability of legumes remains low in southern Africa (Rurinda *et al.*, 2014). Looking at the total area cultivated, legumes such as soyabean, groundnut and common bean can be considered major legume crops in southern Africa (Gowda *et al.*, 2007). However, despite offering diversification and resilience in the face of climate extremes, such crops among other legumes, remain largely underutilised by farmers in the region.

A good example is that of bambara groundnut, a nutritious legume originating from West Africa and cultivated throughout southern Africa (Legwaila and Karikari, 2013). This legume, known for its drought tolerance, is found growing in harsh climates and marginal soils; but in spite of these traits the crop still suffers a status of neglect because of its unpredictability in yields, its long cooking time, and negative social image (Massawe *et al.*, 2015).

Table 1: Some of the legumes grown in Africa

Common name	Botanical names	Other names	Areas available / consumed
Cowpea	*Vigna unguiculata*		Africa
Black-eyed pea	*Vigna sinensis*	Catjan cowpea, hindu cowpea, kaffir bean	Africa
Soybean	*Glycine max*		Africa
Groundnut	*Arachis hypogaea*	Peanut	Africa
Pigeon pea	*Cajanus cajan*	Red gram, congo bean	West Africa, East Africa
Lentils	*Lens esculenta, Lens culnaris*	Split pea, red dhal	North Africa
Mung bean	*Phaseolus aureus*		East Africa
African yam bean	*Stenostylis stenocarpa*		West and East Africa
Lima bean	*Phaseolus lunatus*	Sieve bean, butter bean	Africa
Faba bean	*Vicia faba*	Broad bean, horse bean, windsor bean	Africa
Kidney bean	*Phaseolus vulgaris*	Navy bean, pinto bean, snap bean, black bean, haricot bean, pea bean	East Africa
Bambara groundnut	*Vigna subterranea*		Africa

Modified from Subuola et al. (2012)

Indigenous vegetables

Indigenous leafy vegetables may be defined as plant species that are either native to a particular region, or that were introduced to a region so long ago they have evolved through natural processes or farmer selection. The well-known Pedi proverb, 'Meat is a visitor but morogo is a daily food', captures the important role leafy vegetables have played and continue to play in the food systems of southern Africa. Urbanisation and the influence of urban life style on the rural African population resulting from urban-rural linkages, are altering the species composition of indigenous vegetables in favour of western vegetable species (Yang and Keding, 2009).

In rural areas, indigenous leafy vegetables growing in the wild as weeds, or cultivated in cropped fields, are still extensively used by households. At community and household level, knowledge associated with these vegetables is essentially passed on from one generation to the next. In many parts of rural Africa, there is a risk that this knowledge will be lost. Considering their potential nutritional value, indigenous leafy vegetables could contribute in a major way to the food security and balanced diets of rural households and potentially for urban households (Yang and Keding, 2009). Researchers have asked questions about the bio-availability of the nutrients they contain and answers are required urgently. Further research on aspects of African leafy vegetable species, such as their ecology, use, cultivation and nutritional value needs is therefore warranted.

Cultivation of indigenous leafy vegetables is restricted to a narrow group of primarily indigenised species in southern Africa. Examples of these vegetables are amaranth (*Amaranthus* spp.), spider flower (*Cleome gynandra*), rape or Chinese cabbage (*Brassica rapa* subsp. *chinensis*), night-shade (*Solanum retroflexum* and selected other species belonging to the S. *nigrum* complex), Jew's mallow (*Corchorus olitorius* and *C. tridens*), cowpeas (*Vigna inguiculata*) and pumpkins (*Cucurbita pepo, C. maxima* and *C. moschata*), melons (*Citrullus lanatus* and *Cucumis melo*) and selected other indigenous cucurbits, such as balsam pear (*Momordica balsamina*). These underutilised vegetables help farmers adapt to climate change by enhancing the diversification and resilience of agroecosystems.

Indigenous wild fruits

In southern Africa, trees are often known by individual names, called after members of the community or some important characteristic. The existence of these names illustrates the extent and value of IK. One of the purposes of promoting participatory domestication of indigenous fruits with local communities is to ensure that the benefits of developing cultivars remain within the community (Sanchez and Leakey, 2004).

Forests and homesteads are important sources of non-timber products. These products include indigenous/wild fruits which are consumed by communities and sold on the road-side and at urban markets to generate income. Wild fruits are essential for food security, nutrition and health, and for the social and economic welfare of rural communities. The miombo ecosystem of southern Africa is home to 200 species of fruit – 167 of which are edible (Akinnifesi *et al.*, 2006; Zuma-Netshiukhwi *et al.*, 2013). Fruits and products made from indigenous fruits constitute a cheap and yet rich source of carbohydrates, proteins, mineral elements and vitamins (Table 2). Indigenous fruits and their products are important during the hunger periods. The nutritious food resource helps rural women secure food for their families and generate income for various household needs. Miombo indigenous fruits such as sugar plum (*Uapaca kirkiana*), marula (*Sclerocarya birrea*), monkey orange (*Strychnos cocculoides*), baobab (*Adansonia digitate*) and bambara (*Parinari curatellifolia*) are rich in sugars, essential vitamins, minerals, protein, carbohydrates and oils, essential for human nutrition.

The domestication and commercialisation of indigenous fruits to improve the nutritional status and incomes of rural households, partly depend on the IKS of rural farmers. Studies in Zimbabwe on indigenous fruits show that their location, seasonal availability and preparation or use, is widely distributed amongst ordinary people in rural areas (Savious, 2011). However, IK of these fruits varies according to tribe, between men and women and between generations. In general, the Ndebele ethnic group, are mainly cattle people, and have limited knowledge of leafy vegetables and fruits compared to more sedentary tribes like the Shona and Tonga. In urban areas, knowledge on indigenous fruits and vegetables is limited, especially amongst the youth. The dissemination and application of local community IK for indigenous fruits and vegetables, such as their nutritional value, will enhance their use and value among the general populace.

Table 2: Chemical composition of Miombo indigenous fruits in southern Africa

Fruit species	Protein %	Fats %	Carbohydrates %	Phosphorus	Calcium	Magnesium	Iron	Vitamin C
Baobab *(Adansonia digitate)*	3.1	4.3	79.4	450	1,156	2,090	58	179.1
Bambara *(Parinari curatellifolia)*	3	1.5	88.2	339	129	830	103	10.4
Marula *(Sclerocarya birrea)*	nd	74.8	nd	3	16	27	1.7	nd
Monkey orange *(Strychnos cocculoides)*	11.5	6.0	61.0	2,106	60	1,633	60	22.9
Sugar plum *(Uapaca kirkiana)*	17.0	22.9	47.5	3,164	nd	1,129	43	16.8

Minerals and vitamins (mg/100 g); nd = not determined. Source: (Akinnifesi et al., 2006)

Livestock and climate change in southern Africa

Impacts of climate change for the development of Africa's livestock sector

Climate change is becoming a major threat to livestock production in southern Africa. The livestock sector is likely to be affected by climate changes through the following:

1. Rainfall amount in southern Africa will generally decline, reducing the amount of water available for livestock systems. In most places, rainfall is likely to become erratic with more sudden and destructive heavy downpours, resulting in flash floods and restricting livestock movement;
2. Temperature will increase and this will amplify heat stress on animals;
3. Catastrophic events such as droughts, floods and periodic storms will increase. Hail storms have been known to cause dramatic overnight loss of livestock;
4. Feed/fodder production will decrease;
5. Water availability for livestock will or decrease according to location and seasons;

6. Disease prevalence and distribution will change, dependant on location, hosts and vectors of major diseases. Most diseases prefer warm and humid environments, but the distribution of vector-borne diseases will be determined by complex interactions between the environment, vectors and the hosts. Heat and water stresses will generally increase susceptibility to disease.

Livestock adaptation strategies

Rural smallholder livestock producers have only survived as such due to their adaptive capacity in the face of adversity. In some cases, livestock keeping is defined by adaptability, as is the case with East African pastoral systems, which have elaborate systems for managing livestock in dryland environments (Thornton *et al.*, 2007). Livestock production is itself an adaptation strategy, adopted as a means of diversifying livelihoods, preserving assets and harnessing marginal resources.

Breeding locally adapted livestock species

The majority of livestock in southern Africa are locally bred species kept by small-scale livestock producers. Local breeds are less productive than the high-yielding 'exotic' breeds, however, they are better adapted to their environment and can survive the harsh conditions where introduced breeds cannot. Indigenous breeds are more disease resistant and drought tolerant than exotic breeds and with the absence of such resilient local livestock, smallholder farmers could not manage against diverse climate shocks.

Diversifying livestock types

Most southern African livestock systems consist of a diversity of livestock species that include a combination of goats, sheep, cattle and donkeys. Maintaining a diverse herd has a number of advantages and it represents a critical adaptation strategy. A diverse herd is an adaptation to a diverse ecology where vegetation can be highly varied in both space and time. One area might be dominated by grasses whilst a neighbouring area is dominated by shrubs. Cattle and sheep are better suited to grazing pasture whilst goats thrive on shrubland. In addition to ecological motives, farmers often change their stock type according to market forces, with cattle and sheep often highly saleable. Various species also have different production attributes and uses, with goats providing rapid rates of post-drought herd recovery, sheep providing seasonal income opportunities, and cattle providing prestige and social status in some communities.

Non-livestock farmers have often been observed to take up livestock keeping as an adaptation strategy to climate variability, usually starting with small stock. Selected livestock type depends on the availability of fodder, the capacity to thrive on crop residues, and disease resistance.

A more common animal production system is poultry, which has been advocated as a key survival strategy for many southern Africa farmers (IAC, 2004). Poultry production is a well-known and proven livelihood option in most sub-Saharan countries. It is based on low cost feeds and using locally adapted chicken species which require low veterinary care. Poultry play an important role in the national economies of most developing countries and an equally important role in improving the nutritional status and incomes of many smallholder farmers and landless communities (IAC, 2004). Studies have shown that adoption of poultry production increases food security in southern Africa (Thornton *et al.*, 2007) by providing readily harvestable animal protein to rural households, and eggs and meat that cook faster than pulses and red meat, therefore requiring less wood as fuel. Poultry are particularly important to women because of their relative ease of handling compared with larger livestock such as cattle and the fact that they can be reared on minimal space and using household waste as feed.

Eritrea - Animals grazing in the area around Asmara.

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Developing niche markets to preserve indigenous breeds

Despite the exceptional adaptation of livestock to local conditions, livestock experts have invested a lot of money trying to replace them with higher yielding foreign breeds that are costly to maintain, due to their low adaptation, and which are often rendered unproductive by environmental challenges. As a result, there is a risk of losing some of the adapted local breeds that could play a significant role in future adaptation to climate change. FAO estimates that up to 11% of mammalian breeds and 2% of avian breeds have become extinct in recent years with a further 210 cattle breeds and 179 sheep breeds classified as 'critical' or 'endangered' (Niggol Seo *et al.*, 2008). Maintaining local breeds requires a multi-pronged approach, starting with respect for the rights of local custodians of these breeds, and support for their production systems. Adding value may provide a means of raising the returns on indigenous breeds, and the identification of niche markets – an example can be seen in the marketing of desert lamb in South Africa (Borron, 2006).

The role of edible insects in countering climate induced food insecurity

Agriculture faces multiple challenges and expectations including the need to expand and yield 70% more compared to current output to feed the growing population. Annual cereal and meat production is expected to rise to about 3 billion and 200 million t respectively in order to meet the growing population (FAO, 2012). The higher output demand can only be met by the development of new agricultural technologies. However, agriculture is already facing pressure from scarce resources and is expected to compete for land and water with expanding urban settlements. Agriculture is also expected to serve other major fronts such as adapting to and contributing to the mitigation of climate change, and maintaining bio-diversity (FAO, 2012). While there are opportunities to meet these food, feed and energy demands through improved agricultural technologies and increased land area under production, another global avenue that has been proposed and initiated by FAO is the use of insects as food (FAO/WUR, 2012).

Insects satisfy three important requirements that make them genuine alternative food sources: they are an important source of protein and other nutrients; their use as food has ecological advantages over conventional meat and, in the long run, economic benefits for mass production as animal feed and human food through improved nutritional and health security. In addition, they are also a rich source of drugs for modern medicine, assisting in health security. Edible insects have been identified as key in complementing efforts to feed the increasing global population, and most regions of the world are already consuming them as part of their cultural and traditional values (Chavhunduka, 1975; DeFoliart, 1995; Igwe *et al.*, 2011; FAO, 2012; FAO/WUR, 2012; Van Huis *et al.*, 2013; Kelemu *et al.*, 2015). Kelemu *et al.* (2015) have reported the existence of 470 insect species that are consumed in Africa.

Van Huis *et al.* (2013), among other entomologists, outline the general characteristics that make insects successful living organisms in the face of varied climatic and environmental conditions. The qualities that enable insects to overcome the vagaries brought about by climate change include: high reproductive capacity; ability to fly; ability to diapause and hibernate in order to survive catastrophes; and their small size and high feed conversion efficiency, which allows them to complete their life cycle on minimal food resources. The sexual reproductive behaviour of most edible insect species promotes the exchange of genetic material among populations, thus facilitating the rise of new strains with adaptable genetic makeup. In the face of climate change, insects are therefore expected to rapidly evolve and become more adaptable. Edible insects are ready sources of food compared to crop plants and livestock that require several years of adaptive breeding in order to obtain suitable varieties under changing climatic conditions.

Edible insect growth and reproduction processes in relation to climate change

Most edible insects have reproductive and growth patterns that are similar to most non-edible insect groups. Reproductive patterns are often characterised by adults laying many eggs, for example, an adult female of the edible chaffer beetles *Eulopida mashona* Arrow (*Scarabaeidae spp.*) consumed in Zimbabwe (Musundire *et al.*, 2014a), lays more than 300 eggs in her lifetime. The large investment in egg production compensates for egg mortality during unforeseen disasters that may be brought about by unfavourable environmental conditions. If insects are to be used as food or animal feed, this quality is advantageous as it ensures that enough populations can emerge to satisfy food requirements.

Eggs often hatch in response to environmental or climatic signals such as moisture, frequent temperature changes, or the presence of hosts. The nature and reliability of these signals is likely to change with the varying climate and subsequently, some eggs may fail to hatch, disrupting the natural life cycles of some species. While this seems a possibility, several insect species have demonstrated egg and larval diapauses, which help them synchronise their life cycles with suitable environmental and climatic conditions. Most edible insect are thus expected to rapidly adapt to the changing climate for their survival.

Forecasts for climatic change in southern Africa indicate a possibility for high temperatures and in some instances, frequent droughts with consequent potential changes in the structure and function of both natural and agro-ecosystems (Lobell *et al.*, 2008). These changes are likely to impact positively and negatively on the life processes of most edible insects. In the positive sense, high rainfall and temperature is likely to favour more insect abundance as life cycles will be shorted due to positive responses to temperature and abundant food resources. Increased water stress to some plant species will again work in the favour of some insect species, with a consequent boom in population growth as plant sap, which insects feed on, becomes more concentrated with requisite nutrients. Conversely, high rainfall and temperatures may increase the prevalence of insect diseases in natural environments and thus, negatively impact population growth. Additionally, reduced food availability in the form of plant and animal resources as a consequence of climate change, will negatively impact on insect abundance, diversity and growth.

There is an urgent need to analyse the nutritional components of a variety of insects consumed in southern Africa, and postulate their roles as replacements for farmed animal and crop products in light of climate change. Most edible insect species studied in southern Africa have proximate constituents (protein, fat and energy) at higher levels than those found in the grains, grain products, vegetables and seeds consumed as a major part of the diet in many rural areas (Chitsiku, 1989; Musundire *et al.*, 2014b). Table 3 outlines some of the proximate nutritional compositions for some edible insect species studied in Zimbabwe. Edible insects are therefore a potential good source of nutrients needed for human physiological needs and can be used to supplement diets, especially in the case of anticipated crop failure under climate change.

Table 3. Proximate constituents (percent composition on dry matter basis) of selected edible insects of Zimbabwe (n=3).

Insect species	Constituents (mean %) ± SE					
	Protein	Fat	Ash	Carbohydrate	Crude fibre	Energy (kcal/100g)
Brachytrupes membranaceus	53.4±0.19	15.8±0.23	6.0±0.12	15.1±0.22	5.0±0.30	454.7±2.25
Carebara vidua	43.6±0.13	38.2±0.64	8.6±0.16	0.5±0.05	9.1±0.26	519.8±6.43
**Encosternum delegorguei* (without alarm pheromones)	43.3a±1.30	45.0a±0.95	1.3a±0.06	5.0a±0.61	5.3a±0.54	597.4a±3.12
**Encosternum delegorguei* (with alarm pheromones)	31.6b±1.26	38.9b±0.62	3.8b±0.12	3.7b±0.41	22.0b±0.65	490.4b±2.54
Eulopida mashona	46.3±0.11	11.8±0.26	10.9±0.12	16.2±0.12	14.8±0.15	352.2±2.34
Gonimbrasia belina	55.4± 0.22	16.4±0.36	8.3±0.17	8.2± 0.45	16.0±0.17	329.1±5.21
Gonanisa maia	51.1±0.70	10.9±0.01	7.7±0.29	14.1±0.99	16.2±0.13	355.3±0.89
Gryllotalpa africana	22.0± 0.86	10.8±1.24	12.6±0.97	47.2±0.32	7.4±0.24	362.3±2.34
Loba leopardina	25.8± 1.54	12.6±0.88	6.6±0.37	40.2±0.44	14.7±0.33	367.5±4.52
Macrotermes natalensis (winged reproductives)	37.1±0.29	41.6±0.08	3.5±0.15	0.4±0.05	4.9±0.12	542.5±0.4
Ornithacris turbida	42.7± 2.34	29.4±1.26	4.5±0.21	18.2± 0.52	2.0± 0.01	503.9±3.41

** For Encosternum delegorguei: means in the same column with different superscripts are significantly different (P < 0.05).*
Adopted from: Musundire et al. (2014b).

Strategies for development of edible insect value chains

Entomophagy or insect consumption has been widely viewed as a practice for the less hardworking persons, and the poor and marginal communities. Such associations hinder the widespread adoption of insects as food for hunger alleviation. However, with the increasingly erratic rainfall impacting the harvests of more and more crop farmers, there are fewer available grain food reserves to sustain the notion that entomophagy is for the poor. Edible insects are indeed part of the solution to addressing human food security challenges in the changing climate. These species can also be utilised as livestock feed and thus, provide a sustainable and alternative solution to crop-based fodder under the effects of climate change.

To sustain insect consumption and to increase the utilisation of insects as animal feed, there is a need to develop value chains for edible species. This requires active participation by all value chain players, from the communities and traders involved in entomophagy, and the scientists and researchers involved in product development, to government agencies and potential consumers. The development of structured value chains will improve the livelihoods of participating communities, and allow for the sustainable utilisation of edible insects and the conservation of their habitats.

Communication of the positive benefits associated with insect consumption is likely to increase and become more widespread in areas experiencing crop failure to help address food security challenges. This is because the inherent characteristics of edible insects allow them to grow rapidly and complete their life cycles using minimal food and space resources. Therefore, although such species will be negatively impacted by the effects of climate change through reduced food resources due to drought and flood conditions, rearing insects represents a climate change adaption strategy for farmers because they require less space, water and feed compared to cultivating crops and rearing animals. Their characteristics provide the opportunity for mass rearing/production for human consumption and/or for livestock feed.

Red locust, a dangerous crop pest, for sale at a local market in Madagascar.

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Conclusion

In the face of climate change and variability, the untapped potential of new and underutilised crops and livestock resources could play a crucial role for future food and nutrition security. An evaluation of locally available, underutilised crops and livestock species for climate resilience and adaptation using modeling techniques, is necessary for the rapid analysis of production scenarios. Well-calibrated and validated models could be useful tools in the selection of drought tolerant underutilised crop and animal resources. The ability of smallholder farmers to generate adaptive diversity, select advantageous traits and exchange selected materials with friends and relatives, will be key to climate change adaptation strategies.

While the international community is responding to the threats of climate change and variability by lending increased support to mitigation strategies, very little is being done to support the evolutionary breeding process – on-farm agrobiodiversity conservation – where the largest amount of the world's local crop and animal diversity is maintained for immediate use. Therefore, it is extremely important to understand the agrobiodiversity of underutilised crop and livestock resources, map out species' distributions and their threats, document who maintains/ exchanges both diversity and associated IK, and how these materials and knowledge flow from farmer to farmer. All this information will be important to guide local institutions and governments to develop suitable strategies for climate change adaptation and mitigation.

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CHAPTER 7 - The challenges of documentation and conservation of indigenous knowledge for natural resources management

L.M. Kilemba and P.L. Mafongoya

Abstract

The importance and value of indigenous knowledge (IK) in the management of natural resources has been ignored and not adequately integrated with modern science or formal education systems. This is despite the fact that over the years it has been the main process on which rural communities have relied upon for food security and income generation. Literature shows that there is a real threat to IK due to the advent of modern religions and western education systems. IK has often been regarded as primitive, pagan and unchristian. It has also been labelled as inferior, inadequate and generally looked down upon. Policy makers and planners have ignored it and, as a consequence, not much has been done in terms of recording and documenting it in any form, or disseminating it. The presence of IK is scanty and it is generally passed on orally. However, several studies have established that IK has been used successfully by rural communities and pastoralists over the years, not only as a food security measure, but also as an income generation activity and in the management of arid and semi-arid landscapes for natural resources. Its importance has been emphasised by several studies and government and global initiatives. Since IK is passed on orally to selected community members or by families from one generation to another, there is a real possibility that it will become extinct.

Due to the importance of IK however, there is an urgent need to devise modern sustainable methods of documentation and preservation of IK to avoid its disappearance. IK should also be integrated in school, college and university curriculums so that it can be mainstreamed and

disseminated. Regional IK centres should also be initiated culminating in the establishment of a national IK centre. Planners and policy makers, including national governments, should offer proper guidelines regarding the preservation and onward transmission of IK.

This chapter seeks to examine the various methodologies that can be used to document and conserve IK for its use and transfer to future generations. The chapter also outlines the challenges of IK documentation and conservation in the management of natural resources, and explores the possibility of establishing a national open access IK infrastructure.

Introduction

Indigenous knowledge (IK) sometimes referred to as local or traditional knowledge has been used since time immemorial. It has also often been referred to as a disciplined approach to managing knowledge systems and processes among a set of people with common practices, interests and goals. According to Boven and Morohash (2002), local or traditional knowledge remains an important and fundamental source of information gathered using 'alternative methods', which can be used in critical areas regarding development, environmental conservation, heritage protection and access to information and education. Msuya (2012) defined IK as a systematic body of knowledge acquired through the accumulation of

A Farmer Field School facilitator teaching participants about potable water.

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experience, informal experiments and intimate understanding of the environment in a given culture. In its most practical sense, IK is a traditional knowledge unique to every culture or society that can influence decision-making processes on the fundamental aspects of day-to-day activities like hunting, fishing, gathering and climate change management. Among rural communities and pastoralists, IK is regarded as a day-to-day matter of survival and regarded as a problem solving mechanism, which is not only necessary for their daily lives but also crucial for personal economic development and financial empowerment, culture preservation, income generation and poverty alleviation.

IK has also been used in food production and preservation, water conservation and soil erosion, health products for diseases and supplements; and adaptation to environmental or social change. IK is a complete body of knowledge, know-how and practices maintained and developed (usually) by rural communities and pastoralists who have long interacted with their natural environment. These sets of interpretations and understandings have been part of a cultural complex that includes language, naming and classification practices for resource use, rituals and spirituality, among others. IK is mainly transferred orally from generation to generation and is rarely documented and preserved for either its continued usage, or as a knowledge bank for use by future generations. Therefore, if current knowledge is not transferred to an identified or preferred heir, as per cultural customs, it could be lost forever.

Another current challenge is the marginalisation or exclusion of IK by modern society. It appears that over the years, insufficient attention has been paid to IK, contributing to its lack of development and integration within modern society. Instead, IK has been labelled as primitive by modern society and considered inferior to western-based knowledge. This has resulted in the ostracism and under-appreciation of IK, and the marginalisation of anyone practising IK to resolve medical challenges. Such individuals are regarded as primitive, looked down upon and often marginalised.

Whilst the benefits of IK – including poverty eradication and food insecurity – have often been maligned and ignored, IK is now emerging as a global concern and gaining in importance because of its acceptance as a problem solving mechanism for rural communities and pastoralists. It is effective in assisting rural communities' access and share information which, more often than not, is the only source of information they have or are familiar with. Rural communities and pastoralists have limited information sources, except for IK, which they use in day-to-day activities and for problem solving. These communities own IK, share it amongst themselves orally and more or less depend upon it for their very own survival. Therefore, there is need not only to document and preserve it, but also to initiate processes that require IK to be included in school curriculums so that it can be inculcated and valued by the youth.

Current issues regarding IK in natural resources and climate change management

Recent studies reveal that in the last two decades, there has been growing interest in IK. Research data shows that IK contributes to sustainable development and that social and economic development is no longer seen as the exclusive domain of western science and technology (Boven and Mohorash, 2002). IK also plays a substantial role in enhancing food security and improving agricultural productivity (Ponge, 2013). According to the Food and Agricultural Organization (FAO), food security means food is available at all times, is accessible by all persons, and is nutritionally adequate in terms of quantity, quality and variety in a given culture (Ponge, 2013). In other words, food security activities underscore food production and improved access to food in a given locality; effectively applied IK plays a crucial role in this process.

Each person needs access to enough quality and safe food at all times. It is, therefore, the responsibility of each individual to find a way to contribute to food security. As mentioned already, IK has a crucial role in this process and, therefore, needs to be well documented, preserved and managed for continuity purposes, transfer and transmission. IK can also be regarded as a scientific process because it is obtained through many years of practice and, therefore, provides scientific solutions to problems that communities are facing. IK is shared communally to help solve people's problems and those who possess the knowledge, use or possess it on behalf of the community to benefits all the people within that community. This sharing of information and easy access to it, provides relevant solutions in terms of its future, proper management, documentation and preservation to avoid the threat of extinction.

There are pertinent issues with regard to IK management not only in Africa but worldwide. Recent literature has increasingly recognised the importance of IK and recommended the documentation and recording of this knowledge. However, debates seem to regard IK as a preserve intended only for the survival of the poor, although some cases have been documented in developed countries like Canada and the USA. Most cases however exist in Asia, the Americas and mostly in Africa.

A study by Dixit and Goyal (2011) stated that in view of IK's potential for sustainable development, it is necessary to preserve it for the benefit of future generations. The tradition of rural communities has been that IK is stored in the minds of people through various cultural forms such as folk stories, songs and drama, legends and proverbs. However, available literature has recommended that in order to conserve such a valuable resource, documentation and presentation of IK is required (Caldwell, 2007; Cetinkaya, 2009; Lwoga, 2009, Ghosh and Sahoo, 2011; Kiplang'at and Rotich, 2012). As early as the seventies, the importance of IK has been denoted in literature. For example Rodney (1972), comments that African achievements of the pre-European era stand as contributions to man's heritage of beautiful creation. While this may not be conclusive, perhaps it could be interpreted to mean that prior to colonialism, Africans had their own set of knowledge known as indigenous, traditional or local knowledge. The drawback of such a knowledge system is its transferral through word of mouth, and its preservation only through peoples' minds, meaning it can easily be lost through the passing of knowledge holders. While Rodney's (1972) statement was somewhat appropriate, it remains questionable. In the meantime regardless of whether the government is (was) colonial or not, there is need for proper strategies of accessing, managing and preserving IK for future use. It is also vital to document and preserve IK for it to be understood and acquired by the future generations for their own understanding. Some global organisations such as the World Bank and the Netherlands Organisations for International Co-operation in Higher Education tend to associate IK with the poor (Ochola, 2007), which has added more fuel to the marginalisation debate. As observed by Ochola (2007) in the aforementioned studies, it was intimated that IK tends to be associated with traditional communities or the poor, and often refer to IK as primitive or archaic, reducing the value of IK and contributing to the stigmatisation of such systems. These developments brought into play the notion that in order for an individual or community to be admitted to civilisation or modern society, it had to abandon practising IK (Ochola, 2007). This stereotyping of the IK systems (IKS) has resulted in studies focusing on the poor globally. In Australia studies have focused on the Aborigines, in New Zealand – on the Maoris, in Canada the Saskatchewan, in the US the American Indians and in Kenya, the Maasai. This situation, however, is somewhat changing as the world and 'modern society' come to terms with IK as an instrument for social and economic development, poverty alleviation and food security. Indeed the World Bank (1998) has observed that an investment in the exchange of IK and its integration into the development process can help reduce poverty and hence, acknowledges the need for its preservation, management and transmission.

Countries that have recognised the usefulness of IK and made attempts to document it, include China, Cuba, India, Japan and the Philippines. These countries have experienced an increase in the use of traditional and IK in their day-to-day lives, prompting Posey (2000) to observe the growing interest by the international community in the use of traditional knowledge regarding the identification of flora and fauna, and also in the genetic resources such as the agricultural and medicinal plants. Indigenous people, together with their languages, cultures and knowledge systems, are increasingly becoming the focus of international attention. South Africa is one of the leading countries to recommend documentation of IK for both historic and contemporary uses (Kaawar et al., 2000; Gericke, 1996).

In a study by Thandeka et al. (2011), the role of traditional leafy vegetables (TLVs) for food security provision in the households of rural KwaZulu Natal, was investigated. The study aimed at identifying and assessing rural households' levels of awareness, consumption and attitudes towards TLVs. The survey results revealed that red-rooted pigweed, blackjack and pumpkin leaves were found to be the most popular for food security because they supplied leaves, seed and fruit (Thandeka et al., 2011). While the study showed that there was a general positive attitude towards TLVs among household members and that consumption was significant to their nutrition status, it was also found that the use of TLVs was declining with time – possibly due to changes in customs and land use. The study concluded that due to a variety of reasons, the availability of TLVs has been declining over the years, and indicated the need for preservation because of their demonstrated importance to household food security. The study recommended appropriate nutritional education and communication strategies to help change attitudes and behaviour towards the consumption of traditional foods among the youth. Other

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^ **A vendor arranging leafy vegetables at a market in Lubumbashi, DRC.**

strategies like the production, processing, preparation and marketing of such foods to address the food culture in relation to IK were also recommended.

In Tanzania, Msuya (2007) investigated the challenges and opportunities in the protection and preservation of IK in Africa. Specific examples were taken from the Maasai pastoralists and the Sambaa and Zigua traditional medicine men of north-eastern Tanzania. The study argued that there is a threat of IK extinction due to the lack of documentation and preservation; there is also a problem of protecting the knowledge from those who tend to use it for their own purposes without acknowledging the source and/or even patenting it as their own. Ethical issues in IKS were also discussed with emphasis on returning IK benefits to the owners of the knowledge, as well as involving more people in IK research. One of the major findings of the study among the Maasai pastoralists is their knowledge and experience of supplementing their animals' diet with minerals, which not only provides resistance to disease, but also enhances their appetite, growth, fertility and milk production. This is a typical example of true IK that belongs to the community and is useful for poverty alleviation and food security, but which requires a platform where it can be captured, stored and disseminated. The study recommended adaptation of appropriate IK policies, establishment of IK databases and resource centres, the involvement of government and non-governmental organisations (NGOs) in IKS, and the formation of collaborative teams with other developing countries (Msuya, 2007).

In the coastal part of Kenya, the Taita people – locally known as Wadawida – consider TLVs as not only a delicacy but as an important source of dietary nutrients, containing compounds that have immune strengthening properties and vitamins. Both wild and domesticated TLVs contain high levels of essential elements such as calcium, iron, zinc and other minerals, making them complimentary to cereal crops that are staple foods for many households in Taita and other parts of Africa (Thandeka et al., 2011). The Taita people regard TLVs as a cheap and sustainable food resource crucial for their food security and nutritional wellbeing and have been using them since time immemorial. The Taita peoples' IK has been associated with the preservation and storage of food for later use and is orally passed on – especially to younger girls in the households.

The author of this chapter has attempted to search for any efforts on the documentation and preservation of IK among the Taitas. The search did not yield much but some attempts have been made, for instance by Mwadime (1996), who did a study on changes in environmental conditions and their indicators for monitoring household food security. There is also a Taita Research Station in Taita, set up by the University of Helsinki. While this is a locally based centre, it is run by foreigners without any native person on the management board to provide local input. Indeed it is this state of affairs that prompted this author to undertake a study to address such knowledge gaps as revealed by the two examples mentioned above.

This research hopes to encourage the establishment of IK resource centres in the county governments in Kenya, as well as a national IK resource centre. In addition, the research hopes to encourage the integration of IK within school curriculums to equip youths with the skills to take on active roles in the use of IK, as well as documenting, preserving and transferring IK for future generations, not only for the Taitas but the whole of Kenya as well.

It would appear the Government of Kenya (GoK) has joined her neighbours (Tanzania and Uganda) in their attempts to document, preserve and protect IK. An e-search by the author of this chapter yielded two relevant documents, namely, the *National Policy on Traditional Knowledge, Genetic Resources and Traditional Cultural Expressions*, 2009 (GoK, 2009), and a 'concept note' concerning IK from the then Ministry of Higher Education Science and Technology (MoHEST) on mapping and documenting IK in science, technology and innovation in Kenya (GoK, 2010). The first document was a submission by GoK to the Intergovernmental Committee on Intellectual Property and Genetic Resources, Traditional Knowledge and Folklore in Geneva. According to this policy document, it was developed in response to a growing need compounded by the realisation that IK is being created every day, and is evolving as a response of individuals and communities to the challenges of their social development. Additionally, the policy aims to develop a system that does more than merely document and preserve traditional knowledge created in the past, which may be on the brink of disappearance (GoK, 2009). In other words, GoK is concerned with the promotion and dissemination of the creative and innovative practices of IK, and preserving them for the continuation of national development.

It is hoped that the preservation of IK will encourage and foster creativity and innovation; as well as avoid plagiarism of the goods and services developed through IK by commercial prospectors and scientific bodies. This way, genetic resources – often dubbed the green gold by the corporate sector – of developed countries will also be protected. It is estimated that the market value of products produced by drug companies based on genetic resources (partially biological) are in excess of €6.7 billion today, comparable only to the market in computers and the accessories thereof. This comparison confirms that IK has huge potential for poverty alleviation and food security, and needs to be protected against exploitation through patenting as well as through the saving, documenting and storing of it through various databases and other forms of information technology. Subsequently, relevant stakeholders and organisations like central government, research organisations and universities, especially in the developing countries, need to be more involved in these activities using information technology.

The concept note or proposed research is an attempt by GoK to address IK among various communities, cultures and tribes of Kenya to find out the quantity of IK available in the country, the identification and documentation processes, and the implications of this knowledge for the economy and development within the framework of Kenya's 2030 vision (GoK, 2010). Towards this end, GoK has offered a clear concept of IK and its values, benefits, forms of communication and organisation; its importance in decision-making processes; its preservation, and the processes that will be used as a working tool and guideline in its mapping and documentation for all government departments and relevant stakeholders in the country. This effort is aimed at benefitting indigenous or local populations by improving food production and, among others, resources such as TLVs and edible fish oils; preserving agroforests and seed and tree species; and enhancing the cultivation, harvesting and storage of household foods for future consumption.

Such efforts clearly demonstrate GoK's appreciation of IK and the contributions of IKS to complement our understanding of fields including medicine, animal husbandry, resource management, agriculture and educational practices (GoK 2010). It therefore follows that with these efforts, GoK has recognised and taken measures to safeguard its traditional knowledge systems that have been transferred only through oral communication. Given that studies have shown the underutilisation of some IK methods and practices, GoK has also recommended the need to study, identify and integrate the useful ones with contemporary research agendas in order to enable users to respond to global opportunities and challenges (GoK, 2010). GoK has also indicated the need to support efforts in local technologies and systems of knowledge, since compared with many modern technologies, traditional techniques have proven to be effective, inexpensive, locally available and culturally appropriate. Indeed in some cases, IK is a matter of survival to the people who generated these systems. IK is also cumulative, representing generations of experiences, careful observations and sometimes trial and error experiments. It is regretful that as it is now, when an old IK holder passes on, a whole library disappears.

Promotion, publicity and current awareness on IK

While the issue of protecting and preserving IK has been debated and highlighted in various forums, there are few discussions on the promotion, publicity and awareness of IK. A review of recent studies reveals the extensive efforts that have been directed towards the protection and preservation of IK in Africa. Inevitably, this has brought into play a debate on the promotion, development and protection of existing IK, and the question of which of the two should be given priority. While no effort is being spared on strategies for documenting and preserving IK, the same zeal should be applied in terms of promoting IK awareness to a wider audience.

It is only through strategic and sustainable promotional campaigns that relevant stakeholders, including policy makers and planners, the youth and academics, will come to know and appreciate the usefulness and importance of IK in terms of income generation and food security. While protection and preservation is important, IK awareness should be increased for relevant stakeholders and the general public to ensure it remains pertinent in forums, curriculum developments, and plans and policy development discussions, culminating in the inclusion of IK in strategic plans going forward.

There are various strategies for promotion, publicity and increasing awareness depending on the targeted audience. While it has been generally accepted that IK can reduce poverty, hunger and generate income for pastoralists and rural communities, there is need to develop new tools that can help focus debates and initiatives. A whole new range of modern promotional information and communication technologies (ICTs) should be developed to include webpages on policy briefs, conference papers and presentations, and journal articles dedicated to IK and targeting national and local governments, donors, national academia and other relevant stakeholders. This strategy would encourage a shared understanding of how IK can contribute to reducing poverty; and of where investment in research is most needed.

Since IK is mostly transmitted orally – leading to its marginalisation – there is need to involve and invest in raising the awareness, appreciation and understanding of IK among the new generation who spend most of their time in formal western based education systems. School curriculums expose youths to modern ICT learning skills, but with little or zero appreciation of IK and its existence, thus marginalising IK further. There is therefore a need to establish IK databases in libraries and information centres, make use of modern ICT tools to disseminate IK, and include IK teaching within school curriculums. Indeed teaching and disseminating IK using ICT tools including PowerPoint presentations rather than outdated teaching methodologies often still used in some parts of Africa, should rouse and sustain not only their interest but motivate the young generation to appreciate and accept the benefits of IK given their appetite for web-based learning and social media. Indeed, this is one area that should be exploited to the maximum thus ensuring IK is integrated into the global knowledge system to ensure its transfer and continued survival.

The lack of ICT infrastructure in most developing countries, is proving to a big challenge and the main task at hand is to convince governments and other stakeholders to invest heavily in ICT infrastructure. On the other hand, although ICTs are being touted as the best thing for the documentation, preservation and promotion of IK, care must be taken to avoid the degradation of indigenous culture and the intellectual rights of indigenous people. Therefore, while governments are investing in ICT infrastructure and other resources, appropriate policies and guidelines should be formulated to safeguard indigenous peoples' intellectual property rights by ensuring best knowledge management practises and ethical considerations.

Challenges in documentation, preservation management of IK

Given the increased recognition of IK's importance, it follows that appropriate arrangements need to be done for in-country recording, storing, application and transfer of local IK within and between national and international communities (Grenier, 1998). Attempts to document IK must be considered, along with significant efforts to document, preserve, store and disseminate IK to make it more accessible not only for the future generations, but also to scholars and researchers. These kinds of projects need huge financial support since they are expensive and most likely long term. They will need huge collaborative efforts from individuals and governments as well as NGOs and relevant international organisations. In the developed world, IK has been given the priority it requires and countries such as Zimbabwe have set up national IK depository centres as well as local IK resource centres (Made, 2000). However, this has not happened in most developing counties and this must change.

Although the need for IK has received increased recognition in many countries, this knowledge is still passed on through oral tradition and documented only in people's minds – particularly by community elders – and when they pass on, their knowledge is lost. However, as mentioned previously, Dexit and Goyal (2011) affirm that it is necessary to preserve IK for the benefit of future generations. They recommend that the best way to conserve IK is to encourage youths to learn from their parents, grandparents and other adults within the community, and for education systems to integrate IK within school curriculums, especially for high school, college and university students. Initiating courses leading to diploma awards and undergraduate degrees in IK studies is another recommended strategy.

Ponge (2013) has shown that recent developments in the field of agriculture and rural development have seen a steady and rejuvenated recognition of IK for sustainable development. This development cannot downplay the role modern of scientific knowledge in land cultivation and in the development of ICTs for weather interpretation. But as Ponge (2013) states in his study, it is justifiable to advocate for a marriage of convenience between the two knowledge systems for effective outcomes for food security and sustainability.

More often than not, the role of IK has been neglected or ignored altogether, even as its uses are being increasingly recognised by international organisations such FAO, the World Health Organisation and the World Bank. It has been stated in various policy papers from such organisations and relevant departments of governments, that one

A locust survey officer consulting with local shepherds.

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of the strategies for developing the agricultural sector is to harness the potential of indigenous agricultural knowledge, and that this approach has the potential to contribute towards achieving the millennium development goals – particularly the first goal of poverty and hunger eradication (Ponge, 2013).

From these observations it is clear that IK can help alleviate poverty, if effectively applied in agriculture and supported by appropriate modern scientific technology interventions. It is therefore important to appreciate that the two are complimentary in their strengths and weaknesses and that combined, they are most likely to achieve what neither can individually. Therefore, there is need to value, document and transmit or disseminate indigenous people's knowledge and practices in investment projects, and build upon these assets by supporting pro-poor research that blends traditional knowledge and practices with modern scientific approaches (Ponge, 2013). From the reviewed literature it is obvious that IK has not been paid the attention it deserves, contributing to its disappearance. Such studies re-affirm the need for attempts to conserve IK to be undertaken sooner rather than later, and to compliment government efforts in preserving, managing and transferring IK to youths for its future use.

As already mentioned, IK has never been put down in writing but is passed on orally from one generation to another. This presents challenges regarding the documentation, management and preservation of IK. Boikhutso (2012) suggests that addressing these challenges could help build partnerships between relevant stakeholders like research organisations, universities and government departments for joint problem solving and appreciation of IK.

According to Boikhutso (2012), the lack of coordination in research activities involving IK makes it difficult for institutions to cope with IK preservation demands. It has therefore been suggested that a comprehensive research coordination framework is necessary for IK monitoring and to help different parties share practices and lessons on IK. In most countries of the developing world, IK is not coordinated at all, particularly in libraries and universities, or by NGOs and information centres, and neither do they collaborate on research and dissemination of the same. There is a need for national policies and guidelines to ensure related institutions and stakeholders involved in IK network regarding its documentation and dissemination. Further, those countries without national indigenous centres should set up the same immediately due to their crucial role in IK protection.

IK is usually preserved in peoples' minds and cultural practices which are often eroded by failing memories and death. In addition, IK is shared, transferred and communicated orally through traditions and cultures which is not consistent and is often fragmentary. Since IK is crucial for agricultural development, it is essential that it is managed and preserved in a systematic way using best knowledge management practices. IK is disappearing fast due to barriers that affect its transmission between community leaders, as well as between generations. There is therefore a need to determine a model for managing agricultural IK before most of it is completely lost. Haumba (2015) gives an example of the indigenous people in Kaliro District, Uganda, who have forgotten how to manage traditional food plants, previously a common practice in their culture. Such an example confirms that when older generations die before passing on their IK, valuable knowledge important for sustainable agriculture and food security is lost with them.

While the idea of integrating IK within schools and college curriculums is acceptable as a knowledge transfer mechanism, Msuya (2007) has also posited a caution in that not much research has been conducted in regards to IK. Hence, there is difficulty in obtaining knowledge and incorporating it within the educational curriculum for transmission from one generation to another. While knowledge generated by research institutions and universities is considered a valuable resource that can be used for development, and is well organised and disseminated to a wider community or audience, this is not the case with IK. IK drawn from a wide range of sustainable agricultural practices, environmental conservation, medical techniques, and health practices among others, is still frowned upon and herein lies the problem. Whereas modern scientific research processes are highly appreciated, in many respects IK is not or is still questioned.

Conclusion

This chapter has established that IK is crucial and still relevant to pastoralists and rural communities and is beginning to gain global attention in terms of its documentation, preservation and use for natural resource management. It has also briefly explained the various forms of

IK contributing to pests and disease management, food security and income generation. Concern for the documentation, preservation and dissemination of IK is gaining momentum but as established through various studies and initiatives, processes are not moving fast enough. Since IK is transferred orally, drastic measures need to be taken sooner rather than later to ensure that IK is not lost altogether.

IK is used in several fields including sustainable agricultural practices, environmental conservation and medical advancement, all of which contribute to the socio-economic development of a people and by extension, the country. If preservation of IK is not fully addressed, access to this knowledge will be limited, especially given the fast rate of socio-economic advancement, lack of coordinated research and the lack of research dissemination. Although IK is seemingly readily available to the general public, it would seem only the educated few know about its existence through research, conferences or seminars and workshops. It can be argued that IK is available in libraries, museums and to some extent in laboratories, but at present it seems these institutions play a protective rather than an open access role. Most libraries are also founded on the western model and offer their services to educated users – hardly a conducive atmosphere for a pastoralist or rural farmer. Even university

Sierra Leone - A sign at a farmer field school where farmers learn improved cropping techniques.

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students can struggle to use the readily available e-resources. A study by Nwezeh (2010) confirmed that some students went through their entire university programmes without using the library. It is in view of this that despite the intellectual property rights, it is crucial for government officials and policy makers to craft guidelines that will assist in meeting the needs of both the marginalised and the non-marginalised communities for their information needs in regard to the use of IK. It is also important that the awareness and use of IK is given the attention it deserves. It is, therefore, vital for policies and guidelines to address the challenges involving IK protection and preservation and initiate appropriate mechanisms for its implementation.

Some of the challenges of documenting and disseminating IK relate to its crucial and unique characteristics (e.g. done by oral transmission) which can be culture specific. Other challenge is that IKs does not have a universal scope and meaning that applies to all communities. A study by Haumba (2015) concluded that due to cultural and geographical diversity, each IK practice is culturally distinct from another, making it unique. IK custodians therefore try as much as possible to safeguard their own IK practices from other indigenous communities. One case cites the traditional healers of Kaliro District in Uganda who refused to reveal their healing secrets to their daughters, fearing they would share these secretes with the families they would marry into.

Recommendations

Further to the above conclusions, the following recommendations are put forward with a view of improving the documentation and conservation of IK for natural resource management.

Promotion and publicity of IK

Relevant awareness programmes should be developed to increase the recognition of the value of IK for food security, poverty alleviation and income generation among IK custodians to promote its preservation. At the same time, it is also prudent that pastoralists and rural communities share such knowledge with the younger generation so it is not lost. There is also need to disseminate this knowledge more widely to avoid the risk of IK becoming extinct; this should be achieved through its incorporation within formal education systems. Open access to IK should also be encouraged by libraries, museums and information centres.

The need for regional and national IK resource centres

Both local (regional) and national governments should immediately begin to establish IK resource centres not only as a matter of policy but as a national importance. The need for regional centres is important because each region or county has its own distinct culture, traditional values and by extension, IK. The functions of these centres would include:

- Jointly with the relevant ministry or arm of the national government and all stakeholders, to systematically document, preserve and disseminate all IK information for use by relevant stakeholders.
- With the relevant authorities, designing training materials on the methodologies for recording IK for use in schools, colleges, national training institutions and universities; and carrying out quality assurance of the methodologies and training standards;
- Establishing links between the originators and custodians of IK with the development communities, donors, researchers and national and global communities for networking, collaboration and research dissemination.

Use of ICTs to blend modern scientific knowledge with IK

Modern scientific methods using ICTs should be used including the creation of databases and e-resources on IK to make it more attractive for use, especially by the younger generation. The use of social media should be fully exploited since it is the current trend amongst the youth. Libraries, information centres and research organisations including universities should conduct joint research activities on IK, and network/collaborate to encourage online dissemination of their research findings. All stakeholders should be encouraged and enabled to share or exchange information freely online.

Future research

It is not possible to recommend all or most of the positive developments that could be undertaken within this chapter. However, there is need to deliberate, consult and share widely in terms of the challenges of documentation and conservation of IK going forward. Suffice to say, there is urgent need for all stakeholders to come together and chart the way forward in regards to further research and collaboration. Donors and national governments should allocate more funding to support future research in the key areas of IK documentation and dissemination for sustainable human and animal health, food security, poverty alleviation and income generation among others, not only for pastoralists and rural communities, but for national use.

Universities and other appropriate research institutes should be on the front line with deliberate efforts to conduct further research on IK. Potential future research areas could focus on the specific IKS that exist in Africa; how IK can be applied for productivity; how IK actually works in terms of evidence of its functionality; and best management practices and traditions surrounding the innovation, use and transmission of IK transfer in Africa.

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CHAPTER 8 - Indigenous knowledge to address the challenges of climate change: Case of Machobane Farming System in Lesotho

S.B. Mekbib, A.O. Olaleye, M. Johane and T. Wondimu

Abstract

Indigenous knowledge (IK) is increasingly recognised as important in developing mitigation and adaptation strategies for climate change. In this context, the chapter presents Lesotho's experience with the Machobane Farming System (MFS), an IK system to facilitate the sustainable production of crops, and its use for tackling the challenges of climate change. Lesotho is a landlocked country within South Africa, it has a population of less than 2 million and is highly vulnerable to climatic change. Agriculture remains a major source of income for more than 80% of the rural population. The arable land is only about 9% of the total land area of 30,355 km2 and the current crops (maize, sorghum, wheat, beans and peas) yield less than 2 t/ha, which is about half the level achieved in the late 1970s. Despite its contribution to Lesotho's development, the rural economy has been languishing due to poor land management and farming practices. Among other difficulties, the overall decline has been attributed to poor weather, declining soil fertility and poor management of water resources. Communities living on marginal lands (i.e. land with poor soil characteristics), whose livelihoods are highly dependent on degraded natural resources, are among the most vulnerable to climate change. The MFS is a farming practice, which is highly adaptable and resilient to climate change, enabling farmers to harvest a variety of crops throughout the year. In this study, as well as using a

questionnaire survey documenting the historical implications, current status and future prospects of the MFS and its adaptability to climate change, the physicochemical and microbial characteristics of MFS soil were assessed and compared with soil from non-MFS practicing fields. The MFS soils exhibited a slightly acidic to slightly alkaline pH with high levels of organic carbon, available phosphorus, base cations (K, Ca, Mg and Na) and a diverse group of fertility indicator microorganisms, including *Bacillus* and nitrogen-fixing bacteria (*NfB*). Overall, fields in which farmers were practicing the MFS remained green throughout the year in comparison to non-MFS fields. Although there are discernible challenges for the widespread application of the MFS, it is a climate-friendly farming system that has potential to be easily disseminated, combining IK and technology to produce sustainably high yields of a variety of crops throughout the year.

Introduction

The Kingdom of Lesotho is a country located in the southern part of Africa, situated within the Southern African plateau with a land area of 30,355 km2, at an elevation between 1,500 m and 3,482 m above sea level (Flannery, 1977). It is divided into four agro-ecological zones (Table 1) based on climate and elevation: lowlands (17%), Senqu River valley (9%), foothills (15%) and mountains (59%) (Cauley, 1986). Currently, about 9% of its land area is arable, the remainder of the country, being dominated

V A view of the artificial lake created by the Katse Dam.

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by rangeland, is suitable for extensive livestock production (Bureau of Statistics and Planning, 2007). The highest population density is found in the lowlands of the country, where most of the arable land mass is located. Here the increasing population pressure compounds the problems of serious soil erosion and land degradation (Bureau of Statistics and Planning, 2007). Rainfall is sporadic, and drought, hailstorms and winters can be quite severe. Even the estimated area of arable land in use is declining due to the erosion of the already thin layer of soil and limited vegetation. The high prevalence of mortality due to the AIDS pandemic results in less people being available to plough or cultivate the land, and in turn, the total cultivated land in use shrinks and decreases progressively. Wind and water carry 40 million t of soil away from Lesotho every year (Flannery, 1977). Weather is partly to blame for the soil erosion, but poor management and an ancient land tenure system also play their part. Lesotho has been described as one of the least forested countries in sub-Saharan Africa. However, trees are cut down for firewood and new shoots are eaten by animals, adding to soil erosion and further reducing the land available for agriculture. The soils of the Senqu River valley are an example of this erosion and it remains the most unproductive area of arable land in the region (Cauley,1986).

The Intergovernmental Panel on Climate Change (IPCC) report published in early 2007, confirmed that global climate change is already happening and that communities living in marginal lands are among the most vulnerable to the effects. This conclusion encouraged them to develop valuable knowledge to help communities adapt to climate change. But, the potential magnitude of future climate-related hazards may exceed the adaptive capacity of rural communities, especially given their current conditions of marginalisation (IPCC, 2007). Lesotho developed the National Adaptation Program of Action (NAPA) on climate change, under the United Nations Framework Convention on Climate Change (UNFCCC) in 2007 (Ministry of Natural Resources, 2007), and identified eleven adaptation technology options in agriculture – most of which address land and water management in agricultural production (Lesotho Meteorological Services, 2004; Dejene *et al.*, 2011).

Evaluation of the different types of farming practices (systems) currently in use in Lesotho is crucial, especially under conditions where the existing arable land (9%) is decreasing over time. In a recent assessment of farming practices (Mekbib *et al.*, 2012, 2015), the Machobane Farming

System (MFS), was concluded to be one of the most sustainable practices due to its high adaptability and resilience to climate change. It was developed, in the 1950s by Dr Machobane, for smallholder farmers who rely on the natural resources that exist around them (Robertson, 1994). However, there are uncertainties and challenges surrounding the use of the MFS.

The purpose of writing this book chapter on the MFS is:

1. To develop scientific evidence that the MFS is a more useful indigenous farming practice in Lesotho in comparison to other farming systems.
2. To develop baseline information for the sustainable use of the MFS and how its practices can be applied to smallholder farming areas in Africa.

Agriculture in Lesotho

Crop farming systems

Crop production is one of the most important components of farming systems in Lesotho, across all of the agro-ecological zones. The arable land is dominated by maize (63% of the planted land), followed by sorghum (28%) and wheat (12%), whereas beans and peas only account for 5% and 3% (of areas planted) respectively (Bureau of Statistics and Planning, 2007). The north and south-western lowlands, the Senqu River valley, the foothills and the mountain regions are the main cropping regions in the country. The amount and distribution of precipitation, as well as other climatic conditions in the area, are an important factor influence on crop production activity. The south-western lowlands are among the more susceptible areas to the erratic agro-climatic conditions in the region.

Currently, six farming systems or technologies are practiced in Lesotho, namely: block farming (IRIN, 2009), mono-cropping (traditional farming), conservation farming (SWaCAP, 2001), keyhole gardening (Taylor, 2008), double digging (using a 24 inch [610 mm] deep trench) and the MFS (Machobane and Robert, 2004). Data depicting the percentage of farmers engaged in each farming system is not available. These farming systems are promoted with the obvious goal of assisting rural livelihoods, conserving the environment, and generating income. However, their response to climate change impacts, as well as the adaptability and resilient properties of these systems, remain a crucial factor for consideration in the selection of the best farming practice for rural livelihoods in Lesotho.

Maize is the basic staple food crop in Lesotho, contributing to 40% of the population's daily diet. Sorghum is the next most important cereal, it is used in the preparation of porridge, traditional beer brewing and preparation of animal feed. Beans and peas have been grown as cash crops and are major sources of protein in the local diet. The areas under cultivation, and the yields produced, are very erratic and closely related to rainfall figures. Other major factors – soil infertility; the inadequate use of organic fertilisers; inefficient technologies, characterised by untimely planting; poor land preparation, including inadequate weeding; and delayed harvesting – also greatly affect crop production in Lesotho.

Animal husbandry

In Lesotho, livestock production plays an important role, both economically and socially, next to crop production, and contributes 30% to the country's agricultural gross domestic product (Turner, 1993). The sub-sector consists mainly of sheep (45%), goats (30%) and cattle (25%) (Bureau of Statistic and Planning, 2002). Other livestock reared in Lesotho, include horses, donkeys, pigs and poultry. Cattle are mostly raised for subsistence livelihoods, specifically for draught power (i.e. as transport and for ploughing and weeding heavy soils), milk, fuel (dung), and meat. The 1996 distribution of Lesotho's livestock population, in different agro-ecological zones, is depicted in Table 1.

Livestock are reared near homesteads for half of the year due to seasonal changes (the onset of winter), management practices (shearing and dipping), and to minimise the risk of theft. Thus, most stock have inadequate rations during long periods of the year, in terms of the poor nutritive value of fodder and forage available around the homesteads. This leads to an insufficient intake of dry matter by livestock. Though in some remote areas, rangelands are under-grazed, most village pasture areas are overgrazed. Farmers in Lesotho do not have a tradition of fodder husbandry on arable land, or conserving fodder as silage or hay. Thus, overstocking results in rangeland deterioration, which in turn affects livestock productivity – among other factors, such as the lack of proper feeding and disease control, poor breeding practices and stock theft.

The livestock sub-sector in Lesotho is less prone to erratic climatic conditions compared to arable agriculture. Good rains positively affect rangelands and the water flow in streams and rivers, on which livestock depend. However, the productivity of the sub-sector is severely affected by

Table 1: Agricultural activities in the four agro-ecological regions of Lesotho

Parameter	Mountains	Lowlands	Foothills	Senqu River valley
Main crops	Maize, wheat, peas, lentils potato	Maize, wheat, beans, vegetables	Maize, wheat, peas, fodder crops and potato	Maize, sorghum, beans
Vegetation	Denuded grassland, indigenous shrubs in some river valleys, stunted peach trees near homesteads	Crop stubble, reforestation on some hills, fruit trees near homesteads	Poplar and willow trees along streams and gullies, crop stubble, a lot of fruit trees near homesteads	Denuded dry shrubs, brush, a few trees in the valleys
Livestock summer grazing	High mountain cattle posts	Around villages	Around villages	Unsuitable dry areas
(percent of total livestock population)	*(%)*	(%)	(%)	(%)
Cattle	*32*	26	31	11
Sheep	*19*	10	58	13
Goats	*19*	20	45	16
Horses	*18*	19	49	14
Donkeys	*39*	23	25	13

(Source: Ministry of Natural Resources [MoNR], 2007)

the failure to maintain an appropriate balance between range resources and animal population, as well as the failure to adhere to traditional management practices (World Bank, 2001). The trend of a decline in the numbers of livestock and the sub-sector's output is attributed to declining animal nutrition, which has mainly resulted from the degradation and overgrazing of rangelands (Messner, 1989).

Climate change impacts on farming practices in Lesotho

Climate change offers both opportunities and risks for human development. As per IPCC's assessments, most parts of the world are likely to experience negative net impacts on food security due to falling crop yields, declining human health and shortages of water (FAO, 2011). Though no country is expected to escape the direct and/or indirect impacts of climate change, the magnitude of these impacts is likely to be worse in poorer countries, in which the majority of the population mainly depend on natural resources for survival. In addition, efforts to promote sustainable human development and environmental recovery in agriculture and forestry may also be negatively impacted.

Lesotho is one country that is critically vulnerable to climate change impacts because of its agro-ecological location. The large areas of high altitude rangeland, as well as the thin and highly erodible soils of varying fertility, make the country particularly sensitive to climatic events (Lesotho Climate Change Portal [LCCP], 2017). Climate change impacts on land-based economic activities and associated livelihoods are usually significant via the depletion of critical natural resources, such as fertile soil and water. Drought, as a result of climate change, has become a frequent occurrence in Lesotho, especially in winter and spring when the level of precipitation decreases (LCCP, 2017). Studies have shown that in dry soil the activity of microorganisms decreases tremendously and, consequently, soil fertility is further reduced (Mekbib *et al.*, 2012). Due to climate change, therefore, the overall spatial and temporal distribution of rain is extremely variable, particularly compared to the 30-year average distribution of rain in Lesotho (Ministry of Energy and Meteorology, 2015).

Farmers living in all four agro-ecological zones have noticed that the climate is changing. Long periods of drought and exceptionally heavy rainfall were noted by all focus group discussion (FGD) participants, selected from each of the four agroecological zones of Lesotho to discuss how indigenous knowledge (IK) helps them identify the impacts of climate change (Mekbib *et al.*, 2012). The changing climate has brought about an eminent shift in the planting season, which has excluded certain crops like peas and beans in the mountain areas. Climate change has also decreased yields, causing poorly developed buds, greater pest infestation, drought, flooding and hail storms. In the Senqu River Valley, FGD participants noticed that no particular crop was resistant to climate change. A shift in precipitation patterns ultimately leads to a shift in sowing and harvesting seasons, from which unexpected and disastrous situations can arise before crops are harvested from the fields. In the mountains, locally known as mantsonyane, and foothills rainfall is higher, but the cropping season is much shorter due to the early onset of frost, thus, the climate favours animal farming. An increase in precipitation in winter may cause increased activity in frontal weather systems, which may result in heavier snowfall and strong, devastating winds that often bring disasters and human suffering, posing significant risks to crop production and animal husbandry in Lesotho. In fact, some people have attributed these negative climate impacts to the construction of Mohale dam. In addition, every year, wind and water carries 40 million t of soil out of Lesotho (European Forum on

Rural Development Cooperation, 2002), a process which can also be regarded as intensified due to the impacts of climate change.

Adaptation strategies to climate change made by communities in Lesotho

In Lesotho, the specific measures taken to adapt to changing climate conditions have varied from one agro-ecological zone to the other. In the mountains, some farmers mentioned that they were experimenting to find out which crops are best suited to the short and shifting growing period. In the dry Senqu River valley, though no unique (innovative) measures have been implemented, mulching and returning residue to the fields was observed to be the best way of conserving moisture. Farmers in the Senqu River valley have also proposed water harvesting and the construction of small dams for irrigation during the dry period, as an effective adaptive measure in response to climate change. In the foothills at Pitseng village, farmers mentioned several adaptive measures that they had taken during FGDs, such as:

- Ploughing the land whilst the plant residue is still there.
- Avoiding burning the plant residue in order to conserve soil moisture and not destroy the nutrients.
- Establishing appropriate sowing seasons for different crops to cope with the shifting seasons caused by climate change. Farmers in Pitseng used to sow maize in August, but due to climate change impacts they have shifted the sowing season for maize forwards to the end of July.

In the mountains and foothills, though land productivity is low and subject to wide fluctuations, farmers are still experimenting and carrying out ongoing farm trials with different crops. These trials help farmers to establish which crops can cope best with the shifting sowing season using the MFS. According to the founder of this indigenous farming practice, Machobane, climate change constraints can be overcome by the rational exploitation of the resource base. This is achieved using a simple, low-input technique based on intercropping and crop diversification, with the localised application of manure and ashes.

The MFS and its resilience to climate change and potential for family food security

The benefits of applying organic amendments (manure) and ash are well recognised by farmers using the MFS. Manure provides vital nutrients for plant uptake and enhances long-term soil fertility by improving its physical properties. Ash, on the other hand, provides nutrients such as potassium, and has a liming effect on acidic soils. Though the appropriate application rate of manure and ashes varies depending on the soil quality, crop and availability of amendments; intercropping and relay cropping in a small area maintains crop harvesting throughout the year. Such field practices show that the resilience of the MFS to climate change is primarily in the form of drought resistance and the maintenance of soil fertility and moisture throughout the year. It was noticeable in the mountain and foothill villages practicing the MFS, that the practice sustains soil fertility by releasing nutrients slowly and conserving moisture.

With MFS field practices, a 0.4 ha area of land is considered sufficient to ensure food security for an average family of five members (one third of the area conventionally thought necessary) (Machobane and Robert, 2004). In Lesotho, seven basic crops are commonly grown: maize, potatoes, sorghum, wheat, peas, beans and *Cucurbits* (pumpkins and melons). When these crops are relay-intercropped in a 0.4 ha plot, the cropping pattern allows food to be produced almost all year round, reducing the likelihood of total crop failure and increasing productivity (Machobane and Robert, 2004). The MFS has shown great potential compared to other farming systems, allowing crops to grow in the field throughout the year whilst sustaining soil fertility. Results obtained from physicochemical (Figures 4, 5, 6, 7, 8, 9 and 10) and microbiological (Figures 11 and 12) data analyses demonstrate that the MFS's resistance to climate change has great potential to increase family food security.

The MFS and its requirements

There are some basic behavioural and technical requirements to adopt the MFS as an agricultural farming system. The basic behavioural aspects include the self-reliance of farmers, enabling them to achieve food security without external assistance. It is the farmers' will that makes the difference. Farmers must be convinced that they can improve crop production by fully exploiting their resource base, through their readiness to work hard, learn and teach, and with a commitment to help their neighbours (Machobane and Robert, 2004). Although the specifics of this farming system may be appropriate only in the temperate climate of Lesotho, many of the principles outlined here are also applicable to smallholder farming areas in tropical Africa.

a. Use of organic fertilisers

The MFS uses animal manure and wood ash as fertiliser. For the initial land preparation, approximately 7500 kg of manure and ash are used per hectare. Depending upon the type of soil, different mixtures of organic material are applied as required. About the same amount of organic matter is applied to the field before each cropping season. By the fourth year, the fertility of the soil will have improved, and less organic fertiliser will be needed each cropping season then after. Plant leaf litter and/or remains (mulching) can also be used as effective soil cover to maintain moisture and provide decomposing material to the plant.

b. Perennial vegetative cover

The MFS ensures complete crop cover throughout the year, because winter crops (e.g., wheat and peas) are planted in April-May (for harvest in January-March), and summer crops (e.g., maize, beans and sorghum) are planted in August-October (for harvest in November-December). The system uses minimum tillage (complete plowing of the field is only done once every 5 years) and thus, soil movement is minimised. Since crops are in the field throughout the year, grazing of livestock is not allowed. After harvesting, the residues left in the field build up humus that serves as sources of nutrients (fertiliser) for the next cropping cycle.

c. Cropping pattern adapted to varying climate

Lesotho's climate is temperate, with a warm summer and a cool winter. Late or early frosts, hail and seasonal drought are not uncommon. The Machobane system allows for the planting of cool weather crops, such as peas, wheat and potatoes, which perform well in winter conditions. In the summer months, maize, beans, pumpkins and other crops are intercropped (Figure 2). However, because Lesotho can experience drought in the summer, drought-resistant crops, like sorghum (aptly known as the 'camel of the plant kingdom'), are also planted to reduce the risk of crop failure.

d. Seedbed preparation and planting

In the first planting season, the field is ploughed, harrowed or disked to prepare the soil. A spade or hoe can be used to make the furrows or rows where the seed is to be planted. In April, the winter crops (wheat and peas) are planted. A double row of wheat is planted, with 30 cm between the two rows. Then a gap of 2 m is left, and a double row of peas is planted, again with 30 cm between the rows. Then, comes another gap of 2 m, followed by a double row of wheat, a 2 m gap, another row of peas, and so on. In August, the first batch of potatoes is planted in the 2 m gaps between the rows of wheat and peas; only half of the field is planted at this time. Starting in November, the rest of the field is planted with a second batch of potatoes (Figure 1).

In October the summer crops are planted in a complex intercropping pattern of maize, beans, sorghum, pumpkin and watermelon. In the 30 cm spaces between the double rows of wheat and peas, a single furrow is dug. Maize and beans are planted in this furrow, with 30 cm between the

Figure 1: Potato cultivation under the MFS: Mulching (Mekbib, 2012)

Figure 2: Maize intercropping with pumpkin and watermelon (Mekbib, 2012)

maize plants, and 15 cm between the beans. Every 4 m, two pumpkin seeds are added to the maize and bean hill. In every other row, watermelon is planted rather than pumpkin. Finally, sorghum is sown along the entire furrow (Figure 2).

After the first batch of potatoes are harvested in December, vegetables such as rape, cabbage, and spinach can be planted.

e. Crop management practices:

- **Tillage**

Once the crops are planted in the field, minimum tillage is done using a spade or a hoe. A hand-pushed ripper can also be used to open the furrow to plant the summer and winter crops. New crops can then be planted without harming the standing crops.

- **Weeding**

Weeds in the field should be controlled as they can harbor insects and pests, and can also compete with plants for moisture, light and nutrients.

The first weeding is carried out with a hoe immediately after crop emergence, to break up and aerate the soil around the crops and kill the weeds. The second weeding is done when the crops are about 1 month old. Crop residues are left in the field, helping to improve soil fertility and hinder weed growth.

- **Natural pest control**

Natural pest control is encouraged in the system, while chemical pesticides are discouraged. Since some crops act as natural repellents to certain insects, the intercropping practice contributes to pest control. The deliberate crop rotation helps to break the life-cycle of insect pests. Regular weeding throughout the year also helps to control pests and diseases. Additionally, some plants can create an unsuitable environment for insects, for example, the pumpkin plant has hair which irritates insects. Home remedies for pest control may also be used (Table 3).

- **Relay intercropping**

The relay intercropping practice involves sowing crops at different times of the year to avoid competition during the growing period. Time spent weeding one crop helps prepare the soil for the crop that will follow. The use of available land is maximised with the production of several crop species.

- **Relay harvesting**

The relay intercropping system that the MFS adopts allows for the staggered harvesting of crops, manually throughout the year. No machinery is used for harvesting. The winter crop of peas can be harvested in November (as green peas) and in March (as grain). Harvesting of wheat starts in January. The first batch of potatoes is harvested from late November to March; the second batch is harvested from the beginning of April. The potatoes are harvested as soon as the leaves and stems have become dry using a spade or digging fork. Green maize can be harvested in December and January, and green beans from December to February. Watermelons can be harvested from February and from March to May, pumpkins should be harvested. Beans in grain form are harvested from April to the end of June; rape, cabbage, and spinach can be harvested during the same period. Grain or dry maize and sorghum are harvested in June and July.

MFS practicing farms' soil analyses

The study area covers the four agro-ecological zones of Lesotho: the highlands, foothills, lowlands and Senqu River valley, as depicted in Figure 3. From each of the selected farmers' fields (Machobane and

Figure 3: The study area: Agro-ecological zones of Lesotho.

non-Machobane), undisturbed samples were collected from the mini-pits at the depth of 0-20cm to determine the soil's bulk density (Blake and Hartge, 1986) and water reaction (Klute, 1986). Samples were collected according to pedological horizons, based on the slope/relief of the area for both physicochemical and microbiological analyses. Data about the type of vegetation around each mini-pit, the position of the mini-pit on the slope, the type of parent materials in the area and the soil texture was recorded according to the United States Department of Agriculture's method.

Physicochemical data

Soil texture

Silt, clay and sand fractions of the analysed soil samples are shown in Figures 4, 5 and 6. These sites showed significantly different levels of sand, silt and clay. The silt and clay contents of the soil are good indicators of the soil's nutrient retention capacity. These sites are grouped into two categories those with silt contents > 40% (i.e. PMFS, PNMFS and TNMFS) and those with silt contents < 30% (i.e. MHNMFS, QNMFS, QMFS, TMFS, MHMFS, BBMFS and BBNMFS). The sand content from all of these sites can be grouped into three classes: those with > 50% sand contents (i.e. MHMFS, BBMFS and BBNMFS); sites with sand contents between 35 and

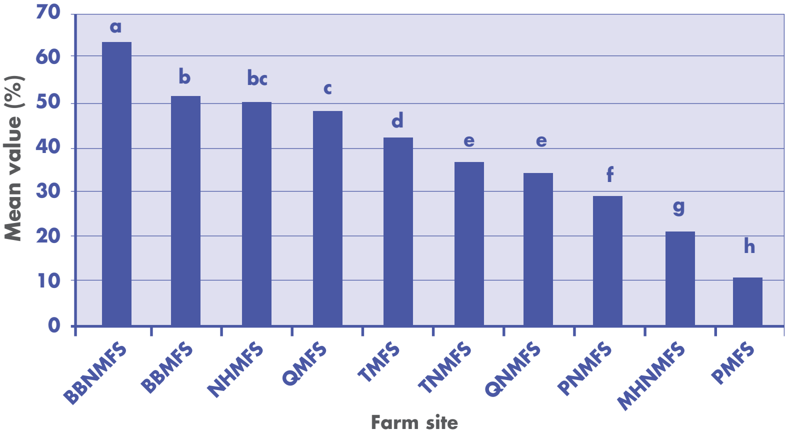

Figure 4: Sand fraction. Means with the same letter are not significantly different according to Duncan's Multiple Rang Test and grouping (P < 0.05).

Legend: Acronyms stand for the following representation: BBNMFS = Butha Bothe non-MFS, BBMFS = Butha Bothe MFS, MHMFS = Mohale's Hoek MFS, QMFS = Quthing MFS, TMFS = ThabaTseka MFS, TNMFS = ThabaTseka non-MFS, QNMFS = Quthing non-MFS, PNMFS = Pitseng non-MFS, MHNMFS = Mohale's Hoek non-MFS, PMFS = Pitseng MFS.

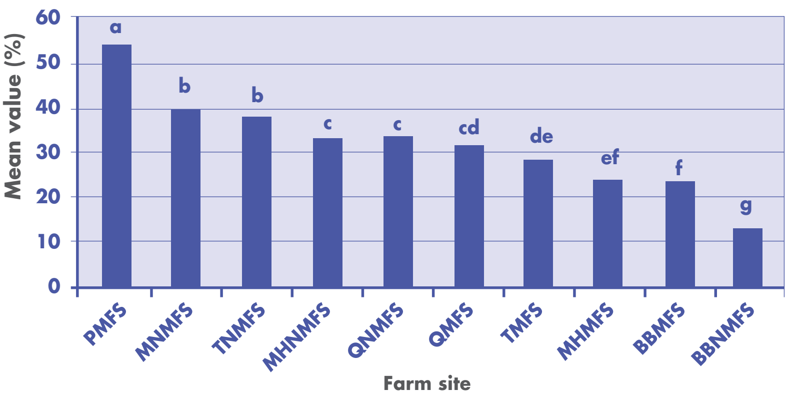

Figure 5: Silt fraction. Means with the same letter are not significantly different according to Duncan's Multiple Rang Test and grouping (P < 0.05). Legend: refer to Figure 4.

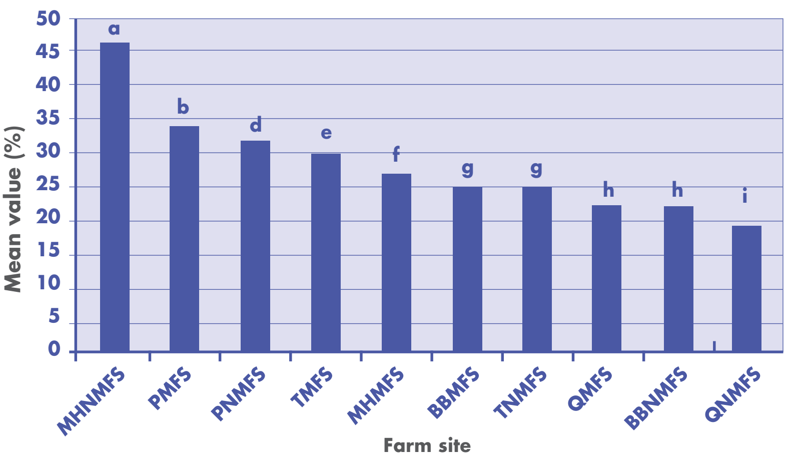

Figure 6: Clay fraction. Means with the same letter are not significantly different according to Duncan's Multiple Rang Test and grouping (P < 0.05). Legend: refer to Figure 4.

48% (i.e. QMFS, TMFS, TNMFS, QNMFS); and those with sand contents ≤ 35% (i.e. PNMFS, MHNMFS and PMFS) (Figure 4). The clay contents from all these sites can also be grouped into two groups: those with > 30% (i.e. TMFS, PNMFS, PMFS and MHNMFS) and those with clay contents < 25% (i.e. MHMFS, BBMFS, TNMFS, QMFS, BBNMFS and QNMFS).

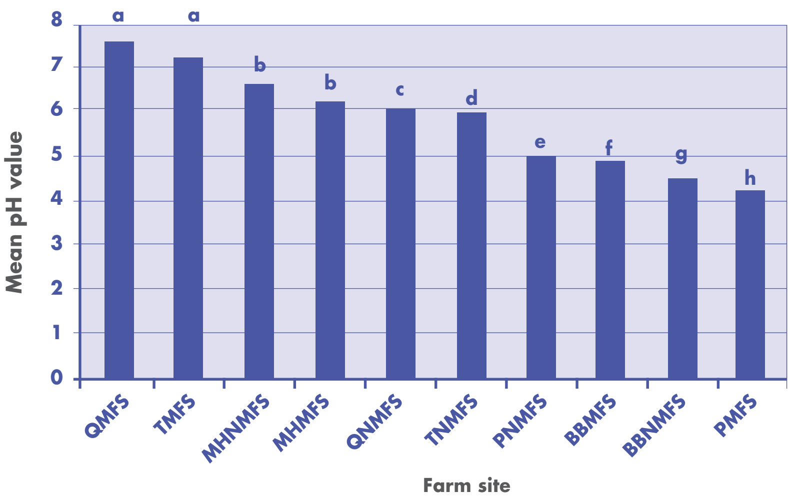

Figure 7: Soil pH. Means with the same letter are not significantly different according to Duncan's Multiple Rang Test and grouping (P < 0.05). Legend: refer to Figure 4.

Soil pH

Generally, the soil pH can be grouped into two classes. Those with pH > 6.0 (i.e. TNMFS, QNMFS, MHMFS, MHNMFS, TMFS and QMFS) and those with pH < 5.0 (i.e. PNMFS, BBMFS, BBNMFS and PMFS) (Figure 7). These sites had significantly different levels of acidity and alkalinity.

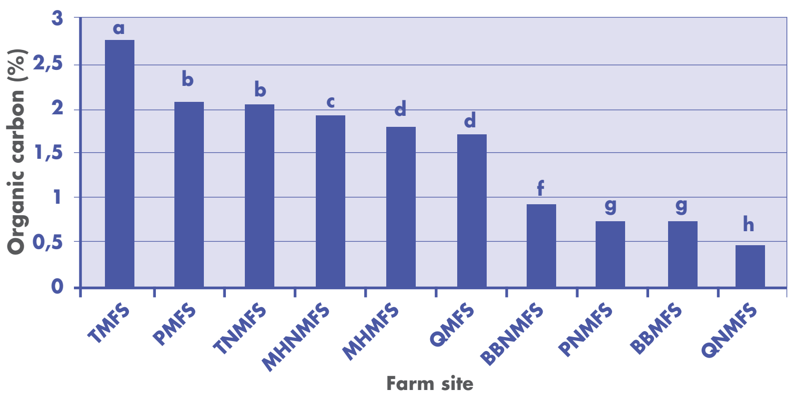

Figure 8: Organic carbon contents of soils practicing different farming systems. Means with the same letter are not significantly different according to Duncan's Multiple Rang Test and grouping (P < 0.05). Legend: refer to Figure 4.

Organic Carbon

The levels of organic carbon (C) can be grouped into two classes: soil with organic C < 1% (i.e. BBNMFS, PNMFS, BBMFS and QNMFS) (Figure 8) and those with organic C > 1.5%. These sites had significantly different levels of organic carbon.

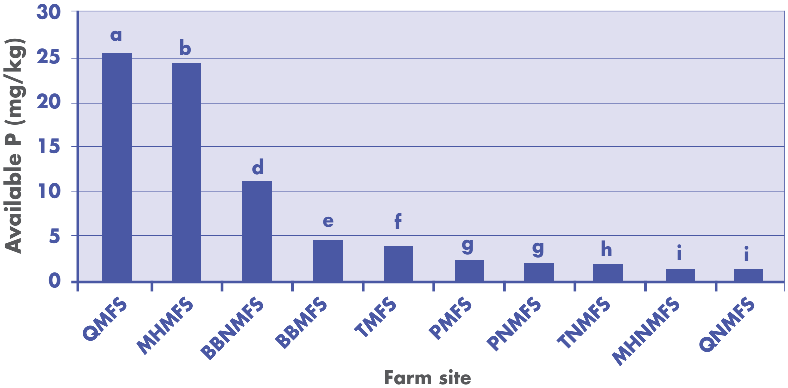

Figure 9: Available Phosphorus (P) in soils of Machobane and non-Machobane practicing fields. Means with the same letter are not significantly different according to Duncan's Multiple Rang Test and grouping (P < 0.05). Legend: refer to Figure 4.

Available phosphorus (P)

The available P was generally low and could be grouped into two classes: soils with available P of > 10 mg/kg (i.e. BBNMFS, MHMFS and QMFS) and samples with < 5 mg/kg of P (Figure 9). The sites had significantly different levels of available P.

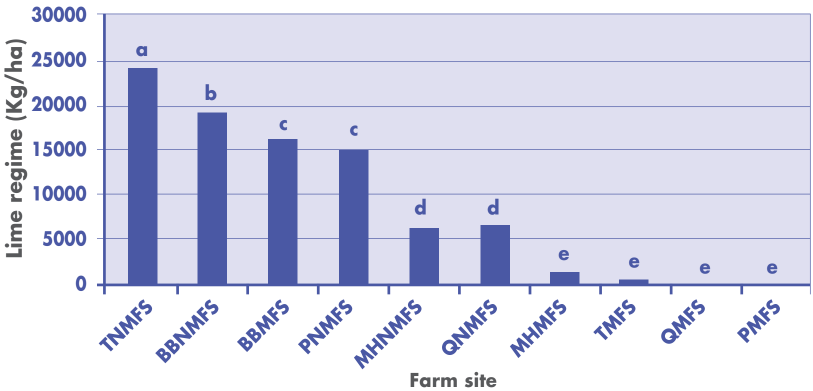

Figure 10: Lime rate (kg/ha) in different soils of Machobane and non-Machobane practicing fields. Means with the same letter are not significantly different according to Duncan's Multiple Rang Test and grouping (P < 0.05). Legend: refer to Figure 4.

Lime rate

Results showed that sites can be grouped into two categories based on their lime requirements: sites with lime rate > 1,500 kg/ha (i.e. PNMFS, BBMFS, BBNMFS and TNMFS) and those with lime rates < 10,000 kg/ha (MHNMFS, QNMFS, MHMFS, TMFS, QMFS and PMFS) (Figure 10).

Microbiological data

Soil samples from different agro-ecological zones of Lesotho were collected from five locations of Machobane and non-Machobane farming plots using (A4 size) brown paper bags. The samples were kept at 4°C in the fridge until processing. As a good indicator of soil fertility, the population dynamics of *Bacillus* spp. strains of plant growth promoting rhizobacteria (PGPR) and strains of non-symbiotic nitrogen fixing bacteria (NFB) were determined using the methods described by Foldes *et al.* (2000) and Kennedy *et al.* (2004), respectively.

Soil samples brought from Machobane practicing plots exhibited a higher number of soil fertility indicator microorganisms compared to the non-MFS soils. The total count of living NFB was 5.4 x 105 cells/ml followed by *Bacillus* spp. (1.96 x 105 cells/ml) (Figure 11 and 12). Soils rich in nutrients and carbon sources, not only increase the microbial population, but also the diversity of microorganisms (Colin, 2002). An increase in number could also be associated with the ability of the *Bacillus* spp. to fix nitrogen in nitrogen deficient soils (Colin, 2002), having an overall ameliorative effect on the soil pH. Significant differences were observed in soil pH improvement in some MFS practicing farms (Figure 7). The

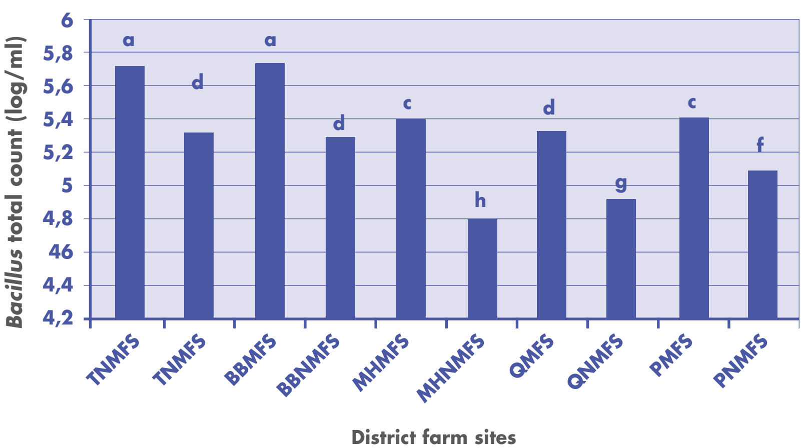

Figure 11: Total *Bacillus* spp. Count. Means with the same letter are not significantly different according to Duncan grouping at (P<0.05). Legend: refer to Figure 4.

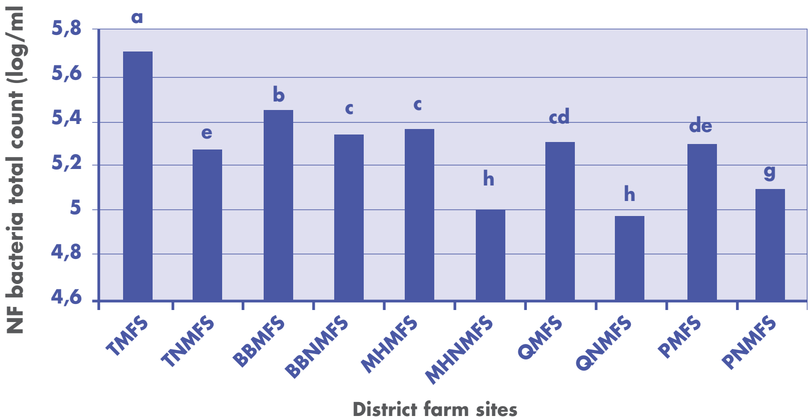

Figure 12: Total NFB count. Means with the same letter are not significantly different according to Duncan grouping at (P<0.05). Legend: refer to Figure 4.

Bacillus spp., as a PGPR, has also been known to exert a direct effect on plant growth by producing phytohormones, increasing the solubility of inorganic phosphate, increasing iron nutrition through iron chelating siderophores and volatile compounds that affect the plant signaling pathways (Joo *et al.*, 2004). They have also been known for their migration to aerial parts of the plant for the mediation of disease suppression activity (Gnanamanickan, 2003).

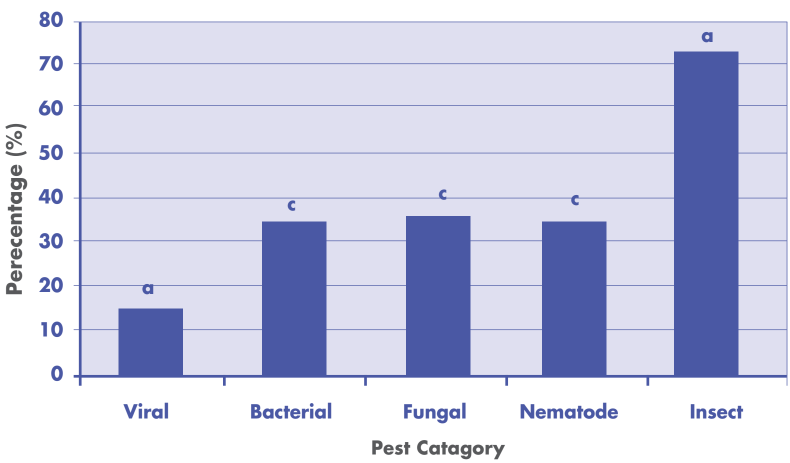

Figure 13: Crop pest category and prevalence.

Pest prevalence and control

Insects were identified as the major pests, followed by fungal and bacterial infections, which cause great damage to crop plants (Figure 13). Stock Borer (*Busseola busca*), and Bagrada Bug (*Bagrada hilaris*) were identified as the major insect pests, followed by aphids, which cause great damage to the crop leaves (>55%) and stem (51.5%), respectively.

Table 2: Crops grown in different agro-ecological zones of Lesotho; pests (cut worms, stalk borer and aphids), rust and smuts that affect them; and their control under MFS and non-MFS practicing farms

Agro-ecological zone (village)			Pest control methods under different farming practices	
	Crops	Pests, diseases and other environmental factors	MFS	non-MFS
1. Senqu valley (Mokanametsong)	• Maize • Sorghum • Wheat • Beans • Vegetables	• Cut worm (*Agrotis* spp.) and stalk borer (*Busseloa busca*) • Aphids (*Hoaba** and *Boroku**) • Rust and smuts • Blight	- Apply *Tigatus minuta* and an *Aloe* spp., onion and pepper concoction.	- Use pharmaceuticals, such as acaricides (*Dezzel NF**), fast take, avalanche* and cut worm. These chemicals are used to control animal diseases such as sheep scab.
2.Mountains (Mantsonyane)	• Maize • Sorghum • Wheat • Beans • Peas • Lentils • Vegetables	• Cut worm (and stalk borer (*B. busca*) • Drought • Drought • Frost • Frost • Frost	- Use *Aloe* spp., soap lather, *seholobe**, *moroko oa joala**, *seholobe** and *mosali mofubelu** - Apply a concoction of smelling types of herbs mixed with chillies during pest outbreaks.	- Use herbicides on small areas like gardens - Some buy commercial pesticides for field crops, such as sorghum, wheat and maize disease control.
3. Foothills (Pitseng)	• Maize • Sorghum • Wheat • Beans • Potato • Tomato • Beetroot • Green pepper • Spinach • Cabbage	• Cut worm (*Agrotis* spp.) • Cut worm (it was observed that Sorghum was not affected by worms in the previous years) • *Gradabug** (on vegetables) • Aphids (on vegetables)	- Apply a mixture of plant concoctions (different herbs), such as Aloe spp. and *Rhamnus prinoide* during pest outbreaks - The main advantage of this mixture lies in its being non-poisonous.	- Farmers use any pesticides as per their economy for application from the nearby available markets whenever there is an outbreak.

** = Vernacular name*

To control pests, about 44% of the respondents relied on the application of commercial pesticides and a further 30% used traditional pesticides in their farm. The formation of concoctions using various plant materials and other inputs has also been explained in the FGD in Table 2. The different types of crops that are grown at different agro-ecological zones and the types of disease/pests that commonly affect them are also listed in Table 2.

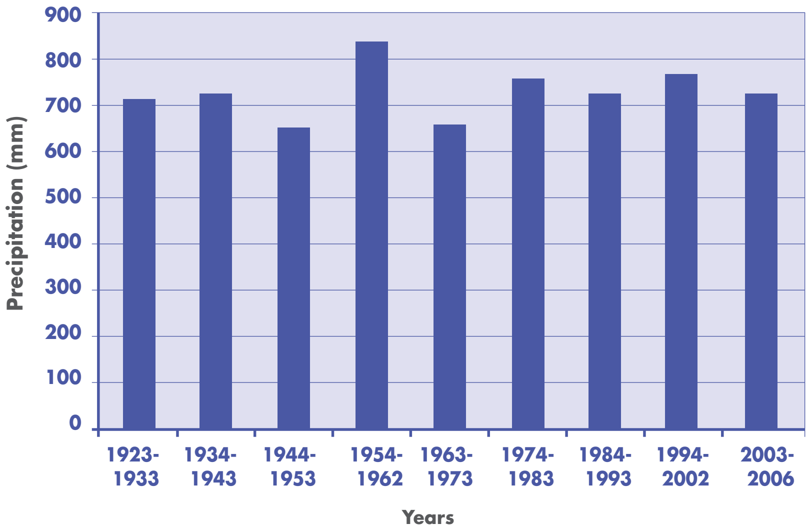

Figure 14: Precipitation irregularity in Lesotho from 1923-2006 (EM-DAT, 2008).

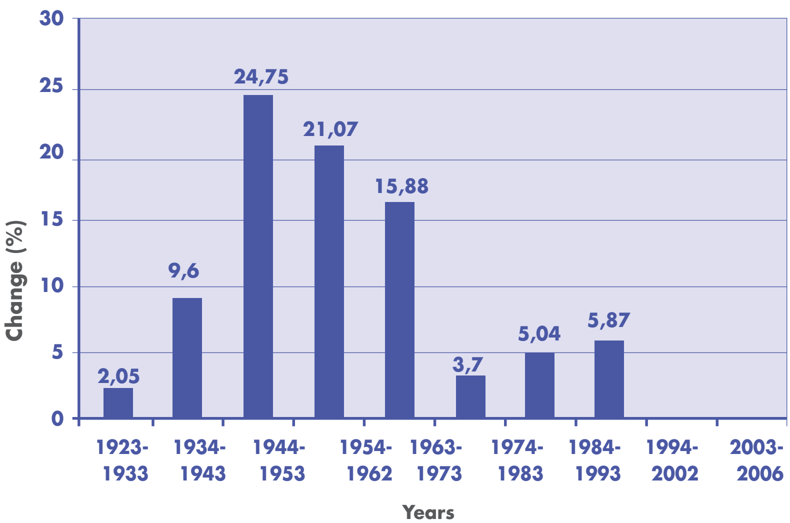

Figure 15: Decadal percentage change of precipitation in Lesotho (1923-2006).

Meteorological data trend analysis

The amount of precipitation and its percentage change over the years (1923-2006) in Lesotho is depicted in Figures 14 and 15 below. The highest precipitation was recorded between 1954 and 1962, but levels fluctuated irregularly, particularly from 1963 to 2006 (Figure 14). Results of the decadal change in rainfall were highest for the period 1944-1953 and this trend decreased successively over the decades to the lowest percentage change between 1974 and 1983 (Figure 15). However, the lowest precipitation change across the whole period recorded was between 2003 and 2006 (Figure 15).

The lowest precipitation change, recorded between 2003 and 2006, is an indication of high temperatures and the initiation of drought caused by climate change. This fluctuation in rainfall has brought an eminent shift in the planting season and excluded certain crops, like peas and beans in the mountain areas. The changing climate has also decreased yields as it has led to the poor development of buds, pest infestation, drought, flooding and hail storms. In order to take full advantage of the potential of new opportunities that may come with climate change, and avert the human suffering that may be associated with its adverse effects, more robust and coordinated national development policies should be in place to mitigate and adapt to climate change for the best advantage of the poor. In the mountain and foothill villages, the MFS was noticeably less affected by climate change than other farming systems. The sustenance of soil fertility maintained by the slow release of nutrients and conservation of soil moisture made the farms practicing the MFS more resilient to climate change impacts.

Current status of the MFS in Lesotho

The MFS pivots around the integration of cropping and livestock rearing activities, and requires a good understanding of land and crop management. Since its re-introduction in the early 1990s, nearly five thousand farmers have integrated this system into their land management,

V A view of a rural village on the side of a mountain, with a view of the central range of the Maluti Mountains in the background.

©FAO/Rodger Bosch

and have increased land productivity three-fold compared to traditional mono-cropping practices (Oakland Institute and the Alliance for Food Sovereignty in Africa, 2016).

In 1991, the MFS was incorporated in the International Fund for Agricultural Development's (IFAD) Soil and Water Conservation and Agroforestry Programme (SWaCAP) (Mosenene, 1999). Five years later, the government of Lesotho and the Machobane Agricultural Development Foundation launched another IFAD-funded programme, called the Sustainable Agricultural Development Programme for the Mountain Areas, in the three mountainous regions of the country: Mokhotlong, Thaba T'seka and Qachas'nek. The programme ran from 2001 to 2006 with 786 households (IPCC, 2007). In addition, a modified form of the MFS was applied to nearly 1,500 backyard garden households. Since 2005, local NGOs, such as the Serumula Development Association and the Rural Self-Help Development Association, have also promoted the MFS in their projects. The Machobane Agricultural Development Foundation's programme met some Machobane farmers in Lesotho and was impressed by their attitude to experimenting with the use and mobilisation of their own resources; their capacity to discuss the agronomic problems that they encounter; their comparison of the results of different procedures that they had experimented with in the past; and their pride in extending their knowledge to others. Farmers have reported three main advantages of the MFS: (i) the intensification leads to much higher land productivity, (ii) potato intercropping produces large cash revenues, and (iii) their fields remain green, even when non-Machobane fields are dry during periods of drought. The number of new farmers adopting the MFS in Lesotho has continued to increase rapidly since 1991, reaching about 1,600 farmers in mid-1996. The MFS projects also promoted soil ripping to break up subsurface compaction and bana grass to reduce sheet erosion between bunds and provide fodder. It was noted that the significantly high adoption rates of the MFS were linked to farmer-driven extension initiatives (Consolidated Appeal Program, 2007). Currently, however, due to the reduced provision of support and lack of available workforce, among many other factors, the practicality and disseminative role of the MFS has weakened slightly.

Challenges of the MFS

Resource limitation

A guiding principle of the MFS involves the application of animal manure and plant ash, two important elements for increasing soil fertility. The availability of animal manure is difficult for some, unless it is donated from other sources. Its widespread application raises the long-term issue of the sufficient availability of organic animal manure. In the mountains, large areas of pasture land are available, albeit some areas are in a serious state of degradation due to overgrazing. On average, a household may own some 30-50 small ruminants (sheep and goats, reared for wool and mohair, and occasionally slaughtered for meat consumption), and 3-6 cattle (essentially kept for animal traction and reproduction) (MoNR, 2007). Well over half of the dung collected in the kraals (livestock enclosures) is consumed as fuel. To sustain the large scale application of the Machobane system, more dung should be produced and collected, and less should be burned. Burning less dung requires the substitution of dung briquettes for an alternative source of energy, which is still much too costly to be considered as a solution. However, fuel wood can be grown, and Machobane farmers in the mountains are aware that this has become an imperative for them to survive. Burning planted wood – a renewable source of energy – would produce the required amount of ash, while increasing the amount of animal manure available for use in the fields. Increased dung production (and collection) does not require more animals, rather it requires healthier animals that are better nourished in winter when they are kept in the kraals. Short of purchasing supplementary feed – an expensive solution for the local people – a better option to provide winter feed would be to grow a fodder crop in the space provided by the improved land productivity obtained as a result of applying the MFS.

Competition over land

Livestock is one of the biggest challenges for MFS farmers. There is endless competition over land for grazing and land for farming. Basotho people are very close to their animals, but they have problems with their management of grazing. Farmers stop cultivating because their fields are being grazed by other people's livestock. The Research and Science Development Agency itself cannot do much to improve the situation, but a new land tenure system probably could and such changes have been discussed for years. Recently introduced local government policies have potential to be advantageous for mediating competition between farmers over land for grazing and cultivating crops. Meanwhile, the lack of formal land ownership keeps people from making substantial investments in the land and taking care of the environment. As quoted from Dr Machobane, "Young people will run away from agriculture if there is no profit attachment."

Nationwide policies and measures

For the nationwide dissemination of the Machobane indigenous farming technology, there should be a centrally administered sector specifically designed to mitigate and/or adapt policy to support MFS activities throughout the nation. As part of its initiative, the Machobane Agricultural Development Foundation has a unique opportunity and duty to work for the increased success of the MFS, in Lesotho in particular, and the rest of the world in general.

Conclusion and recommendations

The overall trend in precipitation and its percentage change over the years (1923-2006) in Lesotho showed high irregularity, which is an indication of the rise in temperature due to climate change. This effect results in decreased yields as buds develop poorly and there are increased instances of pest infestation, drought, flooding and hail storms. On the other hand, it is evident that the MFS practicing villages in the mountain and foothill areas, remained unaffected and appeared green throughout the year. This demonstrates that the MFS sustainably maintains soil fertility, despite irregular rainfall, by slowly releasing nutrients and conserving moisture.

The MFS practice is known to involve the application of animal manure and plant ash to increase soil fertility. The availability of animal manure, unless donated from other sources, can be difficult for some. Thus, its widespread application raises the issue of the sufficient availability of organic animal manure in the long-term. The long-term technical sustainability of the Machobane technology is a distinct possibility, but it requires the close integration of all activities in the farming system: crops, livestock, and forestry.

For the full exploitation of the Machobane farming practice in Lesotho and by other smallholder farmers in Africa, it is imperative that school children, herd boys, youth, farmers and households affected by HIV and Aids are trained to understand the basics of the MFS. The training should enable the poorest and most vulnerable rural communities to implement the system, using locally available materials to grow healthy crops in their gardens, without being adversely affected by climate change throughout the year.

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Tseliso Maetlane harvesting maize from his field, which he has cultivated using agricultural conservation practices.

CHAPTER 9 - Relevance of indigenous knowledge in weather and climate forecasts for agricultural adaptation to climate variability and change in Malawi

M. Joshua, C. Ngongondo, M. Monjerezi, F. Chipungu and C. Malidadi

Abstract

Subsistence rain-fed agriculture underpins the majority of rural livelihoods in sub-Saharan Africa (SSA). Reliable climate and weather forecast is therefore crucial to guide village-level decisions. It is widely agreed that scientific forecasts have spatial limitations at lower spatial scales, such as village level. Traditionally, rural subsistent farmers have relied on indigenous knowledge (IK) to understand weather and climate patterns in selecting crops and farming practices. However, farming environments are diverse and their vulnerability is varied spatially and temporally. Similarly, IK is site specific and its relevance in the context of climate changeability is also varied. Therefore, analysis of IK for agricultural adaptation in all diverse farming environments is necessary for informed interventions. However, there is paucity of documentation at local level. The current study addresses this gap for Malawi with case studies from Chagaka, Mpasu and Mphampha villages in Chikwawa district.

The study assessed the relevance of IK in weather and climate forecasting for adaptation to climate variability in the agricultural sector. IK indicators commonly used for weather and climate forecasting in the villages were established through focus group discussions (FGDs), key informant and household interviews. Subsequently, peoples' perceptions of climate change and variability were compared with scientific hydro-meteorological data, which allowed for applicability analyses of identified IK in agricultural adaptation. The results revealed the various forms of traditional indicators

used in IK, including environmental conditions and certain patterns of flora. Major climatic events reported by the villagers, including warming temperatures and declining rainfall trends, agree with empirical evidence. However, the value of some of these indicators is declining in guiding farm operations mainly due to increased rainfall variability, reducing confidence in IK and its adaptive capacity to climate change. This has impacted smallholder farmer crop and livestock production through changes in cropping patterns and declining yields. Therefore, villagers of the study areas suggested localising scientific weather and climate prediction, and enhancing farmer capacity through training in the collection and use of weather data as priority adaptation strategies to reduce their vulnerability.

In the long-term, scientific weather data is expected to be linked with indigenous observations, hence making both IK and conventional science more reliable. This study recognises the existing challenges of managing physical weather stations and suggests the use of localised automated weather stations.

Introduction

Subsistence rain-fed agriculture underpins the majority of rural livelihoods in sub-Saharan Africa (SSA) and supports the livelihoods of over 60% of the population (Staat *et al.*, 2007; IFAD, 2010; Livingston *et*

∨ A herd of cattle drinking water.

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al., 2011). Rain-fed agriculture also remains a dominant source of livelihoods in Malawi where over 90% of the rural population derive their livelihood from agriculture (NSO, 2009; GoM, 2010). Reliable climate and weather forecasting is therefore crucial to guide village-level farming decisions. It is widely agreed that scientific forecasts have spatial and temporal limitations for use at lower spatial scales such as village level (Adejuwon, 2007; Chang'a, 2010). Scientific weather and climate forecasting is often criticised for not delivering concise information on local climatic variation and for its poor communication, i.e. messages are too scientific and technical for farmers (Adejuwon, 2007; Joshua *et al.*, 2011). Additionally, increased rainfall variability in southern Africa has increased uncertainty in seasonal rainfall prediction, thereby posing a greater challenge to scientists in their efforts to improve forecast accuracy and reliability (Cooper *et al.*, 2007; Ambrosino *et al.*, 2011; Jury 2013; IGAD Climate Prediction and Applications Centre [ICPAC] 2014). In this regard, it is now widely acknowledged that conventional science alone cannot adequately address climate challenges (Finucane, 2009).

Indigenous knowledge (IK) is increasingly recognised as an additional important source of climate knowledge for adaptation strategies in the face of climate variability and climate change (IPCC, 2007; Parry *et al.*, 2007; Perry and Falzon, 2014). IK is a collaborative concept that together with scientific approaches can be applied to produce better knowledge systems and informed policies that are context specific (Whyte, 2013). IK is seen to play a notable role in enhancing "the potential of certain adaptation strategies that are cost-effective, participatory and sustainable" (IPCC, 2010a). Although challenges of uncertainty also apply in the application of IK due to increased rainfall variability (IGAD Climate Prediction and Applications Centre [ICPAC] 2015), many studies are increasingly acknowledging that the integration of IK in weather and climate predictions offers a potential solution to contemporary challenges in climate science, including seasonal rainfall predictions (Chang'a *et al.*, 2010; Nakashima, 2012). Collectively, IK is seen to represent a dynamic information base that has supported many rural communities in adapting to the constantly changing and varying climates (Nyong *et al.*, 2007).

There is no standard definition of IK systems (IKS). Agrawal (2003) and the Intergovernmental Panel on Climate Change (IPCC, 2007) define it as the knowledge systems and practices gained by communities through experience across generations. It is renewed by each generation and guides communities' innumerable interactions with their surrounding environment (Kimmerer, 2002; UNEP, 2012; Whyte, 2013). Similarly, Berkes (2012) defines IK as: "a cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment". In the context of this paper, IKS are defined as a collection of knowledge, beliefs, skills, innovations, experiences and insights of individuals and communities concerning the management of their natural and cultural environments. IK has several labels in literature including IK, traditional knowledge, traditional ecological knowledge (TEK), local knowledge, farmers' knowledge, folk knowledge and indigenous science, but all share similar meaning (Berkes, 2012; Nakashima and Roué, 2002; Nakashima *et al.*, 2012; Whyte, 2013). Hence, in this paper, the terms are used interchangeably and also relate to local knowledge held by non-indigenous rural communities (Grabherr, 2009; Lawrence, 2009).

It is increasingly acknowledged that in weather and climate predictions, IK is found to be more rational, accurate and reliable than scientific knowledge at local scales (Ziervogel, 2001; Nyong *et al.*, 2007; Kalanda-Joshua *et al.*, 2011). It "exists in parallel to western science" (Kimmerer, 2002), and both are seen as "complementary perspectives on the environment and natural resources" (Whyte, 2013). IK "observations tend to be qualitative, and they create a diachronic database, that is, a record of observations from a single locale over a long time period" (Kimmerer, 2002). The observers are the local people (Kimmerer, 2002; Whyte 2013). Success of their decisions is inextricably linked to the quality and reliability of their ecological observations. In contrast, scientific observations made by a small group of professionals tend to be quantitative and often represent synchronic data or simultaneous observations from a wide range of sites, which frequently lack the long-term perspective of TEK (Kimmerer, 2002).

In climate science, IK offers "observations and interpretations at a much finer spatial scale with considerable temporal depth by highlighting elements that may not be considered by climate scientists" (Perry and Falzon, 2014). This is in contrast to scientific scenarios developed at broader spatial and temporal scales (Raygorodetsky, 2011; Whyte, 2013). Although IK is an emerging topic in climate science, rural subsistent farmers have a long history with such knowledge, relying on IK to understand weather and climate patterns and for the selection of crops and farming practices (Nyong *et al.*, 2007; Chang'a *et al.*, 2010; Kalanda-Joshua *et al.*, 2011; Nkomwa *et al.*, 2013; Lucio, 1999; Ngugi, 1999). Several studies recognise the potential contribution of IK in predicting environmental fluctuations and informing localised adaptations, owing to its long history of applicability. Many studies agree that some communities, especially in flood and drought prone areas, have used IK in predicting and responding to the occurrence of extreme precipitation events (such as floods and droughts) (Chang'a *et al.*, 2010; Roncoli *et al.*, 2002; Anandaraja *et al.*, 2008, Chirwa *et al.*, 2011; Warren *et al.*, 1995; Sillitoe *et al.*, 2002; Nakashima and Roué, 2002; Sillitoe, 2007). In this regard, "Indigenous knowledge relating to climate change, whether it concerns agricultural techniques, biodiversity, indicators of change, or weather prediction and response, provides the basis for many successful and cost effective adaptation measures" (Anchorage Declaration, 2009) because of its local relevance (Anchorage Declaration, 2009; Reid *et al.*, 2009).

However, farming environments are diverse and their vulnerability to climate risks or trends varies spatially and temporally. Similarly, IK is site specific and its relevance in the context of climate inconsistency is also varied. Therefore, analysis of IK for agricultural adaptation in all diverse farming environments is necessary for informed interventions. There is a growing body of literature across the globe that has reported on weather and climate patterns, including climate change and responses, based on IK. Nakashima *et al.* (2012) have recorded a long list of literature documented across the world, including studies from the Arctic (e.g. Krupnik and Jolly, 2002; Nichols *et al.*, 2004; Gearheard *et al.*, 2006; Laidler *et al.*, 2009; Aporta and MacDonald, 2011), North America (e.g. Turner and Clifton, 2009; Jacob *et al.*, 2010), Asia (e.g. Raj, 2006; Crate, 2008; Marin, 2010) and Africa (e.g. Ovuka and Lindqvist, 2000; Action Aid, 2006; Kalanda-Joshua *et al.*, 2011; Nkomwa *et al.*, 2013). However, there is paucity of documentation at the local level (Action Aid, 2006; Joshua *et al.*, 2011; Nkomwa *et al.*, 2013; Whyte, 2013). The current study addresses this gap for Malawi with case studies from Chagaka, Mpasu and Mphampha villages in Chikwawa district.

Objectives

The study assessed the relevance of IK in weather and climate forecasting for adaptation to climate variability in the agricultural sector. More specifically, the study:

- Identified climate risks in the Chagaka, Mpasu and Mphampha villages;
- Identified the IKS initiatives practiced by smallholder farmers and the scientific support for their use;
- Assessed the trend over time of the extent to which IKS are used by farmers (including an explanation of this trend) and the relevance of IKS actions in contemporary situations – taking into account population growth and climate change;
- Identified threats to the use of IKS and the policies and actions required for their conservation;
- Evaluated potential synergies for IKS with existing scientific climate approaches, and identified how IKS can be adapted to align with current efforts addressing the climatic challenges facing smallholder farmers.

Method

Description of the study sites

The three study villages Chagaka, Mphampha and Mpasu are located in Chikwawa, a semi-arid district in the southern region of Malawi, which is vulnerable to climate variability (Karanja *et al.*, 2004). The villages are in Mbewe – one of the six extension planning areas (EPAs) of Chikwawa district in the lower Shire Valley (Figure.1). The Shire Valley is a rift valley at a low altitude of 2–300 m above mean sea level and contains the largest river in Malawi, the Shire River, which is the only outlet from Lake Malawi. Mphapha village is approached along an earth road that branches off from the tarmac road to Illovo sugar estates. On the western side, the village is bordered by Lengwe National Park. The village is located about 6 km away from the main road that connects Mozambique with Blantyre, and consists 60 households. Mpasu village is located 26 km away from the same road (Figure. 1), and is bordered by Lengwe National Park to the south and the Mkombezi River to the north. Mpasu village consists 120 households. Chagaka village is located roughly 30 km away from the main road from Mozambique to Blantyre and consists 67 households.

Data collection and analysis methods

The study was informed by a comprehensive desk review, comprising a literature review of assessment/evaluation reports, policies/strategies, and projects and programmes on IKS for climate change management. The review focused on the following topics in regards to IK: the prediction of weather, climate and season quality; management of climatic risks and disasters; and adaptation and mitigation strategies of climate change. Similar issues were explored in a field survey with farmers through

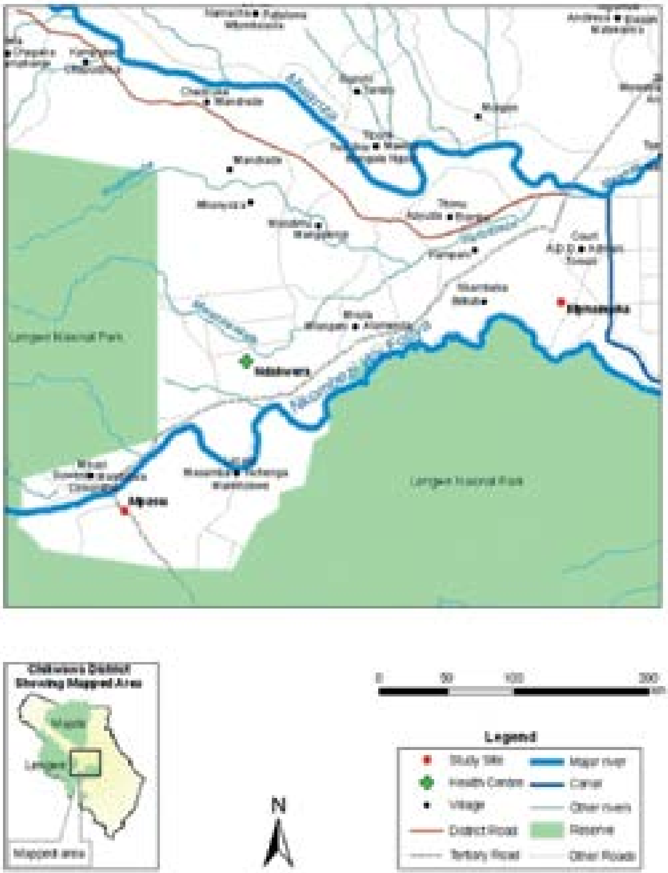

Figure 1: Map showng location of the villages under study in Chikhwawa district.

individual interviews, focus group discussions (FGDs) and key informant interviews (KIIs). The FGDs and KIIs also explored the topic of indicators within IKS and their meanings and uses; the relevance of IKS in contemporary situations and reasons for IKS-related challenges. The survey purposefully selected 10–12 FGD participants and 10 key informants, based on the age of each individual – participants were aged between 18 and 70 years to ensure meaningful participation. The KIIs included agricultural extension and development officers and coordinators, and village headmen and elderly community members with standing peerage.

Eighty six households were randomly selected from Mpasu (40), Chagaka (26) and Mphampha (20) representing a third of a sampling frame, to participate in the household survey. A list of households was generated for each village with the help of the village chief. To ensure household selection was random, the names of household heads were written on pieces of paper and torn into strips, which were then mixed up in a box and pulled out at random. Qualitative data collection using FGDs and KIIs occurred twice using the same checklist, first in April 2012 and then again in October 2016 to explore changes to reported IKS. The main unit of analysis during the farmer survey was the household – defined as those living within the same compound, and who worked or contributed food or income to the unit. There are inherent difficulties and limitations with such a definition, especially when used across countries and cultures, as not all households regard themselves in the same way. However, it was the most practical unit for the purposes of this survey.

The data collected from FGDs and KIIs on perceptions of climate change and variability were compared with scientific hydro-meteorological data from the nearby Nchalo Sugar Estate Station in Chikwawa, which allowed applicability analysis of identified IK for agricultural adaptation. The hydro-meteorological data were analysed for trends using the Mann-Kendal Test (Mann, 1945; Kendal, 1975) as recommended by the World Meteorological Organisation. The study used a mixed methodological approach for the comprehensive understanding of the IK issues under study, and enhanced the validity of findings (Brannen, 1992; Barbour, 2008; Hennink *et al.*, 2011). IK indicators commonly used for weather and climate forecasting in the villages were established through FGDs, and key informant and household interviews.

Results and discussions

Local perceptions on climate, climate change and indicators

Trends and patterns of climatic events

Climate of the Mpasu and Chagaka villages is characterised by high temperatures and erratic rainfall year round. The study revealed that villagers have perceived a change in climatic variables in recent years, notably since 1992. Figure 2 and Table 1 provide a summary of the major climatic events that have occurred in Mpasu village since the 1980s and the associated impacts, according to respondent perception.

FGD and KII participants mainly mentioned changes in precipitation and the high variability in rainfall patterns. People observed that the rains were starting late (e.g. November/December/January instead of October/September) affecting commencement of the planting season and subsequent agricultural activities. Farmers can no longer predict the

Table 1: Perceptions on climate change in the three study villages

Climate trend	Mentioned by village		
	Mphampha	Mpasu	Chagaka
Rainfall – declining amounts, more erratic, high variability, shift in the onset date (from Sept/Oct to Dec/ Jan), early cessation	√	√	√
Temperature – increased in comparison to 1990's	√	√	√
Floods – more frequent	x	x	√
Droughts and prolonged dry spells – more frequent	√	√	√
Winds – increasingly strong winds which often disperse the rain clouds affecting the rainfall pattern	√	√	√

likely arrival, duration or quantity of rain. In some cases, farmers had to plant two to three times before a normal rainfall pattern was established. In other cases, good rainfall activity was observed at the start of the season, only to be replaced by dry spells mid-season, with devastating consequences for crops such as maize.

Results of the FGDs indicated that respondents have perceived a decline in rainfall since the 1990s, resulting in an increase in prolonged dry spells and droughts. However, based on data from the nearby village rain gauge station, information from the KIIs showed that the total amount of rainfall received in recent years had not changed significantly. Conversely, results from KIIs generally agreed with farmer perceptions that dry spells had become more frequent and prolonged. For example, in the 2011/2012 growing season, the longest dry spell was 24 days instead of the more common 10-12 days. The areas had also experienced worse conditions of prolonged dry spells and mid-season droughts every year since the 2007/2008 growing season. Temperatures were perceived to be increasing annually with the warmer periods beginning earlier than was expected. These high temperatures used to be associated with a high probability of rainfall, but this it is no longer the case. Furthermore, during FGDs, the people reported a notable increase in strong winds from the mid-2000s and a reduced frequency of floods.

Similar to Mpasu and Chagaka, the key indicators of climate change reported by the Mphampha village were high inter-annual and intra-annual rainfall variability. The village has been experiencing a variable and late onset of rains with a notable shift from November to December, coupled with early cessation. For instance, late planting rains were recorded on 15 December during the 2009/2010 season. In 2010/2011, these rains began during the first week of January, whereas the onset was on time in 2011/12 – on 11 November. The rains have been perceived to be highly erratic and poorly distributed over the last 20 years. As per the observations in the other villages, the amount of rainfall was perceived to have declined resulting in more frequent prolonged dry spells and droughts. For example, the area has experienced a midseason drought or prolonged dry spells every year for the past 5 years since 2010, despite having an onset at the expected time in some years. In some cases, the rains became more reliable towards the end of the season, however, by this point, food crops such as maize are already in a wilted state hence, low yields were experienced.

Other rainfall related indicators include the occurrence of strong winds and cold nights. The FGD participants reported that the combination of these two events adversely affect the rainfall pattern. Winds are known to drive away clouds, whilst the cold reduces evaporation as well as rainfall. In Mphampha village, the occurrence of floods recently has been rare. The few reported flooding episodes were caused mainly by upland runoff from the catchments nearby Mwanza and Nkombedzi wa Fodya Rivers. In addition, during FGDs, people from Mphampha village also noted that over the past 20 years, they have experienced warmer day temperatures and cooler nights.

Results from the household interviews in the villages provided similar results to what was reported in the FGDs and KIIs (Figures 2a-2c). Respondents from Mpasu (61%) and Mphampha (91%) (Figures 2a-2c) reported that floods have become less frequent over the past 20 years. Conversely, most respondents from Chagaka village reported an increase in floods (65%) over the same period of time. In addition, seasonal droughts, erratic rains, intra-seasonal dry spells, strong winds and high temperatures are more frequent in all villages. On the other hand, stormy winds were perceived to be less frequent, specifically in Mphampha village (70%).

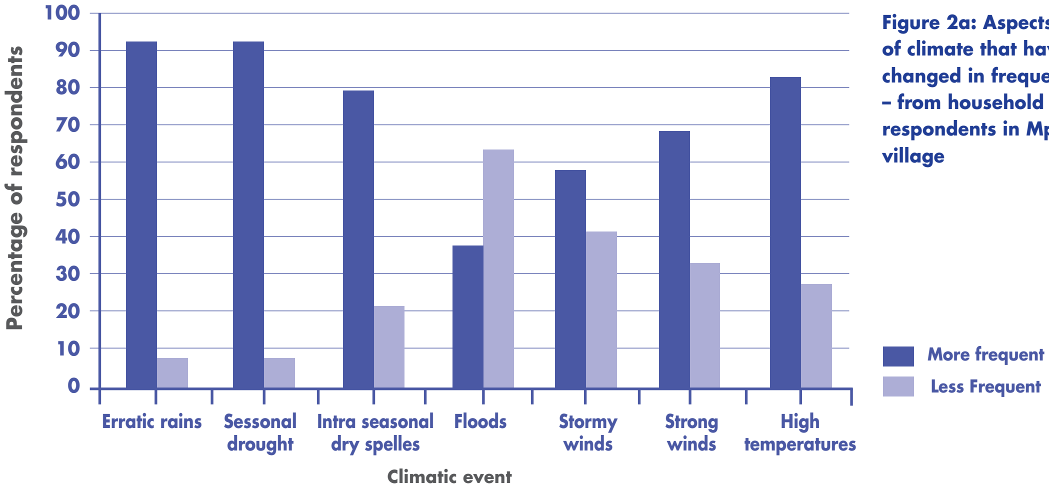

Figure 2a: Aspects of climate that have changed in frequency – from household respondents in Mpasu village

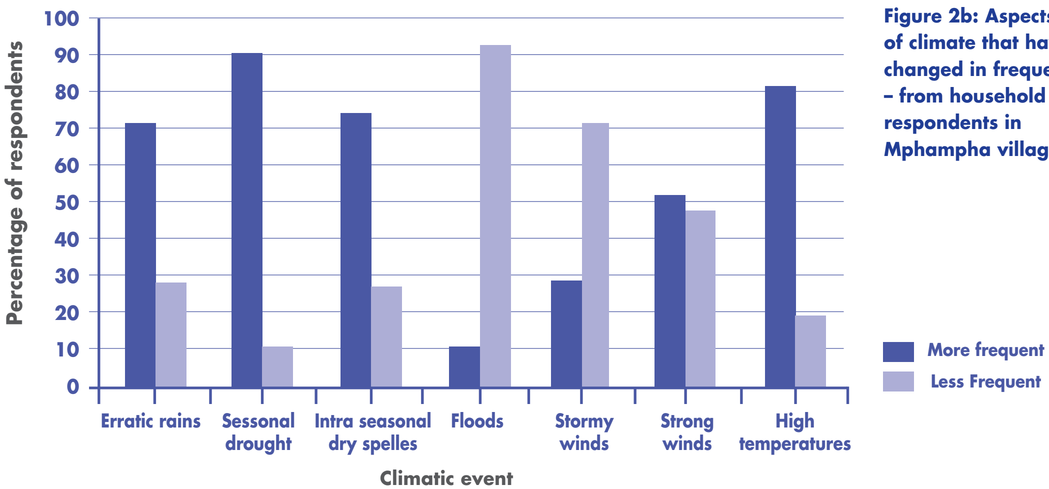

Figure 2b: Aspects of climate that have changed in frequency – from household respondents in Mphampha village

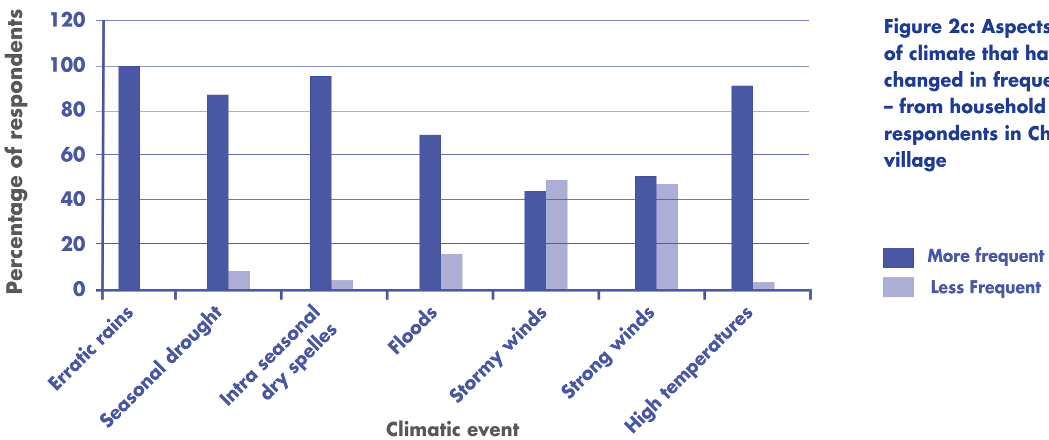

Figure 2c: Aspects of climate that have changed in frequency – from household respondents in Chagaka village

Table 2 provides a summary of major climatic events that have occurred in Mpasu and Mphampha villages since 1980s. This is based on IK information passed through the generations.

From Table 2 it can be seen that drought has occurred more frequently in the Mpasu and Mphampha villages except in 2001/2002 and 2005/2006 seasons when both floods and droughts occurred.

Table 2: Major climatic events in the Chagaka, Mpasu and Mphampha villages

Year	Event	Village		
		Mpasu	Mphampha	Chagaka
1980/81 -1981/82	Drought	√	–	–
1986/87	Drought	√	√	√
	Floods	–	√	–
1989	Floods	–	–	√
1991/92	Drought	–	√	√
1992/93	Drought	√	–	√
1993/94	Drought	–	√	–
1997/98	Floods	√	√	√
1998/99	Strong winds	√	–	–
2000/01	Drought	√	–	–
2001/02	Drought	–	√	–
	Floods/excessive rains	√	–	–
	Strong winds	–	√	–
2005/06	Floods & drought	–	√	√
2007/08 -2012	Prolonged dry spells and mid-season drought	–	√	–
	Prolonged dry spells/ drought for 5 consecutive years	√	–	√
2012[1]	Prolonged dry spells and mid-season drought	√	–	–

Note: √ = event mentioned in the village; - = event not mentioned

[1] No maize was yielded during this year because cotton pests did not respond to chemicals hence, a low cash crop yield was produced.

Climate trends from empirical evidence

A comparison between empirical weather data and the perceived weather changes of the respondents, showed some similarities. Daily rainfall from the WATCH data set for the period 1958–2012 (Weedon *et al.*, 2010; 2011), and temperature data for the period 1971–2008 from three stations in the area – namely Makhanga, Nchalo and Ngabu – were analysed for trends. Monthly and annual values were derived from this data. The Mann-Kendal trends for the stations are shown in Table 3 where a and b represent the 95% confidence interval limits.

From Table 3, significant positive trends in daily rainfall at all three stations are indicated. However, monthly and annual rainfall at all stations has negative but statistically insignificant trends. This agrees with a study by Ngongondo *et al.* (2014) in which extreme rainfall variables, including simple daily rainfall intensity, were found to have increased from 1958 to 2012 over Malawi with a corresponding decrease in annual rainfall. This study also found that the consecutive number of dry days in many parts of Malawi had significantly increased. Together with the indication of a slight decrease in annual rainfall, the results suggest that most of the total annual rainfall in the area is derived from very few but intense rainfall events. This agrees with the villagers' perceptions of an erratic rainfall pattern. Figure 3 presents the trends of annual rainfall for the three stations. The linear regression trend line (dashed) suggests that rainfall was decreasing during the period 1958–2012 at all stations. The linear regression results show a decreasing rainfall slope of -0.64mm/year at Nchalo, -1.98mm/year at Makhanga and -1.46 mm/year at Ngabu.

In agreement with villager perceptions, data from all three stations showed the daily temperature increased significantly at a 95% confidence

Table 3: Mann-Kendal trends in climatic variables

Variable/station	*a*	Ngabu	Nchalo	Makhanga	*b*
Daily rainfall	*-1.96*	11.98	4.51	14.01	+1.96
Monthly rainfall	*-1.96*	*-1.00*	-0.10	*-1.13*	*+1.96*
Annual rainfall	*-1.96*	-0.63	-0.68	*-0.75*	*+1.96*
Daily minimum temperature	*-1.96*	1.49	9.63	4.56	+1.96
Daily minimum temperature	*-1.96*	-1.22	13.52	4.85	+1.96

interval during the period 1958–2012 (Table 2.2). These trends are generally in agreement with those reported and scientifically validated at the national level by the Climate Change and Meteorological Office (GoM, 2009; 2013). We therefore suggest that the villagers' perceptions on changes in rainfall and temperature were, on the whole, in agreement with the empirical evidence and can hence contribute to the generation of climate data at lower spatial scales (i.e. community level).

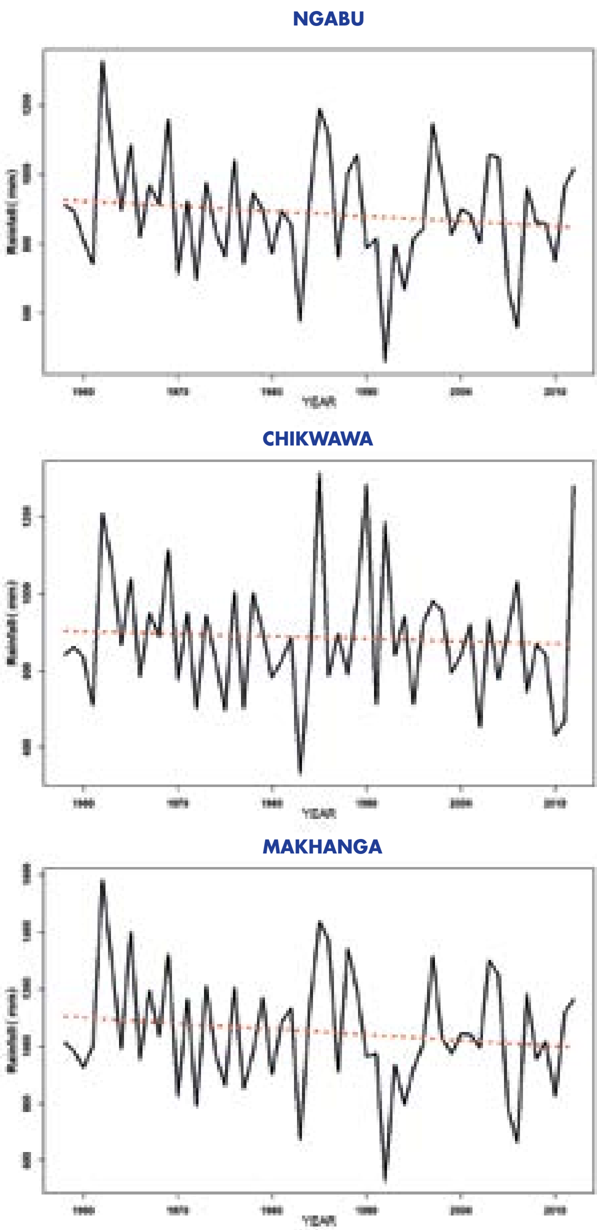

Figure 3: Annual rainfall patterns from the three weather stations within the study area during 1958–2012.

Impacts of changing climatic factors on crop and livestock production

Climate change is impacting on crop yields and types grown as well as farming practices. All three villages have experienced a decline in yield per unit area for most food crops. Maize has been the most affected due to prolonged droughts and inadequate seasonal rainfall. Detailed results from Chagaka are reported in an earlier study by Nkomwa *et al.* (2013).

Similar to Chagaka (Nkomwa *et al.*, 2013), due to a change in the rainfall pattern, the cropping calendars have changed for all crops in Mphampha and Mpasu. Information garnered from FGDs indicated that largely, farm activities are dictated by the onset and distribution of rainfall. For example, for rain-fed production of maize and cotton, planting now takes place in December or January due to late rains. Also similar to Chagaka village, staggered planting is becoming a common practice in Mphampha. Farmers can plant up to five times before the rains become stable. These results suggest a difficulty in predicting and establishing the onset of rains. Table 4 shows other impacts of climate change and variability on selected crops – using information from the FGDs. Results show that different climatic conditions have affected selected crops differently. Almost all the crops grown in the area are adversely affected by floods, too much rain and strong winds. However, sorghum and bulrush millet have been performing much better than other crops under low rainfall and drought conditions, hot temperatures and the late onset of rains. This suggests that sorghum and millet are more tolerant to these climate conditions.

Table 4: Impacts of climate change and variability on crops in Mpasu and Mphampha

Climatic factor	Effect on crop		
	Maize	Cotton	Sorghum and finger millet
Inadequate rain	Produces very small cobs; yields are reduced; yields wilt, then die	Produces fewer bolls or small bolls and few branches; low yield	Fine
Too much rain	Seedlings die; crop becomes yellow; yields are reduced; crop fails to produce cobs	Grows tall but does not produce bolls; crop survives once water dries	Destroyed
Late start of rains	Late planting; reduced yields	Survives	Survives
High temperatures	Plant wilts; dries; stunted growth, low yield	Flowers fall off	Survives
Floods	Destroyed	Destroyed	Destroyed
Strong winds	Stalks fall over	Flowers fall off	Stalks fall over

The villagers also reported that the increased prevalence of crop pests over the years is reducing crop yield. The frequent occurrence of crop pests is being associated with climate change impacts such as high temperatures and very low rainfall. Prevalent crop pest species in Mphampha village are presented in Table 5.

Farmers from all three villages indicated through FGDs the need for a new cotton pesticide, as the current option is ineffective. The American bollworm (*Helicoverpa armigera*), locally known as *mphutsi/mthutsi*, destroys cotton leaves and was reported by villagers to be the most prevalent crop pest. Others include the locally named *anunkhadala/abobo (Zonocerus variegatus)* – a type of locus that also feed on leaves. Infestations by these cotton pests was severe in the 2012 growing season and spraying was not effective, despite the guidance of agricultural extension officers.

Tomatoes and other vegetables are heavily attacked by spiders, locally known as *kangaude*, greenflies or *nsabwe (Aphis gossyphi)*, leaf blight or *chiwawu (Phytophthora infestans)* and stalk boring moths or *mbozi/kapuchi (Busseola fusca)*. Cassava is heavily attacked by the mosaic virus *(Geminiviridae begomovirus)*, known locally as *khate*. Blight was not a problem in the area until 2012, but since then, farmers have been forced to spray their vegetables with expensive chemicals such as marshal and dithane, which are not locally available. Further, during FGDs, farmers reported that although sorghum is more resilient to climate change and variability impacts than other crops, it is vulnerable to head smut disease (*Sphacelotheca reiliana*), which is perceived to be on the increase compared to 15 years ago, and adversely affects sorghum yields. Farmers could not establish the reason for the current high prevalence.

Farmers have observed that livestock production is decreasing due to the outbreak of diseases previously rare in the villages, such as foot and mouth, Newcastle disease, and African swine fever. Incidences of Newcastle disease are related to dry conditions, thereby signifying increased temperature and reduced relative humidity. Other effects of climate variability include decreased pasture quality and quantity, and water shortage. Water shortages are common during the dry season and farmers have to travel up to 3 km in search of water for their livestock. Similar findings were reported by Nkomwa *et al.* (2013).

Table 5: Male and female perspectives from the FGDs on prevalent crop pests in Mphampha

Male perspective	Female perspective
American ball worm reduces cotton yields – the balls drop	American ball worm reduces cotton yields – the balls drop
Drying cotton plants in 2012 were affected by a black pest – new occurrence	American ball worm reduces cotton yields – the balls drop A new species of moth (*Busseola fusca*) –locally known as mbozi – identified in 2012. It attacked cotton roots and was resistant to chemicals
For the past 5 years, maize has been affected by *mphutsi* (*Hericovepa armigera*) and nsabwe (*Aphis gossyphi*), but chemical sprays are not locally available	Nsabwe (*Aphis gossyphi*) attack maize, vegetables and cotton
Kapuchi or mbozi (*Busseola fusca*) attacks maize which then becomes yellow and fails to produce grains	Kapuchi (*Busseola fusca*) attacks maize
Nsabwe (*Aphis gossyphi*) attack vegetables	Grasshoppers cut maize leaves and stalks, especially the irrigated crops
Stalk borer and millipede (*Diplopoda/Eurymerodesmus* spp.) attack maize, especially during the development stage	
Nthedza (*Hodotermes mossambicus* – a harvester termite) eats cotton leaves and roots	

Adaptation to climate change and variability impacts

There has been a change in the type of crops and varieties grown in Mphampha village over the last 10 years. Following recent climatic events such as droughts and prolonged dry spells, rain-fed maize and rice production has reduced and the acreage of cotton and sorghum has increased. Maize production in all three villages is now mainly irrigated – but due to water shortages and limited access to irrigation water, is practiced by few farmers. Of all the crops, sorghum production is preferred for food and commercial purposes (though market opportunities are rare) due to its tolerance to many climatic risks relative to other crops. Crop diversification is also integrated within farming systems to reduce risk and improve yields in such unpredictable weather conditions.

In the context of livestock production, farmers are now stocking a higher diversity of animals than they would have been 10 years ago, to reduce risk and increase income diversification. For instance, there are now greater numbers of goats and poultry than cattle. Farmers prefer to keep goats than cattle as they are more resilient to disease and can survive in dry pasture and drought conditions.

IKS initiatives practiced by smallholder farmers and the scientific support for their use

The study captured a number of indicators used by the villages for weather and climate prediction (see Table 5 for a complete list). Similar to earlier findings from the Mulanje district in the Southern Malawi, as reported by Kalanda-Joshua *et al.* (2011), these are based on environmental and cultural beliefs. Some indicators were common for all study villages whilst others were particular to each site. This result goes some way to reflect the site specificity aspect of IK, but cannot lead to a conclusion that indicators not mentioned by one village do not apply there, because knowledge capturing is based on recall and is not written down.

Some of the common indicators used include the behaviour of birds, ants and insects. For example, the frequent occurrence of flying ants (*ngumbi*) and large numbers of elegant grasshoppers (*Brachytrypes membranaceus*) locally known as *nkhululu*, are indicative of a good rainy season, with well-distributed rains. However, it is worth noting that other indicators of heavy rains (e.g. winds blowing in all directions) can also signify the likelihood of floods in the rainy season. The song of the southern ground hornbill (*Bucorvus leadbeateri*) locally known as *Ming'omba*, the croak of frogs and the high occurrence of bees in gardens are indicators of imminent rains. On the other hand, high occurrence of the stalk-boring moth – *mbozi* – is indicative of drought.

A woman displaying two hands full of corn seeds.

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Respondents of the FGDs noted that 1995/96, 1998/99 and 2003 were 'good' years, when farmers registered high yields in maize and sorghum. However, the three years from 2013–2016 were recalled as bad years because of drought. The farmers noted that the appearance of the *nthanda/mtsinamowa* (morning star/planet Venus) in the west indicates high rainfall, whilst its appearance in the east is an indicator of drought. In addition, winds blowing in all directions suggest a good rainfall season, while winds blowing from the south-east are an indicator of drought.

The villagers also refer to the timing of flowering and fruiting, as well as to the fruit production of certain tree species to predict weather and climate. For example, the appearance of many flowers on monkey thorn (*Acacia galpinii/Acacia nigrescens*), locally called *nkunkhu*, is indicative of drought. Conversely, many flowers on the burning-bush combretum tree (*Combretum Microphyllum Klotzsch./Combretum Paniculutum Vert*) or *mkotamo*, and heavy fruiting of the wild mango (*Irvingia gabonensis*), or *matondo*, Chinese dates (*Ziziphus mauritiana*) or *masawu*, mango (*Mangifera indica*) and baobab (*Adansonia digitata*) trees, are indicators of high rainfall. New foliage on the wild mango, African custard-apple (*Annona senegalensis*) or *mpoza*, ramontchi (*Flacourtia indica*) or *mzunga*, white seringa/white syringa trees (*Kirkia acuminate*) or *mtubwi*, and new fruits on baobab trees are indicative of imminent rains.

However, there were contradictory observations between villages regarding the climate indication of the fruiting of mango trees. In Chagaka and Mpasu, this was considered an indicator of high rainfall, whilst in Mphampha, it was thought to signal low rainfall. Results from Mphampha village are similar to findings from an earlier study in Nessa village of Mulanje District (Kalanda-Joshua *et al.*, 2011). However, taking into consideration observations from Chagaka and Mpasu, the mango tree observation reported in Mphampha probably refers to heavy fruiting of on one side and poor fruiting on the other. This growth pattern is indicative of a good onset of rains, followed by a prolonged dry spell e.g. for a month, with rains picking up again towards the end of the growing season – and is broadly categorised as a low rainfall season.

Similar biotic indicators are used in weather forecasts across Africa e.g. the observation of plant patterns in Burkina Faso and Swaziland (Ayal *et al.*, 2015; Joshua *et al.*, 2012; Roncoli *et al.*, 2001), and animal behaviours and physical body conditions in Ethiopia, Kenya and Nigeria (Ayal *et al.*, 2015, Shukurat *et al.*, 2012; Speranza *et al.*, 2010; Ziervogel and Opere, 2010). Analyses of the indicators used for weather prediction agree with earlier observations by Ayal *et al.* (2015) that some practices are common across cultures. Differences lie in the specifics due to varying spatial systems.

An earlier study by Ayal *et al.* (2015) in Ethiopia, concluded that IK weather and climate predictions are short-term (e.g. 2 weeks) and hence, leave farmers with little time to prepare. However, in the current study, the short-term predictions are used to forecast imminent rains. Predictions for a season are of intermediate term and apply to 2–3 months, giving adequate time for farmers to prepare their farming responses. IK may not be as useful when considering long-term rainfall forecasts, but these can be managed by modern science.

Trend over time of the extent to which IKS are being used by farmers and the relevance of IK in contemporary situations

This section assesses the trend over time of the extent to which IKS are being used by farmers (including an explanation of this trend) and the relevance of IKS actions in contemporary situations, taking into account population growth and climate change. IKS have been guiding farmers in agricultural decision-making processes regarding when to prepare land, what crop to plant, and when to weed, harvest and process, since time immemorial. For example, signs of imminent rains indicate to farmers that rains will fall in a few days-time hence, farmers should prepare to plant. Signs of prolonged drought in the rainy season mean farmers should not weed because crops will be scorched by the sun, but indicators of a short dry spell mean it is a good time to weed. Harvesting should be done when there are indicators of many dry and sunny days. Signs of a low rainfall season indicate to farmers to plant crops with low water requirements such as sorghum, millet, cotton.

Farmers indicated that IK is also used to determine the type of farming system to be practiced (rain-fed or irrigated) in a given year. For example, they explained that if an indicator suggests drought or prolonged dry spells, farmers opt for irrigation (using water harvested in river sand beds locally known as). If the indicators are for rain-fed agriculture, farmers opt to grow sorghum, millet, sweet potato and cassava, which grow well under such conditions. FGD participants in Chagaka and Mpasu illustrated how they had applied IK in their choice of agricultural practice and selection of crops grown over the past 3 years (2013-2016), during which, IK indicators suggested drought conditions.

To a large extent, IK is still in use despite incorrect weather and climate predictions over the past decade, this is because: i) some indicators remain applicable at farm level and ii) meteorological forecasts rarely apply to local situations. The FGD participants indicated that many IK indicators are still relevant, and when asked which had been applied in the 2015 and 2016 seasons, Chagaka and Mpasu farmers reported that the appearance of the morning star in the east had been used to signify drought. Further, they explained that the morning star had appeared in that direction for the past 3 years – which had also been drought stricken. Before the 2016/2017 rainy season, all reported indicators of a good rainfall season were observed, including the presence of Venus in the west. This forecast of good rains for this season aligned with western scientific predictions. In 2015/2016, farmers observed that there were no ants – an indicator of dry spells – and that year, they experienced drought. During FGDs, farmers indicated that nowadays, they mainly cultivate drought tolerant crops, specifically sorghum, due to the increased occurrence of droughts. The farmers indicated that these decisions are in part guided by IKS, which further emphasises the continued relevance of IKS in contemporary situations.

To be confident in their predictions, farmers indicated that they rely on a combination of indicators, not just one. If there are a number of observed patterns (occurring at the same time) indicating a particular weather or climate pattern, farmers believe reliable conclusions can be drawn. Additionally, they emphasised that indicators based on floral patterns still apply today where the trees/vegetation indicator species are still available. Similar study results were earlier established by LEAD (2009).

Despite farmers' reliance on IK, this study notes that the relevance of some local indicators has been challenged in recent times. Largely, these relate to the signs of imminent rains and flood occurrence. Initially, farmers would predict that rains would fall within a few days of observing the indicators highlighted in Table 6. In recent years however, those signs can be observed but the onset of rains may take 2–3 weeks. The role of strong winds has become unpredictable because it either drives away rain bearing clouds, delaying the onset of rains, or can be associated with

Table 6: Traditional weather prediction and climate indicators in study villages

Occurrence	Indicator of	Village		
		Mpasu	Mphampha	Chagaka
Poor fruiting of mango (*Mangifera indica*), baobab (Donsonia digitata) and sunbird tree/wild mango (Irvingia gabonensis) fruit trees	Low rainfall	√	√	
Heavy fruiting of sunbird tree/wild mango (*Irvingia gabonensis*), Chinese dates (*Ziziphus mauritiana*), mango and baobab trees	High rainfall	√	√	
Many flowers on burning-bush combretum (*Combretum Microphyllum Klotzsch./Combretum Paniculutum Vert*)	High rainfall			√
High production of mango fruits	Low rainfall season and maize yield		√	
Heavy fruiting of mango trees (whole tree)	High rainfall	√		√
Heavy fruiting of mango tree on one side and poor fruiting on the other side	A good onset of rains but followed by a prolonged dry spell, with rains picking up towards the end			√
Many flowers on monkey thorn (*Acacia galpinii/ Acacia nigrescens*)	Drought	√		
New foliage on sunbird tree/wild mango, African custard-apple (*Annona senegalensis*), ramontchi (*Flacourtia indica*) and white seringa/white syringa trees (*Kirkia acuminate*)	Imminent rains			√
Heavy fruiting on mango and new fruits on baobab trees	Imminent rains			√
Many flowers on sweet thorn (*Acacia karoo*) tree	High rainfall	√		
Peculiar sounds of male goats	Imminent rains		√	
Large numbers of ants	High rainfall	√	√	
Large numbers of elegant grasshoppers (*Dichromorpha elegans*)	High rainfall	√		√
Ants and northern harvester termites (*Hodotermes mossambicus*) taking food to their holes	Imminent rains			√
Northern harvester termite collecting food to their holes before rains (in October)	High rainfall	√		√
Frequent occurrence of flying ants/winged termite (*Macrotermes subhyalinus*)	High rainfall		√	
Increased occurrence of savanna sculpted tree ant (*Cataulacus intrudens*)	High rainfall	√		
Increased occurrence of termites and mounds in gardens	Prolonged dry spell		√	

Occurrence	Indicator of	Village		
		Mpasu	Mphampha	Chagaka
Sound of large numbers of jarfly (*Ioba leopardina*)	Heavy rains	√		
Sound of southern ground hornbill (*Bucorvus leadbeateri*) singing	Imminent rains	√		
Sound of (white) frogs	Imminent rains	√		√
High occurrence of bees in gardens	Imminent rains			√
High occurrence of moths stalk boring moths (*Busseola fusca*)	Drought			√
Onset of westerly winds	Onset of rainy season (if early – early onset of rains)		√	
Winds blowing in all directions	Good rainfall season (also floods)	√		√
Winds blowing from south-east to north	Drought	√		√
Winds from the south	Good rains			√
Strong winds when about to rain	Dry spell			
Moon halo	Heavy/good rains	√		
Extended cold days reaching end September or October	Drought		√	
Very high temperatures in September and October	High rainfall season	√	√	
Heavy rains in October or November	Drought			√
Cold weather mid rainy season	Dry spell	√		
Morning star appearing in the east	Drought	√		
Morning star/planet Venus appearing in the west	High rainfall amounts	√		√
Black cloud	Imminent and good rains	√		√
Black cloud in the west	Floods	√		
Red clouds	Drought			√
Sight of cumulonimbus clouds in hilly area	Imminent rains	√		
Cattle egret (*Bubulcus ibis*) in a group flying from east to west	Imminent rains	√		
Sun with a greenish circle	Low rainfall	√		
Clouds on Mulanje mountain	Imminent rains	√		
Appearance of rainbow in the east	Drought			√
Prolonged rainfall season	Very cold season		√	
Appearance of a moon during rainfall season	Low rainy days		√	
Neem tree flowers (*Azadiraehta indica*)	A lot of rain			√
Slanting moon position	Less rain			√
Winds blowing from south-east in October-November	Less rain due to cool temperatures			√
Rains starting north to south	Good season			√
A lot of tamarind fruits (Tamaris indicus)	Drought coming			√
High temperatures followed by low temperatures around October/November	Delayed rainfall onset			

heavy rains. This creates confusion for farmers who are then unsure of when to plant, forcing them to practice staggered planting before the rains become established.

Since 2002, villagers have experienced very high temperatures at times previously associated with heavy rains. However, during rainy days which indicate to farmers that the rainy season is about to commence, cold temperatures can occur which disturb the viability of TEK in weather predictions. Similarly, traditional indicators of flooding are becoming less reliable due to sudden occurrences of heavy rains from upland areas which cannot be forecast. These challenges are attributed to climate change and the associated increased rainfall variability, as well as to the loss of biotic species traditionally used for weather forecasting. For example, FGD participants from Chagaka and Mpasu reported that the value of IK has partially declined due to the loss of specific vegetation species, whose patterns were observed as indicators to determine weather forecasts. This problem is particularly felt in indigenous forest areas targeted for biomass energy production; their locations are also cleared for farming purposes.

Low rainfall results in low river water levels and thus, a reduction in the number of aquatic species whose behaviour can be studied as part of IK. This reduces the confidence of farmers in IK, and their adaptive capacity to climate change. This result is similar to earlier findings by multiple

V **Cassava market along the road**

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studies in areas including Zimbabwe (Makwara, 2013; Joshua *et al.*, 2012), Kenya (Kipkorir *et al.*, 2010) and Malawi (Kalanda-Joshua *et al.*, 2011; Kalinga-Chirwa *et al.*, 2011; Nkomwa *et al.*, 2013). Such studies report additional causes of IK erosion, including teaching in contemporary religions, which may contrast traditional beliefs; poor documentation of IK; modern education that disregards the value of IK, and the limited transfer of IK from knowledge holders and younger generations (Makwara, 2013; Nakashima *et al.*, 2012; Chang'a *et al.*, 2010). However, taking into consideration the findings of the current study, this paper criticises generalised conclusions indicating that IK is not relevant to modern day. Addressing the reliability of IKS e.g. through the promotion of regeneration of indicator vegetation, would reduce the occurrence of faulty forecasts, enhance the significance of IK in weather and climate predictions and consequently, increase the adaptation and resilience capacity of farmers. An enabling policy environment is also critical to enhance the significance of IK.

Threats to the use of IKS and policies and actions to conserve them

There is a growing number of policies and acts that recognise the vulnerability of farming communities to climate change impacts and the significance of adaptation, resilience and reliable weather data to inform farming practices. However, the extent to which IK is recognised in building adaptation capacity and generating useful weather and climate data, varies spatially. The policy analysis below demonstrates how much work is yet to be done at the national level.

In 2012, the Malawi Government published its national policy on climate change (GoM, 2012) with a goal to "contribute to the attainment of sustainable development in line with Malawi's National goals, as outlined in Malawi's Growth and Development Strategy II and Vision 2020" (GoM, 2012). The policy aims to achieve this through "better adaptation to, and mitigation against, climate change, with a focus on resilience building for Malawi's citizens" (GoM, 2012). The national climate change policy articulates the principles, strategies and institutional frameworks necessary for the effective management of critical climate change issues, including capacity building through education, training and public awareness; and adaptation and mitigation in agriculture. One of the policy priority areas includes adaptation to climate change impacts and extreme weather events that the country is facing, and addressing factors that impede resilience. This includes the inadequate availability of climate risk information. The policy aims to address this information gap through a number of activities including the integration "of relevant and validated IK and practices in adaptation and disaster response programmes", and promotion "of sustainable agricultural intensification practices that increase productivity while maintaining environmental integrity and ecosystem services" (GoM, 2012). The Malawi Government acknowledges knowledge gaps in climate change issues, specifically:

i. General knowledge and understanding of climate change
ii. Predicting weather and associated impacts of extreme weather events
iii. Managing risks and impacts of climate change
iv. Integrating climate change issues horizontally across sectors and vertically (from the national level down to the district and community levels) among key stakeholders (GoM, 2013).

Similar challenges are observed in the inefficiencies and inadequacies of "research and technology, combined with systematic observation, to generate evidence for decision-making and provide solutions for improved adaptation to, and mitigation of, the impacts of climate change" (GoM, 2012). The Government of Malawi acknowledges inadequacies of scientific knowledge and recognises the contribution of IK in addressing these challenges. In view of this, the policy emphasises that a key strategy for addressing such inadequacies in scientific knowledge is through "supporting the documentation and validation of IK, through community engagement, so that it will be fully integrated within the overall knowledge base that informs policy and action" (GoM, 2012).

This recognition by the Government reflects principles of the United Nations Framework Convention on Climate Change (UNFCCC, 1992) and the Kyoto Protocol (2001). It is also in line with the Paris Agreement of 2015 article 7:5. In the context of adaptation to climate change, the Paris Agreement emphasised the recognition of both scientific knowledge and IKS. Through this article, the Paris Agreement called parties to:

> "acknowledge that adaptation action should follow a country-driven, gender-responsive, participatory and fully transparent approach, taking into consideration vulnerable groups, communities and ecosystems, and should be based on and guided by the best available science and, as appropriate, traditional

knowledge, knowledge of indigenous peoples and local knowledge systems, with a view to integrating adaptation into relevant socioeconomic and environmental policies and actions, where appropriate" (UNFCCC, 2015).

The Paris Agreement Article 7:5 reaffirms earlier international agreements including the Kyoto Protocol and the Cancun Adaptation Framework (CAF), adopted by Parties at the 2010 UNFCCC Conference in Cancun. CAF "has as a guiding principle, the need for adaptation to be 'based on and guided by the best available science and, as appropriate, traditional and IK' (UNFCCC, 2010; Nakashima *et al*., 2012). It also calls for adaptation action to 'take into consideration vulnerable groups, communities and ecosystems' (UNFCCC, 2010; Nakashima *et al*., 2012).

However, most of Malawi's related policies, strategies and legislation provisions on climate change adaptation are inadequate to effectively address the challenges because they are not relevant to local realities (Nakashima *et al*., 2012). For example, there is no mention/provision of the significance of IK in weather and climate prediction and adaptation in the country's constitution (GoM, 1997), the Malawi growth and development strategy (MGDS) (GoM, 2011), the environmental management act (GoM, 1996) or in the national adaptation programmes of action (NAPA) (GoM, 2006). These are key documents providing legal guidance for actors to recognise IKS in Malawi. The constitution provides a framework for all legislation in the country, therefore its recognition of IKS would provide a strong guarantee of IK inclusion in other legislation.

The MGDS is the country's medium term development strategy. It is a reference document for development initiatives in the country, including responses to climate change, but none of the proposed strategies incorporate IK. The Environmental Management Act provides the legal framework for all environmental related legislation governing environmental issues in the country. NAPA provides a national framework for promoting activities that address urgent and immediate needs for adapting to the adverse impacts of climate change among rural communities in vulnerable areas. It outlines the urgent adaptation needs in agriculture, such as improving: i) early warning systems; ii) agricultural production under erratic rains and changing climatic conditions; iii) Malawi's preparedness to cope with droughts and floods, and iv) climate monitoring to enhance Malawi's early warning capability and decision-making. None of the prioritised activities to address these needs integrate IK despite its potential and proven contribution in many areas. The omission of IK's integration within such activities can be considered as a missed opportunity for developing effective knowledge and practices to enhance the adaptation and resilience of vulnerable areas.

In addition, the comprehensive documentation of valid and useful IKS across the country requires some notable financial investment. For example, most documented IK is captured through FGDs and KIIs (Bryan, 2012). Such tools are time consuming, but less costly than obtaining a rich data set (Bryan, 2012) and are hence, justifiably included in national research budgets that focus on climate change management. However, the national climate change investment plan (NCCIP) (GoM, 2013) and the national adaptation strategy for Malawi (Nangoma, 2008) do not include IK (though they recognise climate change issues and the need to improve their disaster preparedness and resilience). The NCCIP emphasises that:

> "To improve a community based early warning system, the programme will enhance weather and climate monitoring, prediction and information and knowledge management systems. Among others, the programme will also develop and modernise weather climate and climate change databases, strengthen the production of weather and climate seasonal forecasts, expand weather observation points, develop capacities in weather and climate information and data collection, and promote a telecommunication system that targets the communities" (GoM, 2013).

However, there is no consideration of IK research for informed policies, or for intervention in the NCCIP 6 year summary budget. This gap similarly features in the MGDS, the national agriculture policy (GoM, 1999) and in the irrigation policy (GoM, 2000) and irrigation act 2001 (GoM, 2001), hence threatens the ability of the country to adequately document and use valid IKS for informed policies, and interventions on community adaptation and resilience in agriculture. Research is needed to evaluate potential synergies of IKS with existing scientific climate approaches, and to identify where IKS can be aligned with current efforts addressing the climatic challenges facing smallholder farmers.

Synergies of IK and scientific information for use by smallholder farmers

The results of this study show the coexistence of modern science and IK in each village. Both have limitations and strengths. In the context of IK, each village is able to predict weather patterns using traditional indicators. Although over time, the value of some indicators has become threatened or declined due to environmental changes, farmers continue to depend heavily on them as opposed to scientific forecasts. The study has established that for decades, villagers have been relying on IK for farm level decisions, as scientific predictions are less applicable to the local environment. Over the past decade, villagers have largely accessed scientific weather data from the department of climate change and meteorological services through radio and extension services. The information provided is mostly linked to how farming practices can respond to climate change and variability. Advice includes planting of early maturing varieties and drought resistant crops, crop diversification, forestation for flood and wind control, and modern farming techniques.

Listeners also receive information on weather forecasts in the month of September, but during FGDs, farmers reported that the weather information was not reliable as it applied to the region as a whole and thus, had limited application at district and local levels. Since 2016, the Zodiak Broadcasting Station, a private radio station, has been providing weather forecasts at district level, making the forecasts more reliable. This weather information is shared with villagers through public meetings where farmers are advised on when to plant crops depending on the forecast. However, the forecasts have largely remained inapplicable at the village level. Further, the study found that each village is in proximity to a rain gauge, but data collection is irregular and therefore unreliable for farmer use. The data managers are volunteers with limited financial capacity to share daily readings with officers for consolidation, and are hence less committed to send off regularly datasets to the responsible office.

Despite repeated forecast failures, farmers are still found to rely on IK. This is probably because IK is dynamic, with practices becoming established after long-term experiments or observations. (Ziervogel and Opere, 2010). Addressing the environmental challenges that threaten the value of IK could enhance its applicability. However, IK is criticised by some scientists as a short-term forecasting method, which cannot adequately prepare farmers for long-term adaptation to climate change (Ayal *et al.*, 2015).

In contrast, scientific knowledge has the capacity to provide long-term forecasts and trends, but these are inadequate without reliable short-term and local scale forecasts. Similar to earlier studies, this suggests that combining IK with scientific knowledge could produce robust and rigorous weather information (Makwara, 2013; Nakashima *et al*., 2010). However, in the study areas of this report, modern scientific weather forecasts are yet to recognise the significance of IK. At the time of this study, the climate change and meteorological department has started to work with Mphampha village to provide seasonal forecasts at the local scale, but due to statistical data challenges at this level, forecasts are not reliable. There is poor functional network coverage and additionally, the forecasts do not integrate IK.

The climate change and meteorological department (MET) recognises the unique contribution of IK, but is yet to integrate it within forecasts due to a number of constraints. Firstly, there is limited documentation on IK because prior to 2015, the focus had been on scientific forecasts. Local policy recognition of IK in climate science, including its potential to enhance adaptation to climate change, is also a recent development, hence, the responsible office, MET had no mandate prior to 2015. Secondly, the climate change and meteorological department lacks the capacity to manage the collection and testing of IK for its integration. This suggests that the implementation of a climate change policy with the provision of IK in weather and climate forecasting, will not be effective unless network stations and their management at local scales improves.

The integration of IK in weather forecasting can occur if the department revises its organogram to include social scientists with relevant expertise in IK. Furthermore, there is need to consider establishing adequate financial support for the systematic documentation and subsequent integration of IK in seasonal rainfall forecasting. The integration of IK offers the potential to increase the resilience of local communities, therefore it is also important to consider putting in place stiffer penalties for noncompliance by relevant authorities. These approaches are likely to reduce policy implementation gaps.

Conclusions

This study has assessed the relevance of IK at the village level in weather and climate forecasting to enhance adaptability to climate variability in the agricultural sectors. The report looked at case studies from the Chagaka, Mpasu and Mphampha villages in Chikwawa district, southern Malawi, a semi-arid area where climate change is impacting on peoples' livelihoods. Farmer perceptions indicated a considerable level of knowledge on climate change and variability. Prominent of these were the noted reduction in rainfall, and increased temperatures and occurrences of strong winds – normally associated with the dry/windy season. These observations have been validated with empirical evidence from weather stations in the area. Key IK indicators used in weather and climate forecasting include plant and animal behaviour or occurrence, and astronomical as well as meteorological events. However, despite the huge potential of IK to improve the adaptability and resilience of farming communities to climate change impacts, current policies do not consider the value of IKS in agricultural production.

A locust eating a stalk of rice.

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CHAPTER 10 - Indigenous knowledge for climate change adaptation in Nigeria

L.T. Ajibade and J.O. Eche

Abstract

The role of agriculture in national development is threatened by climate change in most developing countries. This study presents the indigenous knowledge (IK) on climate change among farmers in selected local government areas (LGAs) of Kwara state, Nigeria, with particular emphasis on the level of awareness, causes, effects, and the effectiveness of farmers' coping strategies to climate change. Random sampling techniques were used to select 266 farmers from three LGAs of Kwara – Baruten, Edu and Irepodun. Structured questionnaires and descriptive analyses were used for data collection and analysis purposes. The findings revealed that; indigenous farmers are aware of the changing environment, particularly the climate, with 97% of farmer responses confirming this; the farmers

∨ Farmers ploughing a field with oxen in preparation for planting crops.

identified human activities such as bush burning, overgrazing, deforestation, and the use of chemical fertilisers as the major causes of climate change; farmers recognise that the effects of climate change have led to crop infestations and diseases, which have subsequently resulted in food shortages and increases in food costs; indigenous people cultivate crop varieties tolerant to climate change and use mulching within their farming systems as coping strategies to climate change impacts.

The study concludes that more attention to IK practices are necessary for effective and appropriate environmental policies, particularly in developing countries. It therefore recommends that governments and development agencies concerned with the issue of climate change, should sensitise farmers more intensively on the realities of climate change, their effects and consequences on food production, and modern adaptation measures. The study also suggests future research activities in IK and climate change mitigation strategies, to expand the scope of IK and create avenues through holistic and environmentally friendly and sustainable policies.

Introduction

Agriculture places heavy burdens on the environment in the process of providing populations with food and fibre, while climate is the primary determinant of agricultural productivity. Given the fundamental role of agriculture in human welfare, concern has been expressed by federal agencies and others regarding the potential effect of climate change on agricultural productivity. Interest in this issue has motivated a substantial body of research on indigenous knowledge (IK) of climate change and agriculture in recent decades (Nelson *et al.*, 2009; Lobell *et al.*, 2008; Darwin, 2004; Fischer *et al.*, 2002).

Indigenous communities have long been recognised as particularly vulnerable to the impacts of climate change due to the close connections between their livelihoods, culture, spirituality, social systems and their environment. At the same time, however, this deep and long-established relationship with the natural environment affords many indigenous people with knowledge that they have long used to adapt to environmental change, and are now using to respond to the impacts of climate change. Local communities and farmers in Africa have developed intricate systems of gathering, predicting, interpreting and decision-making in relation to climate change problems (Simonelli, 2008).

IK is a term used to describe the knowledge system developed by a community as opposed to the scientific knowledge that is generally referred to as 'modern' knowledge (Ajibade, 2003). IK is the basis for local level decision-making in many rural communities. It has values not only for the culture in which it evolves, but also for scientists and planners striving to improve conditions in rural localities. Therefore, incorporating IK into climate change policies can lead to the development of effective adaptation strategies that are cost effective, participatory and sustainable (Robinson and Herbert, 2001). It is necessary to observe that global science has acknowledged the relevance of IK as well; this is evident in the various discussions around IK that take place during United Nation Conferences on Environment and Development.

Most studies on indigenous perceptions of climate change have been carried out in the developed countries of the world, which dominate the uppermost northern region of the earth and where the relationship between scientists and indigenous people is high (Jan and Anja, 2007). Despite the fact that efforts have been made towards the fight against climate change from a scientific perspective, research and policies directed towards the incorporation of IK within climate change strategies are desperately needed. The study of local perception is useful in understanding the true implication of a changing climate (Adesiji *et al.*, 2013).

Most third world countries, especially in Africa, have been making serious and frantic efforts to untangle development problems. Persisting problems include economic stagnation, declining agricultural productivity, natural resource degradation, insufficient infrastructure and a host of other socio-economic issues. However, awareness, understanding and use of local knowledge systems is one strategy that can help facilitate efforts to deal with these problems (Adedotun and Tunji, 1995). The importance of working with and through these local systems is slowly being appreciated by a growing number of development experts and local and international organisations both in developing and developed countries.

In order to approach the problems of climate change appropriately, one must take into account local communities' understanding of climate change, since they perceive climate as having strong spiritual, emotional and physical dimensions. It is assumed that these communities have adaptive knowledge from which to draw upon and survive in highly stressful ecological and socio-economic conditions. Thus, the human response is critical to understanding and estimating the effects of climate change on food production, and for climate adaptation. Accounting for these adaptations and adjustments is necessary in order to estimate climate change mitigation and response (Apata *et al.*, 2009). The current study considers the following specific objectives: examination of farmers' awareness and understanding of climate change; identification of the causes of climate change as understood by the farmers; assessment of the effects of climate change as perceived by the farmers; identification of the farmers coping mechanisms; and appraisal of the effectiveness of these indigenous methods.

Awareness of climate change and link with agriculture

The awareness of climate problems and the potential benefits of taking action are important determinants for the adoption of agricultural technologies (Hassan and Nhemachena, 2008). Maddison (2006) argued that farmer awareness of changes in climatic attributes (temperature and precipitation) is important to decision-making for adaptation. For example, Araya and Adjaye (2001) and Anim (1999) stated that farmer awareness and perception of soil erosion as a result of climate change, positively and significantly affected their decision to adopt soil erosion measures. It is expected that improved knowledge and farming experience will positively influence farmer awareness and thus, motivation to take up adaptation measures. Hassan and Nhemachena (2008) opined that mitigation efforts to reduce the 'source' or enhance the 'sinks' of greenhouse gases will take time, therefore adaptation is of critical concern in developing countries, particularly in Africa where vulnerability is high because adaptability is low.

Farmers IK of climate change mitigation and adaptation

It is generally known that Africa is a minor contributor of global greenhouse gas (GHG) emissions. Its share of carbon emissions, which is by far the most important GHG, was only 3.2% of the world's total in 1992. Africa's share of methane emissions was also low at the beginning of the 1990s – at only 7.7% of the world's total in 1991 (Davidson, 1998).

Articulated in the literature are two lines of actions in dealing with the adverse conditions expected to accompany climate change. These are mitigation and adaptation strategies. Mitigation strategies are procedures or activities that help prevent or minimise the process of climate change. According to Swart *et al.* (2003), mitigation strategies can be categorised into two groups: some represent mainly technological solutions; others involve changes in economic structures, societal organisation, or individual behaviour. In Africa, mitigation strategies are traditionally employed as natural resource conservation measures, but they generally serve the dual purpose of reducing GHG emissions from anthropogenic sources, and enhancing the carbon 'sink'. Strategies aimed at reducing GHG emissions emphasise cutbacks in the burning of fossil fuels – particularly the discontinuation of gas flaring – through improved energy efficiency, and the use of clean energy sources. Carbon sink enhancement generally involves forestry programs that protect the forest and encourage afforestation in marginal areas including range lands (Adesina *et al.*, 1999).

On the other hand, according to Enete *et al.* (2011), adaptation is an adjustment made to a human, ecological or physical system in response to a perceived vulnerability. Specifically, the Intergovernmental Panel on Climate Change (IPCC, 2001) describe adaptation to climate change as an adjustment in natural or human systems in response to actual or expected climatic stimuli, and their effects. Adaptation is one policy option to respond to climate change impact, and it is therefore an important component of climate change impact and vulnerability assessment, (Smith and Lenhart, 1996; Fankhauser, 1996).

In agriculture, adaptation helps farmers achieve their food, income and livelihood security objectives in the face of changing climatic and socio-economic conditions, including climatic variability and extreme weather events such as droughts and floods. (Kandlinkar and Risbey, 2000). Farmers can reduce the potential impacts of such happenings by developing tactical responses.

Until recently, mitigation and adaptation were seen as mutually exclusive strategies in the fight against climate change. However, there is a strong link between the two, and it has now been recognised that their integration may not only provide new opportunities for effective climate change response, but may even be a prerequisite for successfully utilising both tactics. According to Klien *et al.* (2003), integrating mitigation and adaptation strategies will better connect them with natural resource management, biodiversity conservation and measures to combat desertification. While the intellectual argument for integration has been strongly made, its realisation in the policy realm has been less successful.

Relevance of IK in climate change mitigation and adaptation

Developmental projects introduced into rural communities with the hopes and promises of impacting their lives have not taken into consideration the culture of the people they were intending to help, and therefore resulted in low participation and success rates (Woodley 1991; Nyong and Kanaroglou, 1999). As a result, there has been growing interest in the incorporation of IK within such projects to increase local participation and provide environmentally sound approaches to development. This signifies that researchers are gradually recognising the importance of IK systems (IKS) in developmental studies.

Climate change mitigation and adaptation projects can learn from the experiences of developmental initiatives that have recognised the value of IKS. However, two major problems that can be considered obstacles to the integration of IK within formal climate change mitigation and adaptation strategies are: recognising the need to, and how to actually integrate IK into western science (Nyong *et al.*, 2007).

A man channels irrigation water to his cabbage farm.

©FAO/Pius Utomi Ekpei

IK adds value to climate change studies in a number of ways. Firstly, IKS create a moral economy by identifying a person within a cultural context, providing decision-making processes or rules of thumb to be followed based on observed indicators or relationships within events (Adunga, 1996; Woodley, 1991). Community members act within these rules of thumbs to maintain security and assurance – otherwise risk isolation from their community. In an uncertain and biased world, these rules of thumb provide people with a sense of belonging and stability.

Secondly, IK is increasingly exhibiting a resemblance with scientific methods as many ideas in IK that were once regarded as primitive and misguided, are now seen as appropriate and sophisticated. Third, IKS provide mechanisms for participatory approaches to decision-making and project execution (Nyong *et al.*, 2007). A major requirement for the sustainability of any project is the participation of the local population, who must be seen as partners with joint ownership. This is best achieved when communities effectively participate in the design and implementation of such projects. Fourth, IKS share the same guiding principles as the sustainable development framework with three major concerns – economy, equity and environment (Davies and Ebbe, 1995). The essence of most climate change projects is to reduce poverty and ensure sustainable development. This can be facilitated by the integration of IK within climate change policies. Fifth, IKS facilitate understanding and effective communication and increase dissemination and utilisation rates of climate change mitigation and adaptation options.

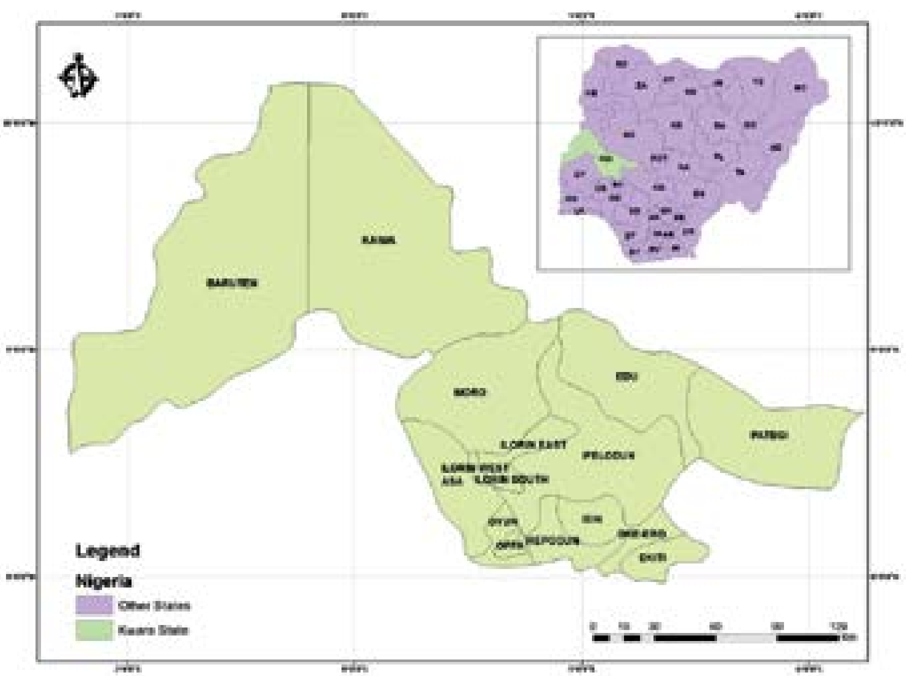
Study area

The study area, Kwara state, Nigeria, is heterogeneous in nature with diverse ethnic groups, mainly dominated by the Barubas, Fulanis, Nupes and Yorubas. Kwara state is made up of seven different dialects including Igbomina, Ilorin, Ibolo, Ekiti, Nupe, Boko/Baru and Baruba/Batunu. There are 16 local government areas (LGAs), of which, 12 are found to be Yoruba speaking. The non-Yoruba speaking LGAs of the state are Baruten, Edu, Kaiama and Patigi (Ajibade, 2001). Kwara state has a total population of 2,371,089 people (NPC, 2006), and covers an area of about 36,825 km^2 with a population density of 42.51/km^2 (Adeoye *et al.*, 2013; Jimoh and Adeoye, 2011). These settlements vary in size and population.

According to Oyebanji (2000), Kwara state lies in the middle belt region of Nigeria and is situated between parallel latitudes – 8oN and 10oN – and longitudes – 3oE and 6oE – of the Greenwich meridian (Figure.1). The state has river Niger as its natural boundary along its northern and eastern margins and shares a common internal boundary with Niger state in the north, Kogi state in the east, Oyo, Ekiti and Osun state in the south, and an international boundary with the republic of Benin in the west.

The geology of Kwara state is over 80% underlain by crystalline Precambrian basement complex rocks, while the remaining part is underlain by cretaceous and younger sediments (Jones and Hockey, 1964; Rahaman, 1976). Topographically, Kwara state is typified by undulating landscape with low rounded hills and occasional, often elongated, quartzite ridges indicating the characteristic pediment-inselberg landscape of typical basement terrain (Durotoye, 1983). The drainage pattern is mainly dendritic – a reflection that the underlying geological formation has horizontal strata (Oyegun, 1983). The natural vegetation belongs to the tropical Savanna. According to Oyebanji (2000), a large proportion of the land area of the state is characterised by ferruginous tropical soils on crystalline acid rock.

Figure 1: LGA map of Kwara state (Ministry of Lands and Housing, 2014).



The climate of Kwara state is tropical and humid with distinct wet and dry seasons each lasting for a period of about 6 months (Babalola and Ajayi, 2002). The wet season begins towards the end of March and lasts until October, while the dry season begins in November and ends in early March.

Agriculture is a climate dependent activity that places serious burdens on the environment in the process of providing sufficient food supplies to the population. However, in Kwara state where 70% of the area is rural, agriculture is the dominant economic activity and engages the major proportion of the populace. Farmers in the area cultivate a wide variety of produce including rice, maize, guinea corn, groundnuts, beans, millet, melon, kola nut, tobacco, cotton, cocoa, coffee, oil, palm and tubers such as yam, cassava and sweet potato. Those living at the river banks are also engaged in fish farming. Other forms of socio-economic activities in Kwara state include mining and quarrying.

Material and methods

Data required for this study was obtained from primary and secondary sources. The data on the socio-economic characteristics of the farmers and farmers' general knowledge on climate change, including its causes, effects and adaptive measures, were obtained through a detailed and well-structured questionnaire. However, secondary data including a map of the study areas, population figures of farmers and data regarding agro-

Table 1: Study samples and the number of questionnaires completed per selected settlement

Serial No	Ethnicity/ language	LGAs	Selected LGA	Selected settlements	Farmer population	Number of questionnaires
1	Baruba	Baruten and Kaima	Baruten	Ilesha	454	31
				Sinawu	302	21
2	Nupe	Edu and Patigi	Edu	Shonga	1939	133
				Lafiagi	762	52
3	Yoruba	Ekiti, Ifelodun, Ilorin East, Ilorin South, Ilorin West, Irepodun, Moro, Offa, Oke-Ero and Oyun	Irepodun	Agbamu	249	17
				Arandun	177	12
Total					3883	266

Source: Kwara state Ministry of Agriculture and Natural Resources, 2010 .

climate relationships were obtained from Kwara state's Ministry of Agriculture, academic textbooks, journals and the internet.

Kwara state was stratified into three locations based on ethnic/language similarities. One LGA from each location was then randomly selected and from each of the three resulting LGAs, two settlements were also randomly selected – making a total of six settlements (Table 1).

Selection of the sampled areas was based on the focus of the study as aerial phenomena, and not location specific. Thus it was assumed that similar problems would be faced by farmers in the same region, and that they are likely to proffer from the same set of solutions. The number of questionnaires administered in each settlement (Table 1) was determined by dividing the population of farmers in each settlement by the total number of farmers in all selected settlements (3,883), multiplied by the sample size (266). The results were determined using Cochran's (1963) equation: $\simeq 266$

Systematic random sampling was adopted for questionnaire administration. The first farmer was randomly selected from the list of farmers in each of the selected settlements after which, every fourth farmer was selected. Descriptive statistics were used, while tables were used for data presentation.

Results and discussion

Characteristics of the respondents

The study revealed that the majority of sampled farmers were male (74%). From the data analysis, the age of farmers ranged from 41–50, but the average age was 50. With an average age of 50, the farmers were expected to have the experience necessary for a study of this nature.

Most of the respondents (71%) were married, 20% had no formal education; 14% attended Islamic schools, 34% attended primary schools and 28% were educated to secondary school level. Only 4% had tertiary education and 14% had received adult education (from schools created for adults interested in further schooling; Table 2). This implies that the respondents are semi-literate – a point that was assumed to be influential on their perception of climate change. The study reveals that farming is the main occupation of the people with 67.67% of respondents being full time farmers, and the remaining 32.33% engaged in other economic activities such as trading, transportation, casual labour and artisan activities. The modal value for farming experience was 21–25 years, while

Table 2: Characteristics of respondents

Characteristic	Frequency	Percentage (%)
Gender:		
Male	196	73.68
Female	70	26.32
Total	**266**	**100**
Age:		
	50	18.80
31-40	58	21.80
41-50	90	33.83
51-60	40	15.04
	28	10.53
Total	**266**	**100**
Marital status:		
Single	26	9.77
Married	189	71.05
Divorced	9	3.38
Separated	12	4.52
Widowed	30	11.28
Total	**266**	**100**
Level of education:		
No formal education	20	7.52
Adult education	36	13.53
Primary education	90	33.84
Secondary education	74	27.82
Tertiary education	10	3.76
Islamic education	36	13.53
Total	**266**	**100**
Primary occupation:		
Farming	180	67.67
Farming and trading	30	11.28
Farming and transportation	10	3.76
Farming and hunting	6	2.26
Farming and fishing	10	3.76
Farming and weaving	3	1.13
Artesan	12	4.51
Casual labour	15	5.63
Total	**266**	**100**
Farming experience (in years)		
1-5	10	3.76
6-10	26	9.77
11-15	28	10.53
16-20	48	18.05
21-25	120	45.11
26-30	22	8.27
Above 30	12	4.51
Total	**266**	**100**

Source: Authors' Field Survey, 2015

the mean was 19 years, indicating that the farmers may have worked in the sector for long enough to have acquired relevant skills in coping with the effects of climate change.

Farmer awareness of climate change

The study revealed that 92.48% of selected farmers are aware of climate change, while the remaining 7.52% claimed not to be aware of it. This suggests a high level of awareness of the subject matter in the study areas. The major media outlets accessible by farmers for climate change information are radio and television (26%); extension services (34%) and farmer cooperatives (30.45%) On the other hand, very few respondents obtained their information through print media or from friends (Table 3).

The majority (97%) of respondents were of the opinion that the environment, and climate in particular, has been changing over the years due to human activities such as farming, deforestation, farmland extension, overgrazing, bush burning and industrialisation. More than half of respondents (59%) 'agreed' in the survey (Table 4) that the weather is becoming dryer every year, causing discomfort and agricultural difficulties for people within the study areas.

About 60% of the respondents strongly agreed that the yearly rains are not supporting crop production as usual, and 53% of respondents agreed

Table 3: Farmers' sources of climate change information

Medium	Frequency	Percentage (%)
(i) Friends	20	7.52
(ii) Extension workers/services	90	33.83
(iii) Farmer cooperatives	81	30.45
(iv) Newspapers	5	1.88
(v) Radio/television	70	26.32
(vi) Entrepreneurship centre	-	-

Source: Authors' Field Survey, 2015

Table 4: Farmer awareness of climate change based on their submission

Statements		Strongly agree	Agree	Undecided	Strongly disagree	Disagree	Total
The climate is changing due to human activities	Frequency	120	138	4	2	2	266
	%	45.12	51.88	1.50	0.75	0.75	100
The weather is becoming dryer every year	Frequency	88	158	10	2	8	266
	%	33.08	59.40	3.76	0.75	3.01	100
The yearly rains are not supporting crop production as before	Frequency	160	94	6	4	2	266
	%	60.15	35.34	2.26	1.50	0.75	100
The temperature is rising	Frequency	116	142	8	0	0	266
	%	43.61	53.38	3.01	-	-	100
The rains are sometimes abnormal and cause regular floods and soil erosion	Frequency	126	112	8	8	12	266
	%	47.37	42.10	3.01	3.01	4.51	100

Source: Field Survey, 2015

that the temperature has been rising over the years. Similarly, the majority of respondents (89%) concluded that rainfall can be abnormal causing regular floods and erosion (Table 4).

Causes of climate change as observed by the farmers

Bush burning is generally the preferred traditional means of clearing farmland for seedbed preparation, which increases the concentration of GHGs and particulate matter in the atmosphere. A high percentage of farmer responses (54.89%) indicated that bush burning contributed to climate change (Table 5). The respondents also identified overgrazing as one of the causes of climate change, and 64.67% of respondents were of the opinion that overgrazing reduces soil fertility and production. Moreover, decreasing soil fertility is one of the impacts of extreme weather events, and as a result, 84.96% of farmers have had to resort to fertiliser use over the past 10 years. Meanwhile, the International Federation of Organic Agriculture Movement (IFOAM, 2007) has reported that conventional agricultural activities contribute to climate change because they apply excessive amounts of nitrogen fertiliser for sustained productivity.

The respondents also acknowledged deforestation as a major contributor to climate change, noting the negative aspects of deforestation such as the loss of trees, vegetation and species. About 74.44% of respondents strongly agreed that deforestation causes habitat loss and can lead to species extinction and reduced biodiversity. With the widely reported rate of poverty in Nigeria, especially among farming households, as well as the ever rising prices of kerosene and cooking gas, burning of fuel wood as cooking energy has become a predominant practice. Wood burning occurs not only among rural families but also among the urban poor; 96.62% of respondents confessing to undertaking this practice (Table 5).

Effects of climate change as observed by the farmers

Table 6 gives details of the effects of climate change as observed by the surveyed farmers. About 60% of respondents agreed that climate change has led to various forms of crop infestation by pests, thereby reducing the quantity and quality of crops produced. As a result of food shortages, 55% of respondents agreed that the price of food will likely

Table 5: Causes of climate change as observed by respondents

Statements		Strongly agree	Agree	Undecided	Strongly disagree	Disagree	Total
Bush burning	Frequency	82	146	12	10	16	266
	%	30.82	54.89	4.51	3.76	6.02	100
Overgrazing	Frequency	70	102	-	69	25	266
	%	26.32	38.35	-	25.94	9.39	100
Fertiliser use	Frequency	119	107	20	11	9	266
	%	44.73	40.23	7.52	4.14	3.38	100
Deforestation	Frequency	198	61	7	0	0	266
	%	74.44	22.93	2.63	0	0	100
Burning of wood fuel	Frequency	187	70	3	4	2	266
	%	70.30	26.32	1.13	1.50	0.75	100

Source: Authors' Field Survey, 2015

Table 6: Effects of climate change as observed by respondents

Effects		Strongly agree	Agree	Undecided	Strongly disagree	Disagree	Total
Climate change has led to crop infestation by pests and diseases	Frequency	107	150	5	0	4	266
	%	40	56	2	0	2	100
Climate change has led to farm produce shortages during the dry season	Frequency	138	126	2	0	0	266
	%	52	47	1	0	0	100
There have been increased incidences of flooding during the rainy season	Frequency	94	170	0	0	2	266
	%	35	64	0	0	1	100
The cost of food has increased due to climate change	Frequency	115	145	0	0	6	266
	%	43	55	0	0	2	100
Climate change has led to a decline of vegetation and forest resources	Frequency	109	148	5	0	4	266
	%	41	56	2	0	1	100
There have been increased incidences of drought during the dry season	Frequency	120	142	4	0	0	266
	%	45	53	2	0	0	100

Source: Authors' Field Survey, 2015

rise. Of the surveyed farmers, 64% reported that they had experienced floods and 53% had experienced drought, both of which are associated with climate change and threaten the livelihoods of farmers. Further, 56% of the respondents agreed that the environment is suffering from excessive de-vegetation and a decline in forest resources.

Climate change coping strategies of farmers

Coping strategies used by farmers in the six study areas to minimise the effects of climate change are presented in Table 7. The results show that 90.98% of respondents cope with climate change by cultivating a variety of crops, such as cassava, yam, maize, guinea corn, and groundnut. This is probably to reduce risk for farmers because different crops have varying levels of tolerance against the adverse effects of climate change such as floods and droughts, and farmers are more likely not to lose entire crops under this system. It was observed that cassava and yam were not only the major staple crops, but were also the major source of income for farmers. Maize, guinea corn and groundnut are also planted on a very large scale, sometimes together in order to minimise loss. This system demonstrates one example of how farmers are adapting to climate change – by moving away from the traditional agricultural practice of monocroping, to multi or intercropping.

About 70% of respondents attested to the fact that they use pesticides to control infestations and reduce the occurrence of crop disease, both of which are impacts associated with climate change – according to 96.62% of respondents (Table 6). To address the problem of soil moisture loss caused by increasing temperatures and decreasing rainfall, approximately 80% of respondents mulch their land, while 72.18% shade their crops to mitigate the same. Farmers consider that these practices allow foliage weight gain and root growth of crops. As another coping strategy, about 75% of the respondents reported to using fertiliser to improve soil fertility. On the other hand, one coping strategy that was not used extensively was bush fallowing, which was only practiced by 20.30% of respondents as it was said there was not enough land on which to carry out this farming system.

Effectiveness of the coping strategies

Effectiveness of the identified coping strategies in Table 8 varied from farmer to farmer and settlement to settlement. However, the majority of farmers claimed to have benefitted from using such strategies over the years, with 58% confirming the effectiveness of intercropping. The use of

Table 7: Climate change coping strategies of respondents

Coping strategies	Yes		No	
	Frequency	%	Frequency	%
Planting of different types of crops (intercropping)	242	91	24	9
Use of pesticides to get rid of/control pest infestations	183	69	83	31
Mulching	216	81	50	19
Shading and shelter	192	72	74	28
Bush fallowing	54	20	212	80
Use of chemical fertiliser	201	76	65	24

Source: Authors' Field Survey

Table 8: Effectiveness of the coping strategies adopted by respondents

Coping strategies	Level of effectiveness				
	Very effective		Effective	Not very effective	Not effective
Planting different types of crops (intercropping)	F	51	154	50	11
	%	19	58	19	4
Use of pesticides to get rid of pests	F	47	140	49	30
	%	18	53	18	11
Mulching	F	126	89	30	21
	%	47	34	11	8
Shading and shelter	F	95	125	29	17
	%	36	47	11	6
Bush fallowing	F	134	90	30	12
	%	50	34	11	5
Use of chemical fertiliser	F	166	81	19	0
	%	62	31	7	0

Source: Authors' Field Survey

pesticides to get rid of pests was indicated to promote production by 53% of respondents. Mulching was also identified as a very effective coping strategy for climate change adaptation, with 47% of respondents in agreement; and the use of shading structures to reduce soil moisture loss was considered an effective coping strategy by 47% of farmers. On bush fallowing, which is not a common practice of the area, 50.37% of farmers said it was very effective as a climate change coping strategy according to their experience. To the farmers, fallow land regains lost nutrients over time and would therefore be useful land for the cultivation of food crops. Finally, it was confirmed by 62% of farmers that the use of chemical fertiliser is a very effective coping strategy.

Conclusion and recommendations

The current study concludes that the threat of climate change is felt more keenly by rural farmers than by urban communities in Africa. It is due to this that the surveyed indigenous farmers of this study were found to take the issue of climate change very seriously. Indeed, they are aware of its occurrence and are capable of identifying its causes and effects, and

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designing adaptation strategies in order to survive. However, poverty is a major factor which reduces the ability of indigenous farmers to respond to climate change, as well as ignorance to various adaptation strategies. To address the existing knowledge and information gaps concerning the effects of climate change and promote adaptation strategies, immediate action is required to increase information dissemination through training programs.

^ A fishing community works with an experimental net with a larger mesh size that does not catch juvenile fish.

Based on this conclusion, the study recommends the promotion of principles of environmental conservation among indigenous people. This can only be possible by enhancing the knowledge of indigenous people regarding climate change implications; and the significance of conserving the natural environment.

Bearing in mind that this study is restricted to climate change adaptation, there is need for future research on IK and climate change mitigation strategies. This is paramount as it will help to expand the scope of IK, and contribute to the development of holistic and sustainable climate change policies.

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CHAPTER 11 - The role of indigenous knowledge in seasonal weather forecasting and planning of farm activities by rural crop farmers in Uganda

J.S. Okonya, O.C. Ajayi and P.L. Mafongoya

Abstract

Indigenous knowledge (IK) has been used by our great grandfathers in timing farm activities long before the invention of modern seasonal weather forecasting technologies. This knowledge has been passed on informally from generation to generation and still plays an important part in decision-making among rural smallholder farmers, who have no access to the official government seasonal weather forecasts and predictions. Since most of the agriculture in sub-Saharan Africa is rain-fed, knowledge of the onset and cessation of rains is key to the timing of most farm activities. Knowing when to sow seed for the most food secure and staple crops, during periods of scarcity or hunger, is of utmost importance. Crop yields are normally expected to be stable and high when rainfall is properly timed. Most of the IK is, therefore, about seasonal weather forecasting of the onset and cessation of rains. Based on results from a number of cross sectional surveys among different cultures or tribes in Uganda, we present over 10 signs used by the indigenous people in forecasting the onset and cessation of the rain season. Indicators for the onset of rain, include changes in the behaviour of domestic animals such as cows, calls by particular bird species, the appearance or disappearance of insects, such as termites and grasshoppers, the wind direction, the appearance and movement of migratory birds, the colour of the clouds at a given time of day, and night temperature variations. Climate variability in the last 10-20 years is starting to impact on the timing and, hence, reliability of some of these traditional indicators. The time to plant crops can no longer solely be based on the calendar, since the seasons have

become increasingly unreliable and variable. Traditional indicators, together with the science-based seasonal weather forecasts, could be very useful in rain forecasting and improving the timing of agricultural activities. This will in the end improve food security and the livelihoods of the resource constrained rural farmers.

Introduction

A number of climatic changes and the occurrence of extreme weather events have been reported in Uganda over the last 3-4 decades, and continue to arise. Okonya and Kroschel (2013) documented most of the climate change impacts that occurred before 2011, which included: floods in the Teso sub-region, Kampala and the Kasese district; landslides in the Bugisu sub-region; extreme heat in the cattle corridor, including the Karamoja sub-region, which led to the death of many cattle; low levels of rainfall, which led to drought due to La Niña (after the effects of El Niño), in 2012 and 1997/98; and higher temperatures on the slopes of Mt. Elgon and Mt. Rwenzori, which lowered coffee production and significantly reduced the ice cap. Extreme weather events continue to haunt smallholder farmers in Uganda with the most recent being the El Niño in late 2015 that quickly transformed into a La Niña, hence the shorter (March to mid-April) rain season in 2016 instead of the usual period of March-May. This was followed by a prolonged dry period stretching into September 2016 that resulted in a number of farmers losing their first season crops and,

V A well-maintained forest reserve.


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hence, hunger/food insecurity in Uganda. Some of the extreme climatic events that have recently occurred (over the last 6 years) in Uganda are: 1) the intense heat and prolonged dry season in 2016 due to La Niña conditions, which increased the frequency and intensity of crop pests and disease outbreaks; 2) floods in Kasese in 2013, 2015 and 2016; 3) a persistent dry season (drought) in 2015 and 2016, which caused food insecurity in the Teso and Karamoja sub-regions; 4) landslides in Bududa due to heavy rains in 2016, which led to internal displacement and loss of lives; and 5) heavy rains due to El Niño, causing floods from October 2015-January 2016, which affected over 2 million people in over 10 districts (United Nations Children's Fund [UNICEF] Uganda humanitarian site report 2016; The Africa report, 2015). Other impacts included; a) 1,196 cholera and 144,370 malaria cases being reported, b) the destruction of 9,334 acres of gardens and unharvested food crops, and d) 40% of gravel roads and 10% of paved roads and bridges being ruined.

Although indigenous knowledge (IK) is often used by rural smallholder farmers to predict changes in the climate, this is barely documented. The scientific support for IK initiatives is also rarely investigated by meteorologists, let alone incorporated into modern weather forecasting. This negligence to include IK in forecasting, let alone in the design of adaptation strategies for climatic changes, has hindered the acceptance, trust or use of official weather forecasts among rural smallholder farmers. However, farmers are often eager to know when the rain season will start so that they can begin planting, especially for the first short rain season. This is because farming systems have evolved around weather patterns.

Management of climatic risks and disasters in Uganda

Climate related disasters in Uganda are a responsibility of the office of the Prime Minister (OPM). This office mainly responds to large scale natural hazards together with other relief service providers, such as the Red Cross, World Food Program and other international and local non-governmental organisations (NGOs). However, the OPM, like many other government ministries, is constrained by limited funds/resources to mitigate or manage climate risks and natural disasters. This leaves many smallholder rural farmers at the mercy of nature or sympathetic donors to help them survive such tough times, whilst lacking basic needs. The dependence on rain-fed agriculture by the majority of smallholder farmers in Uganda, together with the low application of inputs (seed, fertilisers, pesticides) in agriculture, results in most farmers being unable to feed their families after a single season of crop failure. Since the government ministry is not able to provide long-term support (such as subsidised irrigation equipment), or short-term subsidies (like food stamps), most poor rural farmers remain food insecure and vulnerable to disease outbreaks after a single extreme weather event.

The government of Uganda has designed a number of coping mechanisms through which rural smallholder farmers can mitigate the negative effects of climate change. The Uganda National Meteorological Authority (UNMA) programme is implementing a number of projects, through the National Adaptation Programmes of Action (NAPA), to support community adaptation, such as tree growing, land restoration, the strengthening of the meteorological department, rainwater harvesting, the construction of valley dams, and vector/pest/disease control, as well as the use of IK (Government of Uganda, 2007). The NAPA policy was designed to address the challenges brought about by climate change, but also to set priorities to support adaptation.

There are many climate resilient solutions that work for smallholder farmers in Uganda. Okonya *et al.* (2013) listed 14 strategies through which farmers in six districts were coping with the negative effects of climatic change. The most commonly used measures included the planting of trees; the planting of improved, drought-tolerant, quick-maturing, or pest and disease resistant crop varieties; starting or increasing the use of pesticides; the use of mulch in a crop garden; flexible planting dates; and the diversification of income sources other than agriculture. Other climate resilient solutions that are being promoted by the government of Uganda include: 1) constructing rainwater harvesting roofs and tanks in drought prone areas; 2) constructing valley dams for cattle keepers or pastoralists; 3) promoting early maturity crops to escape drought in rain-fed crop farming systems; 4) developing drought tolerant crop varieties in drought prone areas; 5) promoting dietary diversification by including more climate resilient crops, such as roots, tubers and bananas, rather than solely cereal crops such as wheat; 6) promoting the use of conservation agriculture; 7) promoting integrated rangeland management; 8) encouraging improved post-harvest handling, storage (in granaries) and value addition; 9) promoting the construction of food granaries or stores where the surplus after a good harvest can be stored; 10) setting policies that require farmers to allocate at least 50% of their land to food crops rather than cash crops, such as sugar cane or palm oil. The capacity of smallholder farmers to adapt to or cope with natural emergencies in Uganda requires an improvement in factors that increase their adaptability, such as higher income levels, a more diverse number of income sources and a good level of education (Okonya *et al.*, 2013). In this regard, the following avenues are intended to increase adaptability: 1) the distribution of quick maturity staple crop varieties for sweet potato and cassava; 2) wealth creation programmes to increase the income and asset ownership of peasant farmers, including the distribution of free coffee seedlings, heifers, goats, piglets, banana suckers and tractors; 3) training programmes on the use of conservation agriculture practices, such as no tillage and terracing; 4) encouraging diversified income sources, which do not only depend on agriculture, but include off-farm activities such as tailoring, retail shops and motorcycle taxi driving, popularly referred to as boda boda; 5) universal primary and secondary education to boost the social status of citizens' race, ethnicity, indigenous identity, gender and level of income to help define both their vulnerability and their capacities to adapt to climate change; and 6) the distribution of drought tolerant crop varieties, such as beans, upland rice and maize.

Different indigenous knowledge systems (IKS) employed by smallholder farmers in Uganda

The IKS initiatives, which farmers in Uganda have practiced for centuries to plan their agricultural production activities are many, but for this study we limit ourselves to those IKS related to agriculture with a bias towards weather and climate forecasting. Thus, climate in relation to agricultural IK can loosely be sub-divided into about four categories: 1) indicators for the onset of the rain season, 2) indicators for the dry season, 3) indicators for extreme climatic events, and 4) practices for the management of soil, water, rangelands and forest resources.

One early warning sign of the onset of the rain season that Ugandan farmers look out for is a change in the direction of prevailing winds to blowing from west to east (Orlove *et al.*, 2010; Egeru, 2012; Okonya and Kroschel, 2013; Nganzi *et al.*, 2015). The shift in the direction of the wind could be due to the arrival of the Intertropical Convergence Zone from the south in March and its return from the north in September (Orlove *et al.*, 2010). Normally, the fist short rain season is from March to May, while the long rain season is from September to December. Calls by rain birds, such as the black cuckoos (*Cuculus clamosus*), ducks, Abyssinian hornbills

(*Bucorvus abyssinicus*) and the grey crowned crane (*Balearica regulorum*) (Orlove *et al.*, 2010; Egeru, 2012; Okonya and Kroschel, 2013; Nganzi *et al.*, 2015.), as well as many other bird species, always start instinctively when the rains are near. This could be due to the fact that their phenology or behavior, including courtship, mating, egg laying and migration to another area, is linked or in sync with the onset of the rain season. Shukla (1989), as cited in Acharya (2011), suggests that the black cuckoo birds sing in response to changes in the air waves caused by changes in the air humidity.

The appearance or arrival of migratory birds, such as the ground Abyssinian hornbill (*Bucorvus abyssinicus*) also coincides with the arrival of rains (Orlove *et al.*, 2010; Okonya and Kroschel, 2013; Nganzi *et al.*, 2015). These birds either come to Uganda to breed or escape the cold winters. The movements of fronts are used by these migratory birds to provide them with tailwinds (Liechti, 2006). The movement of insects uphill (like the African army ants) or out of their nests (like the African flying white ants or termites) is another indicator of the onset of rain (Okonya and Kroschel, 2013; Nganzi *et al.*, 2015). It is possible that these insects can sense differences in the humidity, pressure and temperature of the air vis-à-vis that inside their nests in the soil. The uphill migration of the African army ants from low land areas is probably a natural instinct to avoid areas that are likely to be flooded. Black ants (*Componotus herculeanus*) have been observed to carry their eggs uphill when rains are approaching.

Local communities have reported a feeling of excess body heat during the night and day in the weeks before the rains, which could be due to increased temperatures, resulting from increased convection over the Lake Victoria basin. This increased convection at the onset of the rain season suggests an increased downward motion over the land; the warming of air that accompanies downward movement and compression could be associated with unusually warm nights (Orlove *et al.*, 2010; Okonya and Kroschel, 2013; Nganzi *et al.*, 2015). A number of tree species, including coffee, neem (*Azadirachta indica*) and the African teak (*Milicia excelsa*) are known to flower when the rain season is about to begin (Orlove *et al.*, 2010; Okonya and Kroschel, 2013). Curran *et al.* (1999) observed that El Niño events may be linked to the triggering of the flowering of trees. After the onset of monsoon and when temperatures are high (over 40°C), a low pressure zone is created that attracts the clouds and, hence, induces rain (Chhaganibhai, 1992 as cited by Acarya, 2011). The formation of dark clouds (Okonya and Kroschel 2013; Nganzi *et al.*, 2015), observation of celestial bodies, such as the halo moon and a group of stars in the east (Orlove *et al.*, 2010; Okonya and Kroschel 2013), the sprouting of tree leaves and croaking by frogs (Okonya and Kroschel, 2013; Komutunga *et al.*, 2013; Nganzi *et al.*, 2015) are all signs indicating the imminent coming of rain.

IK indicators for the end of the rain seasons have been reported by Okonya and Kroschel, (2013) and Nganzi *et al.* (2015), including winds blowing from east to west, the shedding of leaves by some trees, the appearance of insects, such as the bush cricket and butterflies, colder temperatures at night and a clear sky. The increased number of butterflies observed could be due to higher temperatures, which shorten their generation time, hence enabling them to have many generations in a short space of time (Okonya *et al.*, 2015). The reduced rainfall conditions also reduce the effectiveness of natural entomopathogenic fungi, such as Beauveria balbisian, that often limit butterfly life stages.

A number of government programmes, such as The Northern Uganda Social Action Fund (NUSAF), include a community reconciliation and conflict management (CRCM) component, which aims to integrate IKS into its operations of peace building and conflict management (Laker and Namara, 2006). The NUSAF programme empowered traditional institutions to not only engage the local government, but also to facilitate post conflict reconciliations among local communities. The knowledge and skills of both traditional leaders facilitated reconciliation, and brought healing and cohesion to the disrupted communities in the Acholi region. Community interaction was strengthened and social capital enhanced through this CRCM programme. The National Agricultural Research Organization (NARO) implemented a World Bank supported agriculture research and training project with the main aim to incorporate IK into agricultural research (Aluma *et al.*, 2001). Integrating IK into NARO's technology development process was noted to increase farmer adoption rates, but also lower the adoption costs of NARO's technologies. This project identified a number of IK practices to be promoted, which included technologies for seed and food preservation, crop and livestock management, educational methods, and cultural values and taboos.

Farmers in Uganda continue to practice traditional farming practices for the management of their crops, soil, water, forests and rangelands. Among the most common traditional practices is the use of local herbs (plant extracts) to make biorationals/biopesticides in order to control pests and diseases. For instance, Agea *et al.* (2008) reported that up to 25% of farmers in Soroti applied local homemade concoctions instead of using chemical pesticides to control pests and diseases on their farms. Akullo *et al.* (2007) also reported the use of IK in most of the farming activities of farmers in the Hoima, Masindi and Kibaale districts. Survey results from the Masaka and Mukono districts report that over 70% of smallholder farmers practiced shifting cultivation, crop rotation, mulching and used scare crows in their fields; all of these practices have been learned from their parents (Agea *et al.*, 2008). Additionally, the conservation of plant species for cultural reasons, such as taboos, has played a big role in biodiversity conservation and the restoration of degraded landscapes. Amidst deforestation for fuel production (charcoal and firewood), some tree species in the Kaliro district continue to thrive because they cannot be used for cooking due to cultural reasons. These trees include, *Piliostigma thonningii, Flueggea virosa, Gardenia ternifolia, Dracaena fragrans, Euphorbia tirucalli,* and *Hymenocardia acida* (Tabuti and Van Damme, 2012).

Trends and the extent to which IKS are being used by farmers

Statistics on the use of IK are only just starting to emerge due to the little research and documentation accorded to this field. A few references are, however, available for Uganda in the mainstream scholarly literature, all of which are quite recent, i.e. less than 10 years-old. In 2007, Akullo *et al.* (2007) carried out a study in the three districts of Uganda (Hoima, Kibaale and Masindi) and reported a number of IK practices that were being used in agriculture by smallholder farmers, but did not indicate the percentage of use for each IK practice. The study involved interviews of 240 individual farmers and 12 focus group discussions of 15-25 key informants (elders, community leaders and agricultural extension officers). Orlove *et al.* (2010) reported that 21% of the farmers in Rakai district used local indicators to predict the start of the rain season. Survey results by Okonya and Kroschel (2013) from six districts in Uganda (Gulu, Kabale, Kasese, Masindi, Soroti and Wakiso) in 2013, showed that on average 50% of the farmers used at least one IK indicator to predict the onset of rains and 38% for the start of the dry season. According to Egeru (2012), 85% of the households in the study area used IK on a daily basis whilst carrying out crop production activities, for predicting the start of the dry season and for spiritual matters (Egeru, 2012). In a study covering

22 districts of Uganda, Nganzi *et al.* (2015) observed that IK in weather forecasting was being used by 94.6% of the 135 interviewed agricultural communities and the majority of the 53 district officials (97%) interviewed re-affirmed this.

The extent to which IKS actions are still relevant in contemporary situations

Investment in weather forecasting

Economic, and specifically financial, constraints make it impossible for governments to afford or purchase powerful and state-of-the-art equipment (computers and computer programmes) that can accurately predict climatic events based on satellite observations. Additionally, the meteorological department is unable to hire and facilitate enough technical staff to man the few weather stations that do exist. Poor staffing can, therefore, sometimes be a source of error in weather predictions, resulting in less precise forecasts that farmers cannot always rely on. Furthermore, out of the 110 districts in Uganda, active ground weather stations are in less than a quarter, which is not spatially representative and can negatively impact weather predictions. So, IK continues to be relevant with very few weather stations in the country to give reliable forecasts and the inefficiency of the meteorological department's dissemination of its weather forecasts.

A young boy observing a swarm of locusts filling the sky near farmlands.

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Accuracy and reliability of weather forecasts

UNMA has time and again issued official seasonal weather forecasts that have not been accurate at the local level. This is probably because the models used in most African countries for seasonal prediction give predictions that are too general, and at times not relevant at the local level. This has therefore increased skepticism among the general public and specifically smallholder farmers. 91% of the 223 farmers interviewed in Uganda by Nganzi *et al.* (2015) reported that official seasonal weather forecasts were unreliable. In the same study, 79% of the respondents continued to use both IK and official forecasts to plan their farm activities. In a related study in the Kaboong and Soroti districts, Komutungi *et al.* (2013) reported that more farmers (58%) considered IK more reliable than meteorological forecasts.

Access to weather information

Since most of the weather/climate forecast messages are relayed on radio, television and print media, many farmers who do not have access to these information sources due to poverty, or otherwise, base planning of their farm activities on IK. Secondly, due to the large number of ethnic groups/languages spoken in Uganda (over 56 tribes and nine indigenous communities), it remains a challenge for the weather forecasts to be translated into all local languages, leaving IK as the only option for illiterate farmers or small tribes (Nganzi *et al.*, 2015). Although the modern weather forecasts may be very accurate and accessible in certain areas, some elders prefer to hold onto and use IK indicators because they learnt them from their fore fathers, whom they trust and believe to be accurate. Some IK practices have become a part of these people's culture, which they are not ready to give up for modern scientific methods.

Threats to the use of IKS and policies and actions to conserve IK

IKS, like most knowledge systems, come with a number of threats even if policies to conserve them are in place. The implementation of polices that are not directly related to politics is not treated with the utmost importance in most African countries. Among the factors that threaten the use of IK is rural to urban migration: when most of the youth move to urban centres to seek employment, very few are left in rural areas to interact with the elders and learn IK skills. At the same time many rural youths are abandoning agriculture due to high inputs and low returns. Urban growth activities, such as hunting, charcoal burning, timber production, the construction of modern infrastructure like buildings, roads, and large commercial farms/plantations, threaten IKS by either changing the landscape, or destroying/displacing the natural ecosystem (forests, water bodies), which provides the habitat for the birds, animals or insects whose sounds/songs/calls/movement are needed for IK. The disappearance of IK indicators from the ecosystem due to environment degradation also poses a great risk to their continued use. A generational shift in attitudes towards IK also threatens its continued use and existence. Many young people think it is old-fashioned, unreliable or primitive to follow or use IK, so they are abandoning the use of IK in favour of scientific methods from developed western countries to make climatic predictions.

Changes in the climate: farmers used to plant some crops, such as millet, potato and maize, during the dry season when they were sure of the seasonality of rain. However, this traditional practice is becoming less and less common nowadays due to the unpredictability of the start of the rain season (Olive *et al.*, 2010; Egeru, 2012; Nganzi *et al.*, 2015).

Inadequate documentation and illiteracy: most IK practices are not documented, but rather, orally communicated, practiced or demonstrated and may be lost with the death of elders and gifted foretellers.

Gender differences: some cultures (Iteso and Kuman) in eastern Uganda also have limitations on who in the community acquires the IK. Some IK practices are restricted to a certain gender, age, family, clan, leader or community. This restriction in transmission bars others from accessing and using this IK (Egeru, 2012; Haumba, 2015), and inadequate frameworks to conserve and patent IK, coupled with the total disregard for the value of IK due to misconceptions and disrespect of cultural values, threatens the survival of IKS (Uganda, 2007).

Some policies do exist in Uganda regarding the use of IK, for instance, Uganda has a policy on climate change which seeks to reduce the country's vulnerability to changes in the climate. Although, the policy emphasises the need to promote community-based approaches to adapt to climate change, no explicit mention is given on the use or involvement of IK (GoU, 2015). To increase household income, the Poverty Eradication Action Plan (PEAP) of Uganda lays emphasis on the inclusion of IK in the design of sustainable community-based agricultural programmes, to improve the ease of implementation and acceptance of programme technologies by smallholder farmers (PEAP, 2004). In the NAPA for Uganda, local communities are often consulted on how IK can be used in sustainable environment conservation, traditional medicine and weather forecasting (GoU, 2007). Section 7.3 of the *Uganda National Culture Policy* emphasises the need to preserve, integrate, use and promote IK (Ministry of Gender, Labour and Social Development [MGLSD], 2006). Section 4.1.4 of the *National Science, Technology and Innovation Policy* provides a guide to the judicious use and application of traditional, conventional and emerging technologies for sustainable development. IK is included in this policy (Ministry of Finance, Planning and Economic Development [MoFPED], 2009) and a national IK strategy (Kampala Declaration) was formulated by all stakeholders in Uganda.

Actions to conserve IK in Uganda should include:

Education: the introduction of IK into primary school curricula and competitions among school children that promote the mastery of cultural norms and traditions of a given ethnic group, offering appropriate incentives to winners. The use of indigenous languages should also be encouraged e.g. children should not be punished for speaking their mother tongues at school. At Ugandan universities, competitions between different cultural groups do exist and most students feel proud to be members of these groups, which have taught them their cultural values. Examples of such groups include Nkobazambogo of the Buganda Kingdom and Basonga Nsete of the Busoga Kingdom, among others.

Documentation and dissemination: there is a need to identify, document and disseminate IK. This will facilitate its accessibility and increase usage. Creating digital copies of IK to make it available in universities and national libraries would go a long way in promoting its use and conservation.

Cultural kingdoms: there are over five kingdoms in Uganda and each kingdom should be charged with promoting its cultural heritage and the conservation of IK. An IK Resource Development Newsletter published by the Uganda National Council for Science and Technology does already exist.

Potential for synergy of IKS with existing scientific climate approaches

It should be noted that both meteorologists and indigenous people base their seasonal forecasting on the same atmospheric parameters, such as prevailing winds, type of clouds and sea temperatures. It is therefore possible for these two fields (farmers and scientists) to support and complement each other to increase the accuracy, acceptance and reliability of seasonal forecasts. There are a number of ways in which IK can be synergised with existing scientific approaches to mitigate climate change. Among them is the inclusion of IK in the development and testing of climate change related adaptation technologies, such as flood or drought tolerant crop varieties. This will increase the adoption rates of new technologies as the use of IK will improve their relevance for farmers. In order to improve food security and risk management strategies in rural areas, there is a need for the integration of IKS into official forecasts, which requires better awareness among village elders and chiefs of how the official forecasts work to complement the IK approaches. This can be achieved through routine discussions and meetings with the custodians of the IK and a continuous exchange of information between meteorologists, local chiefs and village leaders on how to improve the accuracy of weather forecasts. Examples can be seen in Kenya, Niger and Ghana where local groups, farmers, meteorologists and pastoralists are coming together to collect, share and plan for climatic events with the support of the United Nations Educational, Scientific and Cultural Organization (UNESCO) and CARE (CARE, 2013).

More studies are needed to explore if and how the traditional indicators for climatic events are responding to changes in the climate. Adaptation strategies that smallholder farmers are using will also need to be documented. CTA has developed and integrated IK to create a participatory 3D relief map. This elicited discussions and suggestions by local communities on how best to adapt to the changing climate. Local leaders were then able to use the different layers of the model to explain to the relevant authorities their understanding of climatic change, but also task their government to take action (CTA, 2012). Farmers are very keen on observing changes to the climate in their locality, on a daily basis over an extended period of time. Sharing such information with scientists can help them to identify the most vulnerable locations that need immediate interventions.

Below are suggestions of ways in which IKS can be adapted to the current efforts to address climatic challenges facing smallholder farmers:

(1) Biodiversity conservation of tree, bird and other wildlife species – some cultural beliefs and values exist in a number of cultures that do not allow the cutting down of certain tree species or the eating of some animals and birds. Identifying these cultures and promoting the strict observation of indigenous beliefs and values that promote conservation can significantly contribute to biodiversity conservation for trees, birds and animals.

(2) Absence of official forecasts at a community level – in the absence of accurate official weather forecasts for particular villages, there is a need for farmers to be trained on IK, specific to their area, which is proven to work. This will help both villagers and the government not simply to rapidly respond to crises, but also to be proactive and put in place a risk management plan based on IK outcomes and predictions.

(3) Adaptation to climate change – indigenous people should be involved as key partners in the design of adaptation plans for climate change. The observations and IK of the local people should form an integral part of a successful, sustainable, cost-effective mitigation and adaptation strategy.

(4) Matching indigenous indicators with their meteorological equivalent – indigenous indicators of climatic events, like those based on plant phenology, should be linked to their meteorological equivalent. This would not only increase local farmers' trust in official weather forecasts, but also increase the effectiveness of adaptation strategies in coping with climatic shocks (Ziervogel and Opere, 2010).

(5) Participatory data collection and analysis – tools that prioritise the use of IK in data collection and analysis, for the design of climate adaptation strategies, need to be developed. An example of one such tool is the climate vulnerability and capacity analysis (CVCA) by CARE. The CVCA tool involves participatory methods, such as the use of historical timelines, hazard mapping, a vulnerability matrix and seasonal calendars. Such a tool can be used at all decision-making levels, including by policy makers (Dazé, Ambrose and Ehrhart, 2009).

(6) Strong and specific policies – tailored policies need to be put in place together with an operational plan of specific objectives to integrate IK when planning for adaptation strategies to climate change.

(7) Documentation of IK – the documentation of IK in journals, such as the *Indilinga African Journal of Indigenous Knowledge Systems*, may help to conserve as well as disseminate IK. However, such knowledge needs to be open access for its contents to be easily used and have maximum impact. The formation of networks of professionals – such as the agriculture network, which routinely gathers and publishes IK in magazines – can go far in creating awareness and increasing readership of IK (Anonymous, 2016).

Conclusion

Rain-fed agriculture is the main source of income for many smallholder farmers in rural communities, who are always eager to know the best time to plant their crops. Most IK and weather prediction indicators are, therefore, related to rainfall. Rainfall is key to food security with a year of bad rain directly resulting in household food insecurity among most farmers in Uganda. IKS and scientific approaches to seasonal weather forecasts are two systems that could be harmonised to strengthen mitigation and adaptation measures towards climate change impacts, such as unpredictable rainfall patterns. In order to achieve this, the documentation of IK needs to be encouraged. Some policies regarding the use of IK to complement official weather forecasts exist, but their enforcement needs to be emphasised. Specific policies on the use of IK in seasonal weather forecasting ought to be elaborated with a clear formal framework in the climate change policy of Uganda. The growing interest among researchers, donors, and governments regarding the importance of understanding the role of IK in improving the adaptive capacity of a given community (IPPC, 2014), provides opportunities to use IK in strategies to address the challenges of climate change .

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CHAPTER 12 - Indigenous knowledge systems for managing climate change in South Africa

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Abstract

It is well documented that farmers have used a variety of information sources in order to manage climate risks in southern Africa. Some farmers in this region rely on indigenous knowledge systems (IKS) that utilise environmental information, such as cloud formations, wind formation, insect behaviour and floral characteristics, as climate monitoring tools. The knowledge, or beliefs from IKS, are transferred from one generation to another, with the farmers and traditional community chiefs of sub-Saharan Africa (SSA) – including South Africa – always having had their own strategies/local methods of predicting seasonal climate. However, farmers of this region have, since the 1900s, been exposed to the scientific climate forecasting approach, and some have started to use the information as a guide during decision-making processes as part of climate change adaptation.

Three case studies are used in this chapter to highlight the role of IKS in regions of SSA. The first case study focuses on three sites of the Limpopo province in South Africa – Rabali, Tshakhuma, and Tshiombo. The second case study focuses on the Karoo region in the Western Cape province of South Africa, and the third, on the role of IKS in other southern African countries. Results from the Limpopo province show that farmers base their production decisions on information from IKS, developed from years of observation, experience and experimentation. Similar observations were found for the smallholder farmers in the Karoo region of the Western Cape province. In other southern African countries such as Lesotho, Malawi and Zimbabwe, some farmers used environmental indicators such as cloud

formations, the patterns of stars and constellations, floral characteristics and wind direction, and animal behaviours such as pigs grunting and the migration of birds, to help manage climate risks.

Introduction

According to Masinde and Bagula (2012), indigenous/traditional knowledge (IK) is described as the knowledge of an indigenous community, accumulated over generations of living in a particular environment. It is a traditional, cultural knowledge that includes intellectual, technological, ecological and medical information. Ncube and Lagardien (2015) define IK as a body of knowledge built up by a group of people through generations of living in close contact with nature. This knowledge is established where people have survived for a very long time and have become familiarised with their surroundings. IK systems (IKS) applications vary from region to region, for example in southern Africa, IKS refer to bodies of knowledge embedded in African philosophical thinking and social practices that have evolved over thousands of years (Maferetlhane, 2012; Ncube and Lagardien, 2015). According to Ncube and Largardien (2015), the South African cabinet approved the IKS policy in 2004, which provides a broad basis for the recognition, understanding, integration and promotion of IK resources within South Africa (Maferetlhane, 2012; Ncube and Largardien, 2015).

∨ **Maize processing in Nhamuka Village.**

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In their 2015 paper, Ncube and Lagardien highlight the sharp increase in the number of publications focused on the area of IK in Africa, especially in South Africa, where tens of research projects have been funded through the National Research Foundation. Despite this encouraging trend, publications in the category of weather, drought and climate variation prediction, and more specifically, studies on agriculture and the environment, are still rare, and minimally represented as compared to other subject areas such as culture in relation to environment (Masinde and Bagula, 2012; Ncube and Lagardien, 2015). Similar concerns were highlighted in a study by the Water Research Commission in 2015. Generally, publications on the topic of IK within African climate management strategies reveal that communities use various mechanisms to predict drought and weather forecasts (Mpandeli, 2006; Masinde and Bagula, 2012; Ncube and Lagardien, 2015). Communities have been found to observe or use climate prediction indicators during the changing seasons, including lunar cycles, the behaviour of animals and the appearance of certain plants (Alcock, 2010; Masinde and Bagula, 2012; Ncube and Lagardien, 2015). Like modern weather forecasts, IK also involves studying meteorological parameters such as air temperature, cloud colour and wind direction (Masinde and Bagula, 2012; Ncube and Lagardien, 2015). It has been noted that researchers nowadays concur that IK and modern science complement each other.

In contrast to developed countries, the majority of the rural populations in sub-Saharan Africa are engaged in farming. And small-scale farmers are known to produce the greater proportion of food consumed in SSA (Broad and Agrawal, 2000; Ifejika, 2010; Ncube and Lagardien, 2015). The production practices of these farmers are largely based on local knowledge and the experience they have gained over the years (Adger, 2001; Gommez, 1999; Ncube and Lagardien, 2015), as such, strategies and perceptions of risk very with location.

Background

According to the Intergovernmental Panel on Climate Change (IPCC, 2007), climate change exerts multiple stresses on the biophysical as well as the social and institutional environments that underpin agricultural production. The impacts of climate variability on the African continent have been observed by many, particularly those affecting agricultural systems (Mark *et al.*, 2008; Khanal, 2009; Jiri *et al.*, 2016). Such impacts include: (i) the alteration of land suitability for agricultural production (ii) seasonal changes in rainfall and temperature, impacting agro-climatic conditions; altering growing seasons, planting and harvesting calendars; water availability; and pest, weed and disease populations (iii) alteration in evapotranspiration, photosynthesis and biomass production. The impacts, however, vary from region to region and consequently the strategies to adapt to the impacts vary across spatial locations. Factors that can influence adaptation strategies among countries include: economic disparity, cultural differences, severity of climatic change impacts, and the socio-economic activities carried out by the population (Adger, 2001; 2003). The capacity of a country to respond effectively to climate change is bound up in the ability and interest of its societies to act collectively. However, specific groups within society such as government and organisations that champion IK and climate change issues, tend to act on behalf of society as a whole. Therefore, decisions made regarding climate adaptation can privilege one set of interests over another, creating winners and losers (Adger, 2001; 2003; Tompkins and Adger, 2003).

The most widely used climate change adaptation strategies in southern Africa include the production of drought resistant crop varieties and early maturing crops; crop and livestock diversification; and animal culling and food storage (Dabi, 2005). Another coping strategy for farmers in this region is the use of traditional or indigenous forecasting techniques that have evolved over time. Such strategies may provide farmers with useful information in order to optimise their agricultural practices (Alcock, 2010; Masinde and Bagula, 2012; Ncube and Lagardien, 2015).

Due to the poor dissemination of climate information in South Africa, the majority of farmers in Limpopo province use IK/local knowledge as a way of counteracting climate risks. However, feedback from the farmers in the study areas of Rabali, Tshakhuma and Tshiombo showed that there are large numbers of farmers who are ready to use technically derived climate forecasting in order to increase their yields, and produce higher quality products. It has been highlighted in various studies that farmers in southern Africa are farming in very difficult situations due to the lack of proper extension services and access to climate advisory information – especially in the Limpopo province and Karoo region in Western Cape of South Africa (Mpandeli, 2006; Maponya and Mpandeli, 2012; Ncube and Largardien, 2015). A major constraint to farming locations that experience marked climate variability are also generally subjected to periods of drought and flooding.

One tool that could be added to farmers' risk management portfolios is seasonal climate forecasting. The majority of agronomic crops produced in southern Africa are highly sensitive to high climate variability and change. For example, research carried out in various countries of southern Africa has demonstrated that a 2° rise in ambient temperature, and a rise in mean temperature by 4° would significantly lower crop yields (Jiri *et al.*, 2016). Previous studies have tested the potential effects of climate variability and change on maize, a staple crop in Zimbabwe, using a general circulation model and the dynamic crop growth model CERES-maize. Results showed that maize production was expected to significantly decrease by approximately 11-17% under conditions of both irrigation and non-irrigation (Mpandeli, 2006; Maponya and Mpandeli, 2012; Jiri *et al.*, 2016).

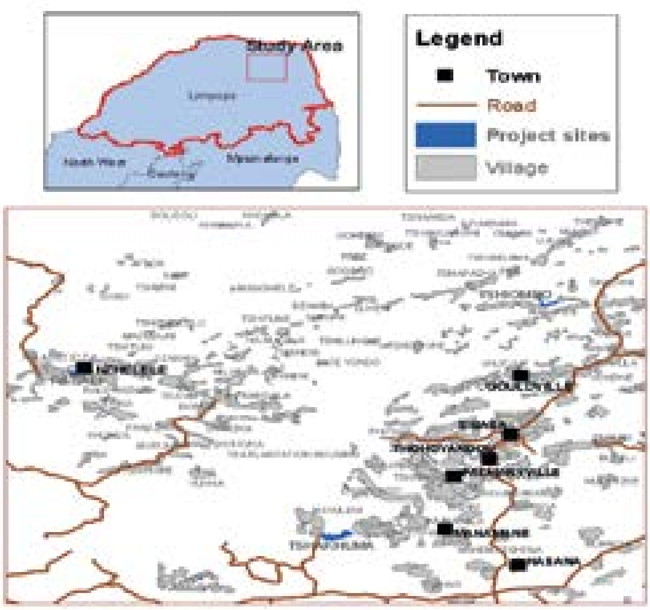


Figure 1: Map of Limpopo province showing different villages in the Vhembe district (formerly Venda homeland)

Source: ARC-ISCW, 2013

Methodology used in Limpopo province

Three study areas were selected for this research. The study areas are situated in Venda, in the Vhembe district, which is located approximately 184 km north of Polokwane in South Africa. The research sites are rural with proximity to larger areas of commercial activity, e.g. Tshakhuma village, the first site to be visited, is 37 km away from Thohoyandou Central Business District (CBD), and 40 km away from Makhado (Figure.1). Tshakhuma is situated 28° 30' east longitude and 24° 25' south latitude and is an area where major horticultural crops are grown. The following villages share boundaries with Tshakhuma village: Elim, Levubu and Lwamondo. These villages are situated at an altitude of 600 m above sea level.

Rabali, the second site visited, is a semi-arid area where farmers produce different types of livestock such as cattle and goats. Rabali area is situated 30° 30' east longitude and 24° 58' south latitude, 25 km from Thohoyandou CBD and 15 km from Makhado (formerly known as Louis Trichardt). The following villages share boundaries with Rabali village: Dzanani, Ha-Matidza, Mauluma and Raliphaswa. These villages are situated at an altitude of between 600-700 m above sea level. In Tshiombo, the third site, farmers plant maize, groundnuts and other olericultural crops such as spinach and onions. Tshiombo village is 35 km from Thohoyandou CBD. The Tshiombo area is situated 30° 50' east aongitude and 22° 79' south latitude, 35 km north of Thohoyandou CBD. The following villages share boundaries with Tshiombo: Makonde, Pile, Thengwe and Tshandama. These villages are situated at an altitude of 650 m above sea level.

The second case study is from Karoo region in the Western Cape province of South Africa, which focused on three municipalities: Beaufort West, Oudtshoorn and Prince Albert (Figure. 2). The study sites lie within the dry Central Karoo district and Oudtshoorn, which is in the Eden district (Ncube and Lagardien, 2015). The Karoo region covers a huge area, roughly 45% of the Western Cape province, and is home to about 6% of its people.

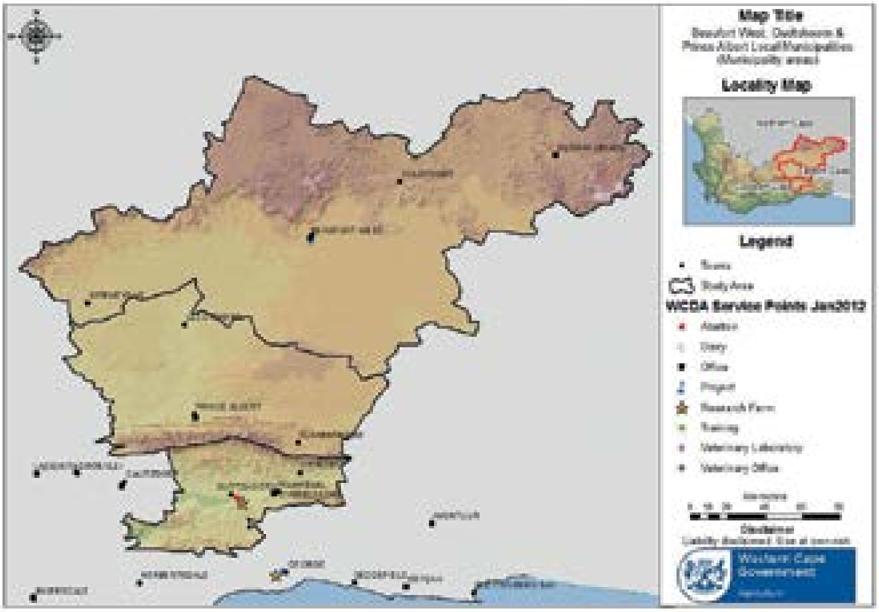
Research methodology

An assessment of the coping and adaptation strategies used by farmers in the study regions was undertaken. Embedded in this chapter is also an evaluation of the role that information – which includes IK – could play in managing climate risk. The methods used to achieve this aim included literature reviews, survey instruments, participatory rural appraisal and focus group discussions (FDGs) with farmers in the area, as well as stakeholder and key informant interviews.

Chronology of research activities

The various phases of the research undertaken in the Limpopo province and Karoo region, are detailed below.

Figure 2: Location of Beaufort West, Oudtshoorn and Prince Albert municipalities.



(Source: Western Cape Government Department of Agriculture GIS Unit, 2014).

Phase 1

Pre-survey visit: A pre-survey visit of selected areas was arranged with the tribal authorities of each area. The objectives of the pre-survey visits were:

(a) To meet the tribal authorities of the selected area such as headman, chief and civil organisations;

(b) To demonstrate the objective of the survey and the content of the intended questionnaires;

(c) To introduce the survey team to the tribal authorities and seek permission to work in each of the communities;

(d) To meet agricultural officials including extension officers from both the Limpopo Provincial Department of Agriculture and Environmental Affairs and the Western Cape Provincial Department of Agriculture.

Phase 2

A detailed desktop review of IK was carried out and case studies from the various study regions were completed. The interviews with farmers, key informants and stakeholders were undertaken in collaboration with extension officers, agricultural scientists and local community members of the Limpopo province and Karoo region in the Western Cape province. Methods for capturing IK were also reviewed and those appropriate were selected for use within the study. Participatory research methods were adopted throughout the study, particularly during interactions with the famers.

Valuable information obtained during both the formal surveys and the FGDs – including on the use of indigenous climate information and coping strategies used for drought and flood periods – will be dicussed in this chapter (Ziervogel *et al.*, 2004; Mpandeli and Maponya, 2012; Ncube and Lagardien, 2015).

Results and discussion

Case study 1: Limpopo province of South Africa

Traditional and local knowledge systems still play a major role in farmers' decision-making strategies. Results from the Rabali, Tshakhuma and Tshiombo study sites show that farmers use cloud formation to monitor possible rainfall occurrence. More than 60% of the 90 farmers surveyed in the Rabali, Tshakhuma and Tshiombo areas perceive cloud formation as the best climate-monitoring tool. A key area for further research would thus be to identify where/how these practices can be integrated with seasonal climate forecasts for improved risk management decisions.

More than 45% of farmers in the Rabali, Tshakhuma and Tshiombo areas were using external forecast information only. During FDGs, it was indicated that the majority of farmers accessing and utilising external forecast information were young people, who obtained such information through the radio and newspapers. The results from the formal survey showed that more than 45% of the farmers in the Rabali, Tshakhuma and Tshiombo areas preferred to receive external climate forecast information during September, when it is time to assemble all inputs such as fertilisers, herbicides and seeds.

How farmers in the Rabali, Tshakhuma and Tshiombo areas cope with climate change using IK/ traditional methods

Farmers in the Vhembe district have developed their own risk management strategies for climate change using indigenous/traditional climate indicators. Coping strategies refer to the actions or activities demonstrated by farmers or households, usually over short time spans, to survive when confronted with unanticipated livelihood failure. For example, during drought periods, farmers may adjust fertiliser inputs and/or adopt drought-tolerant crop varieties.

Adaptation strategies refer to farmer responses to climatic conditions that may be used to reduce vulnerability. These are usually referred to as longer-term coping strategies (IPCC, 2001). Adaptation strategies used by farmers during drought include the utilisation of climate forecasting to obtain valuable information for optimised agricultural productivity (Ncube and Lagardien, 2015). Indigenous/ traditional forecasting indicators have been used for decades in the Vhembe district in Limpopo province, and the majority of farmers have high confidence in incorporating them within their coping strategies. Although traditionally used for shorter-term coping strategies, the use of indigenous/traditional indicators has evolved, and in some cases is now incorporated within longer-term adaptation strategies. This is particularly the case for farmers in the Rabali, Tshakhuma and Tshiombo areas and Karoo region.

The results from this study are comparable to results obtained by Hammer et al. (2001) and Phillips et al. (2001), who both reported case studies where farmers were using a variety of forecasting methods to reduce risks. For example, farmers in Zimbabwe in 1997-1998, and again in 1998-1999 used seasonal climate forecasts and local knowledge based on the readings of clouds, wind, flora and fauna. All these indicators were usually based on local and cultural beliefs. Similar findings have been described in other case studies (Luseno et al., 2000). Research conducted in Kenya indicates that some farmers also use indigenous/traditional knowledge indicators in order to cope with climate variability and extreme climatic events in their farming activities. Farmers used indicators such as cloud formation, wind behaviour and lightning (Luson et al., 2000). Others observed the behaviour of livestock, wildlife or local flora (Luseno et al., 2000).

Results from the three study sites in Limpopo indicated that the majority of farmers are also using a range of indigenous/traditional indicators to 'read' the weather and climate in order to manage risk. Cloud formation was perceived as the best parameter by all farmers in the study sites to monitor possible rainfall occurrence. While cloud formations usually relate to changes in weather in the short-term, the repeated observation of certain cloud patterns has enabled farmers to begin to adapt such observations for longer-term planning. All of the interviewed farmers indicated that the lack of timely external forecasting information makes them reluctant to abandon these traditional methods in their farm management, even though IKS are losing value due to increasing climatic variability and change.

Osunade (1994) indicates that in order to cope with climatic variability and climate change, farmers use a series of indicators to plan production activities. These indicators have been developed over time through the observations of stars and the moon, and are used in combination with farmer experiences and information passed down from previous generations (Mpandeli, 2006). As shown in this chapter, farmers at all study sites use indicators such as cloud formation, wind behaviour, and cultural beliefs in their strategies, which have been used repeatedly over time and have become part of a risk-management portfolio.

When the clouds are clustered and dark, farmers know that rainfall is imminent; almost 88% of surveyed respondents in Tshakhuma use cloud formation as an indicator of possible rainfall. Two percent of farmers in the same area indicated that if the wind direction is from east to west, it means that rain is coming within the next 24 h. At least 10% of the respondents indicated that they use different kinds of indicators in their farming activities e.g. by observing wind formation and temperature (Figure 3a). This knowledge was inherited from their ancestors and grandparents; however, some of the farmers raised concerns about IK becoming less effective due to the increasing frequency and intensity of extreme climatic events.

The high usage of clouds and wind direction as indicators of possible rainfall was also found in the other sites. In the Rabali area for example, 78% of the respondents used cloud formation as a traditional rain forecasting method (Figure 3b). At least 6% of respondents indicated that wind behaviour was also used within indigenous/traditional forecasting. If the wind direction is travelling from east to west, this is perceived by older farmers as an indicator of high rainfall.

The use of plant and tree characteristics as indicators within indigenous/traditional climate forecasting systems was indicated by 6% of respondents in the Rabali site. A further 10% indicated that they used other pointers such as the behaviour of specific animals. Despite the observation that only 10% are using agricultural indicators (e.g. assessing changes in mango flowers), these are still important indicators that were used, particularly during planting.

The majority of farmers (68%) in the Tshiombo area also use cloud formation as an indication of possible rainfall. Two percent noted wind behaviour and the behaviour of insects as local indicators of rainfall (Figure 3c). For example, older farmers in the Tshiombo area believe that if the wind blows from the west, rain will be received within the next 12 h. These farmers also stated that the behaviour of insects such as the locust, locally known as bapu, sometimes indicates to them the occurrence of crop disease problems during the season (Figure. 3c). While the interesting observations of traditional indicators have been described, the role of indigenous/traditional beliefs, myths and superstitions require more research in the Limpopo province.

Studies conducted in Botswana, Malawi and Uganda show that IK forecasting is frequently used. This is

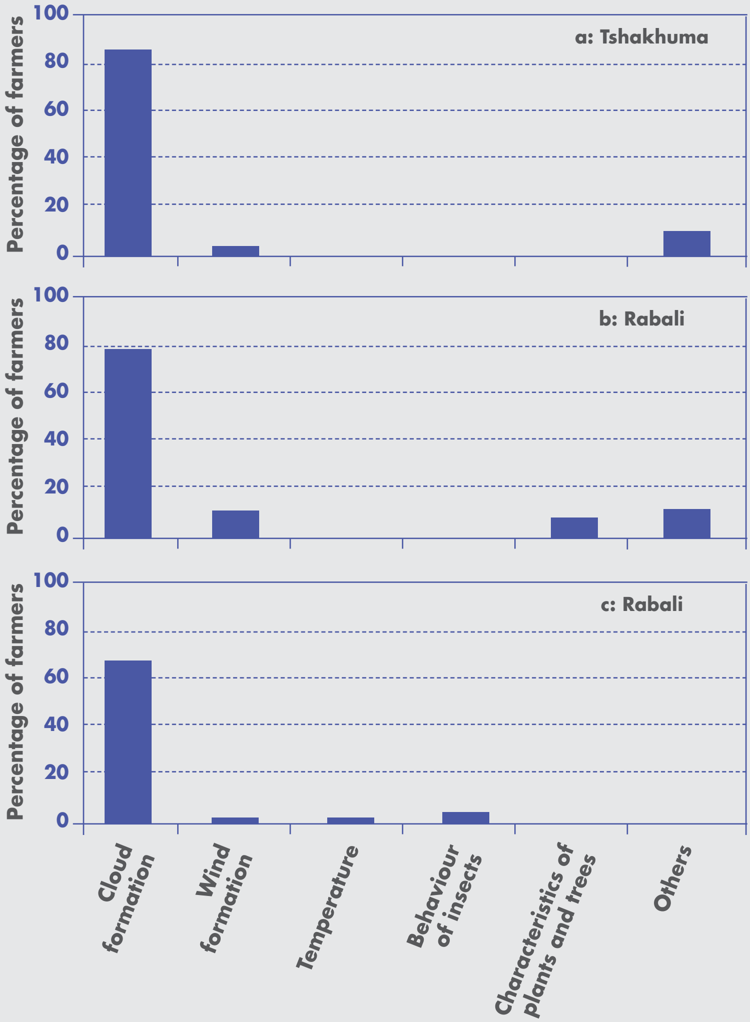


Figure 3: Traditional forecast methods used by farmers in the areas of Tshakhuma, Rabali and Tshiombo, Limpopo province, South Africa.

because community elders who are the predominant custodians of this knowledge command respect, and their stock of personal experience is considered to be valuable (Briggs and Moyo, 2012; Kolawole et al., 2014; Orlove et al., 2010; Jiri et al., 2016). It is highlighted in previous studies that farmers tend to share their experiences and knowledge on forecasts with others at a large scale to give them a sense of the arrival and progress of the rains (Orlove et al., 2010; Jiri et al., 2016). Farmers in Botswana and Malawi claimed that indigenous forecasts tend to be more accurate and simple to understand to farmers, as opposed to the complex nature of scientific forecasts (Ouma, 2009; Briggs and Moyo, 2012; Kolawole et al., 2014). This is due to scientific forecasting requiring sophisticated equipment, formal education, training and financial investment (Ouma, 2009; Briggs and Moyo 2012; Kolawole et al., 2014; Jiri et al., 2016). Local farmers prefer to use tree phenology, animal behaviour, wind circulation, cloud cover and social indicators to predict rains and season quality.

Use of forecasts, both indigenous and scientific, in the Rabali, Tshakhuma and Tshiombo areas

The majority of surveyed farmers in the Vhembe district in Limpopo province use IK as a system of knowledge

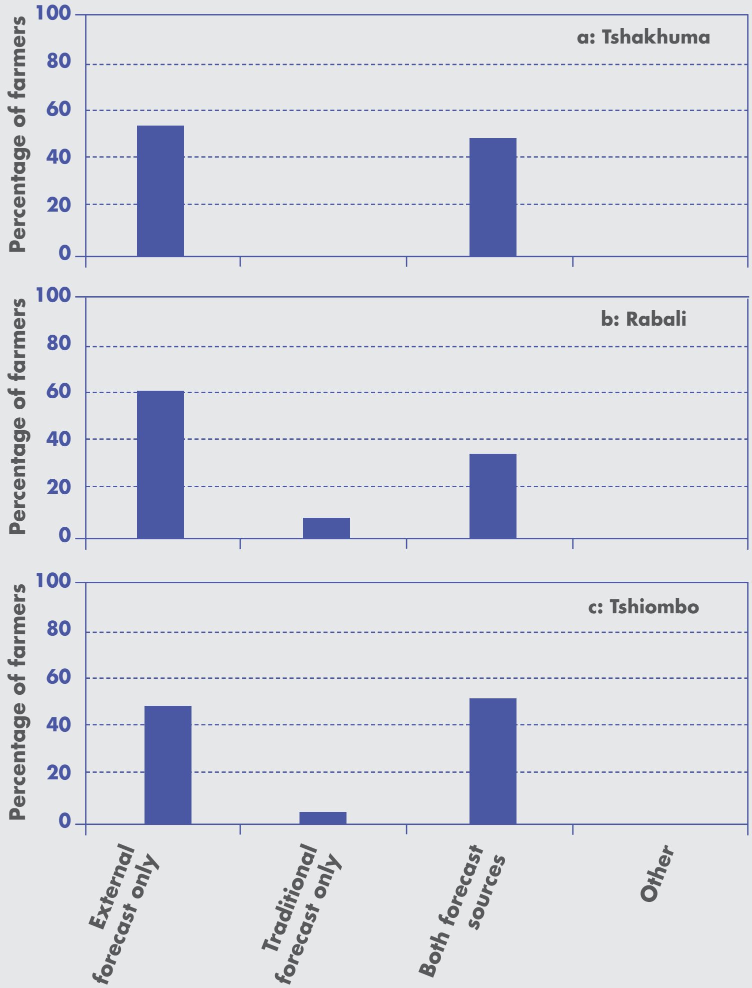


Figure 4: Use of various forecast information sources for farm management in the areas of Rabali, Tshakhuma and Tshiombo, Vhembe district, Limpopo province.

that has been sustained over time. The information has been inherited from previous generations and helps communities with their farming businesses during times of climate stress. However, since scientific climate forecasting was introduced to these farmers in the early 1990s, the majority have begun combining IK forecasting with external, scientific forecasts in order to reduce risk and increase production. Despite the awareness and use of scientific forecasts, there is still reluctance, however, to entirely replace IK forecasting in favour of scientific knowledge.

Similar results have been highlighted in previous studies carried out in Botswana and Zimbabwe (Kolawole et al., 2014; Roudier et al., 2014). The aim of such studies was to assess the use of indigenous and scientific forecast information by smallholder farmers in these two countries. There is evidence to show that farmers have an inclination towards applying indigenous forecasting methods as opposed to scientific knowledge, because they prefer to rely upon their own/their community's experiences over the years (Kolawole et al., 2014; Roudier et al., 2014). Farmers rely on historical patterns, weather observations and signs to formulate expectations on weather and climate (Orlove et al., 2010). At least 20% of the farmers in the present study stated that it is difficult for them to abandon IK and replace it with scientific knowledge completely.

However, other farmers perceive that IK is slowly losing value and becoming less reliable with time due to increasing climate variability and change. Due to this observation, and the fact that external climate forecasts can provide additional valuable information regarding crop management, planting times and advice on the choice of cultivars, some have started to use and apply technically derived forecast information within their agricultural activities. The majority of these farmers, especially young farmers, are incorporating external forecast information disseminated by weather service personnel and local extension officers (Figures 4a, 4b and 4c). At least 46% of the farmers indicated that, by using external climate forecasting only, their confidence was high when making farming-related decisions.

In the Tshakhuma area, at least 54% of respondents preferred to use external forecasting sources over IK. These farmers believed that external forecasting could add value to their farming businesses by facilitating more profitable decisions regarding management strategies. These results complement similar findings from studies by Orlove et al. (2010) and Roudier et al. (2014), which highlight the inevitable demand for seasonal and medium- to long-term climate forecasts to support decision-making.

The farmers of both study regions tended to use a combination of meteorological information and IK in their seasonal forecasting, primarily relying upon IK (Orlove et al., 2010; Roudier et al., 2014). All the respondents interviewed in Tshakhuma had a radio so access to external forecasting was facilitated – for both daily weather forecasts and seasonal climate information – when such information was made available during radio programmes. The majority of farmers tuned in to stations such as Phalaphala FM, Radio Univen and the South African Broadcasting Corporation; whilst some farmers used other media sources such as the Mirror newspaper for accessing climate information, especially during periods of drought. However, due to high levels of illiteracy, newspaper information is less accessible.

More than half of the respondents (60%) interviewed in the Rabali area preferred to use external forecasting to assist them in their decision-making processes (Figure 4b). These farmers also adjust their practices as more local information and scientific real-time forecasts become available (Furman et al., 2011; Frimpong, 2013; Orlove et al., 2010). At least 6% of respondents interviewed in the Rabali area preferred to use traditional forecasting methods only; these are the farmers who continue to resist incorporating external forecasting knowledge within their decision-making processes. Another 32% of respondents in this area preferred to use information from both sources (Figure 4b).

In the Tshiombo area, 50% of surveyed farmers prefer to utilise information from both external and IK forecasting systems (Figure 4c), while 48% of respondents prefer to use external forecasting information only. Farmers within the latter group are more likely to have access to external information sources such as local newspapers and are more likely to be literate. Only 2% of respondents in the Tshiombo area used indigenous/traditional climate forecasting methods only for farm-related decisions. These farmers resist using external forecasting information completely because they claimed – during FGDs – that IK is easy to access, and is more reliable because it has been inherited from previous generations. Some farmers also indicated that IK forms part of their cultural belief system and that scientific forecasts should therefore be distributed in such a way that does not devalue their traditional forecasting methods, but rather builds on local expertise and is mindful of the cultural norms associated with IK, and its validation and effectiveness within society (Roncoli et al., 2000a).

Climate information is very important for the farming community to be able to make informed decisions, and in many cases, is a prerequisite for coping and adapting to the negative impacts of climate variability and change (Goddard et al., 2010; Roudier et al., 2014 and Mapfumo et al., 2015). Several studies have shown that farmers tend to make decisions regarding their farming practices based on potential evidence on climate occurrences – particularly in relation to rainfall patterns (Goddard et al., 2010; Mapfumo et al., 2015; Roudier et al., 2014).

Case study 2: Application of IKS in the Karoo region in the Western Cape province of South Africa

According to several researchers, most IK studies report on how the knowledge is used as a coping/adaptation strategy for just one aspect of agricultural systems, (Mpandeli, 2006; Mpandeli and Maponya, 2012; Ncube and Lagardien, 2015); how IK is used relating to specific crops such as rice; or how IK is used in relation to soils. According to Ncube and Lagardien (2015), their study assessed how IK is used across the entire Karoo agricultural system – looking at crops, livestock and mixed systems. Information was collected under a variety of farming contexts with different kinds of activities at different levels of production. This complexity meant that the study could not go beyond documenting insights. The definition of IK had to be all encompassing i.e. 'traditional or local knowledge, that is embedded in the community and is unique to a given culture, location or society.' This was necessitated by the fact that the Karoo community is made up of both traditional Khoisan communities and other communities adjacent to the Karoo area, who have also been living in Western Cape since the late 1700s.

A summary comparing indigenous with scientific knowledge is provided in the next section. This summary provides a good overview on how farmers in the Karoo region have been using, conserving and also maintaining their IK since the late 1700s, and the trends that still remain even with the introduction of scientific knowledge. It is interesting to see that farmers still believe in the relevance of IK in contemporary situations, even though they are farming in semi-arid areas under the impacts of climate change such as poor rainfall distribution and high temperature fluctuations (Ncube and Lagardien, 2015). According to Ncube and Largardien (2015), a comparison of indigenous/local knowledge systems with scientific knowledge was carried out using information collected from farmers and extension officers. Table 1 summarises IK methods and gives corresponding scientific methods currently used in Karoo and other regions.

A policy brief on the potential of IK for agricultural development in South Africa in 2012 focusing on the application of IK and local innovation at micro level of the farming household or community, giving seven case studies (Mpandeli, 2006; Ncube and Largardien, 2015). The value of the briefing was in the way IK was presented, and in the similarities between some of the findings of the case studies and the smallholder farming systems in the Karoo region.

Ncube and Largardien (2015) highlight that farmers have developed IK methods around soil management. Further, in Burkina Faso, farmers' perceptions of soil types and characteristics match well with scientific investigations, thereby reconciling IK with scientific knowledge. According to Ncube and Largardien (2015), farmers in the Karoo region have developed and maintained a number of IK methods that they use to manage soil fertility and soil moisture. Subsistence farmers who cannot afford expensive chemical fertilisers use organic manure and compost instead to maintain soil fertility in vegetable patches. New scientific methods to conserve soil moisture include drip irrigation, although sprinkler systems are still widely used.

Table 1: IK and scientific knowledge in the Karoo region in Western Cape province of South Africa

Typology	Indigenous/local knowledge	Recent scientific knowledge
Drought indicators/ early warning indicators	• Wind direction, temperature changes, low rainfall • Animal behaviour, changes in plant characteristics	• Inter-tropical convergence zone moving south • Weather prediction models • Rainfall records
Farm practices & animal behaviour	• Manure and compost to conserve soil fertility • Bottles can be dug in the ground to water vegetables through seepage • Cover crops to conserve moisture • Destocking to reduce herdMigrating with animals to places with more grazing • Saltbush (*Atriplex nummularia*) for feeding livestock • Prickle pear (*Opuntia*) for feeding livestock • Agave (*Agave americana*) for feeding ostriches • Feeding mesquites (*Prosopis*) to livestock	• Use of chemical fertiliser • Drip irrigation • Sprinkler irrigation • Shade netting • Pen feeding pellets and purchased feed • Scanning for pregnancy to destock ewes • Creation of garzing reserves and rotation of animals • Planting and storing lucerne to feed during drought
Reduction in production level/ scale	• Planting and irrigating small areas • Destocking and keeping breeding herd	• Farmer decides on the focal enterprise and produces intensively • Destocking and keeping breeding herd • Alternative low input farming such as ostriches and game • Government voucher scheme provides funding to cover destocked animals and feed for the smaller herd
Scheduling activities	• Flood irrigation • Abandoning crop farming for other enterprises during drought	• Drip irrigation • Use of probes to monitor soil moisture • During drought farmer irrigates a few hectares for production
Water management	• Mountain slope water harvesting • Use of stock dams for water storage • Traditional water rights system	• Roof rainwater harvesting and storing water in tanks • Reliance on boreholes/ground water • Improved water rights system to minimize conflicts
Soil and water conservation	• Branches and stones to conserve soil • Contours and silt traps • Weirs along sluits for water storage and to capture silt	• Storm drains • Spreader banks in the veld • Gabions • Eradication of invasive plants
Other resource management	• Use of plants to treat animal diseases	• Use of modern medicines to vaccinate and treat animals

Case study 3. Use of traditional weather/climate knowledge by farmers in the south-western Free State province of South Africa.

Table 2a: Traditional climate prediction indicators and their use in interpreting rainfall conditions in the Free State province of South Africa (Source: Zuma-Netshiukwi et al., 2013).

Indicator	Indication for weather occurrence	Time of occurrence	Activity to do or action to take
Appearance of plant	• Blossoming of fruit trees above normal like peach (Prunus persica), apricot (Prunus armeniaca), budding of acacia spp., and other ornamental trees in the farm surroundings and development of young leaves, emerging grass, sprouting of cape aloe (Aloe ferox) in the mountains are indications of good rains • Flowering of wild lilies in the veld indicates summer • Dropping of fruits before maturity indicates very dry season or drought season • Dropping of leaves of the fig tree (Ficus carica) indicates summer. • Immature fruits drying on trees and/or dropping from the trees is an indication of drought	September September September/ October September September/ October	Spring season, prepare for sowing in November (general knowledge all groups). Farmers should consider drought tolerant crops and short cultivar varieties
Months of the year	July to forecast for first August rains rains that moisten the soil.	July and August.	After rain the land can be ripped. The soil is ready to be turned over to minimise weeds.

Table 2b: Traditional climate prediction indicators and their use in interpreting rainfall conditions in the Free State province of South Africa (Source: Zuma-Netshiukwi *et al.*, 2013).

Indicator	Indication for weather occurrence	Time of occurrence	Activity to do or action to take
Clouds	• Dark clouds indicate rainfall • Dark clouds are an indication of heavy rainfall to occur within a few hours	September - March Throughout the season	Sowing/rainfall season (general knowledge all groups).
Cloud types	• Dark clouds preceding strong winds indicate thunderstorms in a few hours. • Rainbow colours: if red dominates - this means more rains are to come, but if blue dominates and the sky clears, it means that rain has passed. • Stratus cloud is a sign for cold days.	June, July	Always be prepared to minimise damages that might occur due to heavy rains and arrange for roof water harvesting to be stored for use as irrigation is needed (general knowledge all groups). Prepare for extreme cold conditions (general knowledge all groups.
Soil structure and its dryness	Soil well moistened tested by hand. Soil not well moistened.	October-December October-December	Introduce seeds or seedlings under wet watered soils. Wait for rainfall onset (Mr. Mokhethi, Sannaspos)

Table 2c: Traditional climate prediction indicators and their use in interpreting rainfall conditions in the Free State province of South Africa (Source: Zuma-Netshiukwi et al., 2013).

Indicator	Indication for weather occurrence	Time of occurrence	Activity to do or action to take
Appearance of various insects	• Appearance of red ants and rapidly increasing size of anthills which are moist is used to predict good rains • Occurrence of army worms is an indication of drought	November/ December Mid-April, July and early August	Prepare for sowing season.
Birds	• First appearance of sparrows • Flock of swallows proceeding dark clouds • Migration and immigration of birds good sign of rainfall	October-March	Prepare for drought season (general knowledge all groups).
Moon phases	• A moon crescent facing upwards indicates upholding water and when facing downwards is releasing rainfall in the next 3 days. • When the moon is surrounded by moisture (halo profusion), this indicates good rains. • First rains should occur before the appearance of the new moon and then full moon covered by the clouds indicates good rains.	October-March September/ November October/ November	Rainy season is at hand, farmers should prepare for planting and act to minimise risk and disaster that might result from above normal rains (general knowledge all groups).
Star constellation	Star pattern and the movement of stars from west to east at night under clear skies, indicate onset of rainfall in 3 days and patterns also used to predict cessation of rainfall.	August-November	Planting time for vegetables and cash crops suitable for the area, farmer should follow moon phases as control to the days with and without rainfall
Animal behaviour of domestic animals	• Grunting of pigs indicates low humidity and an increase in temperature. • Well-fed calves jumping around happily in the veld and on their way home from grazing in the mountains and unwilling to graze the following morning indicates good rains on the way. • Increased libido in goats and sheep with frequent mating is a sign for good rains.	October to March Throughout the season August, September, October August, September September-November	Prepare the land and buy inputs to plant as it is the rainy season, select suitable days, cultivar and crops to plant (Mr. Mahlangu, Koffiefontein).
Appearance of reptiles	• Increased libido in goats and sheep with frequent mating is a sign for good rains. • Certain snakes moving down the mountain sign of good rains. • Frequent appearance of tortoises wandering around indicates that we should get good rains.	September-November September-November September-November	Prepare for agricultural activities (general knowledge all groups).

Table 2d: Traditional climate prediction indicators and their use in interpreting rainfall conditions in the Free State province of South Africa (Source: Zuma-Netshiukwi *et al.*, 2013).

Indicator	Indication for weather occurrence	Time of occurrence	Activity to do or action to take
Wind swirls	High frequency in occurrence of wind swirls is a sign for good rains.	October/November	Farmers should prepare and plant since good rains are predicted.
Wind direction	High frequency in occurrence of wind swirls is a sign for good rains.	October/November	After rain the land can be ripped. The soil is ready to be turned over to minimise weeds.
Mist covering hills and mountains	Early in the morning changing direction from west-east signals good rains	November – March Throughout the season	Prepare and plan ahead for rains to come (general knowledge all groups).
Atmospheric temperature	This is a signal for good rains to come.	September- November	Ensure that when rain comes the crops are already planted and developing (general knowledge all groups).
Water sources	High temperature at night is a sign for good rains and a long crop growing season, low temperatures at night is an indication for late onset of rains and late planting season. Rapid drying up of wells, springs, rivers and wetlands is an indication of good rains.	Springs	Farmers plan on when to plant and crop types of a season to expect (Brandfort group). Farmers could prepare for a good rainy season and plan their activities in advance

According to Zuma-Netshiukwi et al. (2013), farmers in the Free State province are using various indicators as part of their coping and adaptation strategies (Table 2), examples include: (a) the appearance of plants, (b) cloud formations, (c) the appearance of various insects and birds, (d) and wind Swirl (Table 2a, b, c and d).

Case study 4: Summary of the drought coping and adaptation strategies used by farmers in the Limpopo province and other southern African countries.

In this chapter it has been found that farmers in southern Africa – including in Limpopo, Free State and Karoo – use a variety of different coping, adaptation and mitigation strategies during periods of weather uncertainty. Different indigenous/traditional coping and adaptation strategies in the southern African region are well documented (Archer, 2003; Ziervogel et al., 2004; Ncube and Lagardien, 2015). However, in the Limpopo province of South Africa, literature concerning climate change coping and adaptation strategies is very limited (Ncube and Lagardien, 2015; Jiri et al., 2016). Differences in such strategies exist across the region, however, some methods such as crop diversification and the use of hybrid and drought resistant seeds, are common among areas.

Aspects of such strategies now form part of rural production systems. Some of these coping and adaptation strategies used by farmers in the southern African region include animal destocking, adjusting fertiliser inputs, use of drought resistant seeds and adopting a multicropping system.

Limpopo province	Southern African Development Community countries, e.g. Botswana, Mozambique and Zimbabwe
Strategies used by farmers in Limpopo province	**Strategies used by farmers in southern African countries**
(a) Destocking. (b) Distribution of water tankers. (c) Planting of crops that require less water. (d) Crop diversification. (e) Purchase of crop insurance. (f) Adjustment of fertiliser inputs. (g) Use of local climate indicators, for example cloud formation.	(i) Dispersal and mobility of foragers (Botswana). (ii) Food preservation (Zimbabwe) (iii) Dietary change and participation in government farm programmes (Mozambique). (iv) Crop diversification (Botswana, Mozambique and Zimbabwe).

Many farmers in the Vhembe district are now developing some alternative coping and adaptation strategies that could increase production, even when farming in marginal areas. The case study review from this chapter has also shown that farmers have adapted certain coping practices over time that enable them to 'read' and interpret the weather. While farmers in the study areas exhibited coping and adaptation strategies for drought in relation to planting, they also drew upon a wealth of IKS to help them adapt under increasing climate variability and change.

IK in disaster management in southern Africa

In order to increase crop yield, the strategy of cultivating a diversity of crops was demonstrated by farmers. This coping method helps to reduce total crop failure due to the varying tolerances of crops to environmental stresses. Mixed cropping or intercropping proved to stabilise yields, preserve soils and make it possible to harvest different crops at the same time. There are several strategies used by communities and farmers to minimise disaster, including: (a) growing drought-resistant and early-maturing indigenous crop varieties; (b) gathering wild fruits and vegetables; (c) use of early warning systems. Various early warning systems have been documented in the literature, for example, in Zimbabwe, elders carry out rainfall predictions to inform the wider community and each homestead has a dugout canoe ready for transport in case of heavy flooding. In Swaziland, the height of Emahlokohloko birds' nests (Ploceus spp.) on trees is used as an indicator to predict floods. The Swazis also listen for the cry of certain bird species to predict rains, and the yields of certain wild fruit plants to predict famine. Other indigenous methods used by the Swazis to predict natural hazards include wind direction, the shape of the crescent moon and the behaviour of certain animals e.g., snakes and bees.

Local strategies to manage climatic risks

In contrast with developed countries, the majority of rural populations in SSA are engaged in farming. Farmers are known to produce the greater proportion of food consumed in SSA (Mpandeli, 2006; Ncube and Lagardien, 2015). The crop and production practices of these farmers are largely based on their local knowledge and experiences developed over the years (Mpandeli, 2006; Ncube and Lagardien, 2015). The strategies of these farmers, and their perceptions of risk, vary across the region. Some researchers such as Fujisaka (1997), argue that it is necessary to pay attention to local knowledge systems and to analyse their relationship with seasonal predictions.

Fujisaka (1997) reviewed the various strategies of Ethiopian farmers and farmers in the Andes of Ecuador to minimise seasonal climatic risk. Farmers used multicropping systems as a means of reducing/counteracting climatic risk – where perennial and seasonal crops are grown together. Farmers' adaptations to climatic variability and risk in dry-land agriculture is often established on a trial and error basis in a farming system that is conservative, and provides a minimum return during all seasons (Gommez, 1999; Broad and Agrawal, 2000). Faced with the uncertainties of climate, economy and politics, and in the absence of insurance markets, these farmers have been rendered highly risk averse due to their adaptation strategies, which include local knowledge.

IKS policies in southern Africa

Currently, South Africa has a policy on IKS. The policy that have been developed on IKS take cognisance of developments in the southern African region, as well as the African continent as a whole. The Department of Science and Technology in South Africa is funding a project that looks at best practices in IKS within the southern African region in the context of the New Partnership for Africa's Development. Although these are positive developments, the IKS policy and further research should focus more on IK for climate prediction in these areas.

In Namibia, it has been found by the Convention on International Trade in Endangered Species to Wild Fauna and Flora, that the Kalahari cactus (Hoodia gordonii) can be harvested for commercial gains and as such, the Namibian government has since written to the Convention to have the cactus be classified as a commercial product. It is now clear that such plants as the Kalahari cactus and the carrion flower (Amorphophallus titanium), which are found in southern Africa, are likely to stimulate the economy of several countries in this region. If handled properly, southern Africa and the continent as a whole can benefit from this through job creation, economic growth and the strengthening of collaboration across the continent.

The main IKS policy drivers in South Africa include: (a) affirmation of the value of African culture in the face of globalisation – a clear imperative given the need to promote a positive African identity; (b) interfaces with other knowledge systems, for example, the use of IK together with modern biotechnology in the pharmaceutical and other sectors; (c) underpinning the contribution of IK to the economy; (d) practical measures for the development of services provided by IK holders and practitioners, with a particular focus on traditional medicine but also including areas such as agriculture, and wealth creation.

Conservation of IKS

According to Ncube and Lagardien (2015), there are several IK approaches for environmental conservation including shifting cultivation, mixed cropping or intercropping, minimum tillage and agro-forestry, as well as transhumance. These technologies and practices are commonplace with various other methods of land use and management to promote higher yields, while at the same time conserving the environment.

Conclusions

The analysis from this chapter shows that IKS play a very important role in climate adaptation strategy development for farmers in southern Africa, including in the Limpopo province and Karoo region. Farmers in SSA, including in South Africa, are finding it difficult to use IKS alone in their agricultural practices, and this is because local knowledge is losing value because of increasing climatic variability and change. At least 50% of the farmers interviewed argued that it is better to combine IKS with scientific knowledge in order to counteract the threats posed by climate change.

In the Limpopo province, farmers were found to use cloud formation to monitor possible rainfall occurrence. It was noted that more than 60% of surveyed farmers in the Rabali, Tshakhuma and Tshiombo areas perceived cloud formation as the best tool (Figures 3a, 3b and 3c). When the clouds are clustered and dark, for example, farmers know that rains are imminent. Almost 88% of respondents in the Tshakhuma area used cloud formation as an indicator for possible rainfall.

In this chapter, it was noted that several other IK indicators are being used by farmers to predict weather patterns, such as the behaviour of wind and insects, and the characteristics of plants and trees. Two percent of surveyed farmers in Tshakhuma indicated that if the wind direction is from east to west, it means that rain is coming within 24 h.

More than 45% of the farmers in the Rabali, Tshakhuma and Tshiombo areas are using only external forecast information for climate change adaptation strategies. However, more than 50% urged that scientific forecasts had failed them previously due to poor information dissemination by extension services, lack of interpretation of the information in the local language, and inaccessibility of the information. Therefore, farmers are also using local or traditional knowledge as a tool to manage climatic risks. It is important to note however, that IK forecasting has its own challenges. At least 60% of the farmers surveyed preferred to use external forecasting due to the increasing occurrence of extreme climatic events, which make IK less reliable.

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CHAPTER 13 - Indigenous knowledge practices for climate change adaptation among agro-pastoral communities in the semi-arid areas of East Africa

E.T. Liwenga

Abstract

Livelihoods and natural resources in semi-arid areas are threatened by a number of climatic and non-climatic factors. Historically and to date, local communities in different parts of the world, including those in semi-arid areas have continued to rely on indigenous knowledge (IK) to conserve the environment and deal with natural disasters. It is argued that East African agro-pastoralists and pastoralists, for instance, have developed various strategies to adapt to the different stress factors affecting their livelihood systems. Climate change and variability is likely to affect the way of life for communities in semi-arid lands and add to the unpredictability of livelihood systems. It is along these lines that the analysis of the relevance of IK in this chapter is undertaken to understand how agro-pastoral and pastoral communities in these semi-arid areas adapt in a changing climate.

It has been established that both the agro-pastoral and pastoral communities within the semi-arid environment of East Africa have considerable knowledge of weather prediction, which contributes to their adaptation to climate change. Using IK, their adaptation strategies involve exploiting seasonality, diversity and flexibility in crop farming practices – strategies that are also necessary for adaptation in a dryland environment. In spite of IK's utility in weather and climate prediction it is under threat of disappearing due to the lack of systematic documentation and coordinated research to investigate the accuracy and reliability of IK forecasts. It is therefore important to understand the extent to which the agro-pastoral knowledge system can be integrated with modern/scientific technologies in order to contribute to resilience to climate variability and change, among other stress factors.

Introduction

East Africa is home to thousands of agro-pastoralists and pastoralists who herd their livestock in the semi-arid areas of the region. These indigenous groups of people have developed special natural resource management systems to adapt to the changing climate. As such, despite the harsh living conditions, local communities have developed strategies to cope with the various stress factors affecting their livelihood systems. Research suggests that some of the strategies to cope with climate variability are currently ineffective due to the communities' exposure to intra- and inter-annual droughts, as well as floods. The nature of the climate variability that agro-pastoralists are used to dealing with will itself change, which is likely to add new variability to their resource management systems (Intergovernmental Panel on Climate Change [IPCC], 2001). It is therefore important to understand the extent to which the agro-pastoral knowledge system contributes to the resilience of these communities to climate variability and change, among other stress factors. This chapter specifically explores the role of indigenous knowledge (IK) in contributing to adaptation by agro-pastoral communities, located in the semi-arid areas of central Tanzania and East Africa in general. Discussions are focused around an analysis of the role of IK systems (IKS) in weather forecasting, in the context of the changing climate, using a case study of agro-pastoral communities, living in the semi-arid areas of central Tanzania, particularly in the Mvumi division.

A young Maasai woman with a cup of fresh milk.

Agro-pastoral and pastoral communities across the world are considered to have in-depth knowledge of the traditional methods of rangeland assessment, which in turn influence their patterns of land use (Mills *et al.*, 2002; Oba, 2006).Likewise, the East African agro-pastoralists are known for having a diverse range of strategies to sustain their livelihoods. These strategies are important for their own livelihoods, taking into account both crop farming and livestock keeping. Among the key livelihood strategies are pastoralists' mobility patterns – using IK to move livestock according to vegetation needs and water availability – keeping species-specific herds to take advantage of the heterogeneous nature of the environment, the diversification of income sources and, in some cases, temporary or permanent emigration (Oba, 2006). It is therefore argued that pastoralists can no longer depend on their livestock as the sole basis of their livelihoods, however, they have few opportunities for livelihood diversification (Food and Agriculture Organization [FAO], 2009).

The Ugogo area in Mwvumi Division is well known for its long history of droughts and famine (Koponen, 1988; Maddox, 1996). The livelihoods of these agro-pastoralists have undergone some changes with respect to the expulsion of livestock from Mvumi in 1986, as part of soil and water conservation measures. As a result agro-pastoralists have had to depend much more directly than before on arable farming and more labour is now invested in crop production. The Gogo ethnic group, traditionally agro-pastoralists – though they live in a harsh and dry environment – have given great priority to farming as their major means of living. This chapter explores how farmers in Mvumi utilise IK and exploit the natural resources in a semi-arid and changing climate.

Methodology

The research methods

The study entailed a detailed literature review of studies covering the East African region, particularly literature focused on the semi-arid areas of central Tanzania, as a case study. The study employed different approaches that necessitate both quantitative and qualitative data collection. As Strauss and Corbin (1990), have pointed out, quantitative and qualitative techniques are tools that play a useful complementary role. This approach was intended to gain an understanding of the patterns of livelihood strategies in a changing climate, as well as a detailed understanding of the complex nature of the relationship between humans and their environment. As well as the detailed literature review, some of the information presented in this chapter was generated through focus group discussions with villagers, coupled with the use of various rural appraisal methods; i.e. seasonal diagramming, participatory mapping, and preference ranking.

Description of the case study area

Location and climatic conditions

The Mvumi division, part of the area known as Ugogo, is located within the semi-arid[1] area of central Tanzania (Figure 1 and Figure 2). The Ugogo area covers most of Dodoma rural district in the Dodoma region. The Mvumi division is located some 40 km southeast of Dodoma town, the capital of Tanzania. Of special attention is the fact that the M vumi division is situated within the sphere of a soil and water conservation project called *Hifadhi Ardhi Dodoma* (HADO)[2] .

Most of the semi-arid central zone of Tanzania receives less than 600 mm of rainfall per annum. The rainfall pattern is highly variable in this semi-arid environment and is characterised by a long dry period between May and November. The rains usually arrive in December, and this is normally interrupted by a short dry spell between January and February. In some years this dry spell becomes extended such that crops planted at the onset of the rains dry up. Low and unreliable rainfall is therefore one of the major constraints to agricultural production in these areas. This condition normally results in crop failures and, hence, frequent food shortages.

The socio-economic environment

The agricultural conditions in the semi-arid central zone of Tanzania differ from those in the humid and sub-humid areas of Tanzania, not only in terms of quantifiable variables such as rainfall, but also in terms of the intensity of the adaptive challenges imposed on the human communities. Notwith¬standing the natural challenge, people in Mvumi have been subjected to a number of land-based policies that have presented both oppor¬tunities and challenges to the survival of the inhabitants. Among the factors that have influenced livelihood patterns in Mvumi are villagisation[3] and destocking[4]. Villagisation, implemented in the early 1970s, caused a change in settlement patterns, while destocking, carried out in 1986, meant the total removal of livestock from the Mvumi division. Traditionally, the Gogo people, the main inhabitants of the study area in Mvumi, are considered to be agro-pastoralists. Their homeland, the Ugogo area, is regarded as a marginal area for agricultural production due to its low and unreliable rainfall. The local people are therefore

Figure 1. Location of the study area (within Ugogo) in Tanzania. Source: Christiansson (1981)

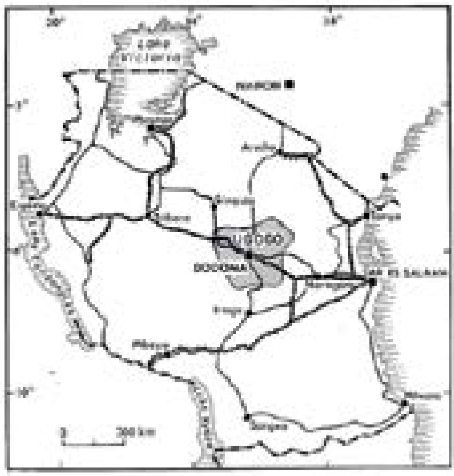
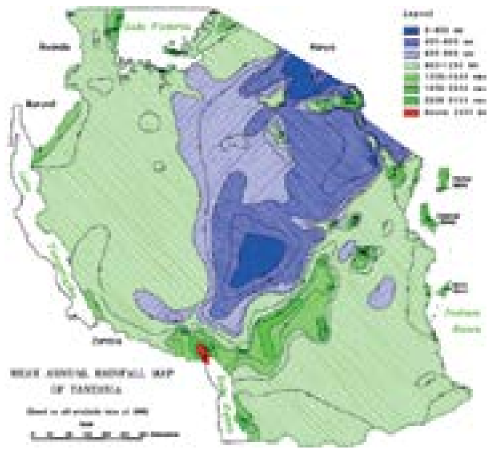


Figure 2. Mean annual rainfall map of Tanzania. Source: Shechambo *et al.* (1999)



accustomed to subsisting within the agricultural economy and grain production and livestock have played an essential role in the local socio-economic system (Christiansson, 1981). Although Mvumi has long been recognised as an area that faced frequent droughts, surprisingly, it is twice as densely populated as the surrounding villages, with a population density of 76 inhabitants per square kilometre (Holtland, 1994).

Agro-pastoralism as a livelihood system

Africa is one of the most vulnerable continents to climate change and climate variability (Boko, *et al.*, 2007). Overtime, East African farmers have developed several adaptation options to cope with current climate variability, but such adaptations may not be sufficient for the future likely changes in climate. Research demonstrates that farmers' adaptation to climate change and variability impacts crucially depend on whether they are locally able to predict weather patterns, such as rainfall fluctuations, and their ability to apply this information in an appropriate way to make informed decisions on agricultural production. Several studies have shown

[1]A semi-arid environment is one that allows the development of more or less continuous vegetation cover, but is too dry and variable to permit the secure, regular rain-fed cultivation of cereals or other crops (Mung'ong'o, 1995). Most of Dodoma region is classified as semi-arid because its precipitation is on average 200-600 mm per annum (Mascarenhas, 1977).

[2]Hifadhi Ardhi Dodoma are Swahili words, which translate to mean 'conserve the lands of Dodoma,' referring to the Dodoma region in Tanzania. Among the major measures taken in this area to conserve land was the total removal of livestock (destocking) in 1986.

[3]Villagisation was a policy measure or nation-wide campaign involving moving rural populations to concentrated planned settlement areas called villages (see especially Kikula, 1997).

[4]Though the term destocking implies a reduction of the livestock herd size, in this study the term denotes the eviction of all livestock from a specified area.

that farming communities, relying on agro-pastoralism and pastoralism as the basis of their livelihoods, have been disrupted by climate change and variability.

Adaptation to climate change and variability has been uncertain, partly due to the unpredictability and uncertainties associated with conventional agricultural weather forecasts (East African Community, 2011). Climate change and variability is posing a great challenge to agricultural production, especially to poor and marginalised farmers who desperately depend on agricultural weather forecasts. This situation exacerbates the instability of food security in many parts of Africa.

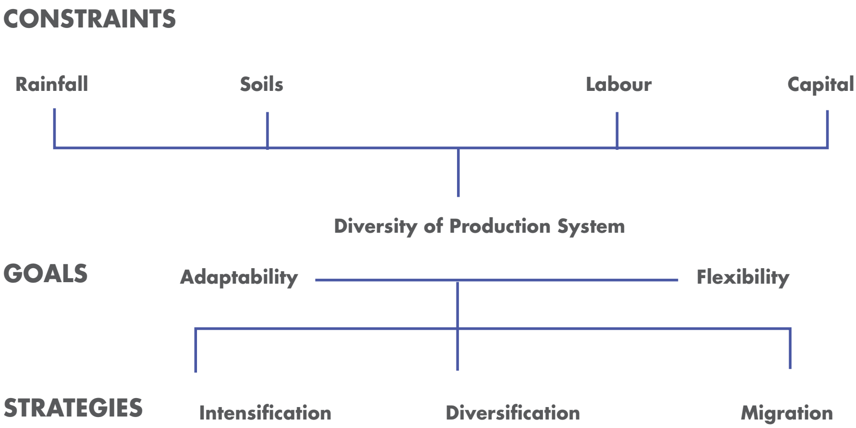
In the semi-arid communities, livestock provided a means of adaptation to the harsh climatic conditions as an alternative income source in case of crop failure. During the rainy season, cattle were kept near homesteads. In the dry season, cattle were driven away from the homesteads in search of grazing water. Some fields were purposefully set aside to serve as grazing reserves for the dry seasons. Fields set aside for communal grazing areas were locally known as *luwindo*, whilst the privately owned lands that set aside for grazing were known as *milaga*.

The agro-pastoralists in Mvumi area practised a system of shifting agriculture with the cultivation of millet on large plots, usually within a reasonable walking distance from their houses and near the valley bottoms (Liwenga, 2003). Accordingly, there were two categories of fields that were planted with grain crops. Firstly, the fields located near the homestead that could be fertilised with manure from the existing cattle pen, or from the pens of old homesteads; secondly, the bush fields that could be cultivated for two to three years before being left fallow.

In relation to the ways in which people living in semi-arid areas cope with their harsh environment, the research carried out by Mortimore and Adams (1999) in the Sahel provides important insights on how people living in these areas organise resources, as well as a useful basis to analyse IK and adaptation issues. The conceptual framework of 'constraints and responses', by Mortimore and Adams (1999), as shown in Figure 3, is useful for analysing livelihood patterns in the changing climate in Mvumi.

The framework of constraints and opportunities as applied in the semi-arid context, expresses the relationships between, on the one hand, the

Figure 3: A framework of constraints and opportunities. Adapted with modification from Mortimore and Adams (1999).



key constraints of rainfall, soils (bio-productivity), labour and capital; and on the other hand, households' responses to these constraints through managing the diversity, flexibility and adaptability of their livelihood and production systems.

The goals of households living in dryland areas normally involve managing and maximising diversity, flexibility and adaptability in their production and livelihood systems, despite existing vulnerabilities (Liwenga, 2003). The diversity of resources and options available to households defines the scope of the responses that can be made. The term flexibility refers here to the ability to easily adapt to new conditions and particularly relates to short-term decisions concerning the use of resources. This includes decisions pertaining to the deployment of family labour on a weekly or even a daily basis. Adaptability, on the other hand, refers to an adjustment to new conditions and this relates to long-term decisions and to yearly adjustments and responses (Liwenga, 2003).

IK in a changing climate in agro-pastoral communities

The IK-based system

Historically, local communities in different parts of the world have continued to rely on IK-based weather forecasts to conserve the environment and deal with natural disasters (Kijazi *et al.*, 2012). The IK-based weather forecast system (IKFs) refers to bodies of knowledge for predicting the weather that indigenous people of a particular geographical area have survived on for a very long period of time (Mapara, 2009). Local knowledge is not a single epistemology or technology, but a bundle of practical knowledge, modified by communities (Wangui *et al.*, 2012). IK is systematic, covering both what can be observed and what can be theorised. It comprises of the rural and urban, the nomadic and settled, as well as original inhabitants and migrants (Battiste M, 2002).

It has been established that wherever humans have settled around the world, being able to predict the weather has been necessary, since man has never been a passive recipient of environmental changes and impacts. Knowledge about past disasters and climate variability in Africa is accumulated from experiences that have been handed down to generations through oral tradition (Makwara, 2013). Accordingly, a IKFs determines decision-making in activities such as agriculture, social events and resource management (Mhita, 2006). IKFs methods have been used since time immemorial, but with the coming of modern conventional methods of weather forecasting these traditional methods have tended to be ignored (Chang'a, 2010), and now are disappearing as most of its custodians (largely the elders) are passing away (Makwara, 2013).

A shift in how adaptation is addressed by farmers to mitigate the impacts of climate change and variability has been dependent on the use of IK-based weather forecasts. However, IKS also have their limitations, as they are not always reliable. The new outlook promotes the integration of indigenous weather forecasts with conventional scientific weather forecasts provided by meteorological and hydrological agencies (Nganga, 2006). Studies have found that farmers possess vast knowledge of the resources around them, which could be extrapolated, up-scaled, updated regularly, and used to make comparisons and create locale specific information and advice (Mbilinyi *et al.*, 2005).

IK in a changing climate

Regarding weather forecasts, existing climate change literature reflects a tendency to place more focus on modern approaches to weather forecasting. The modern approach to weather forecasting is normally based on systematic observations to monitor changes in the climate and provide forecasting services, as well as to plan adaptation options. However, systematic observation and data availability is limited in many fragile ecosystems, which applies to most of the ecosystems that indigenous people live in (Kirsty, 2010). Climate change is impacting on the local communities and indigenous people because they live in ecosystems that are already suffering from other stressors as a consequence of historical, social, political and economic rejection and exclusion.

In recent years, there has been an increased realisation that IK provides a good basis for local community driven adaptation strategies. It is now increasingly understood that local observations of the direct effects of climate change by indigenous people support scientific predictions. These climate change effects include changes in temperature, precipitation changes, environmental change, changes in wildlife, frequent pest and disease infestation, increasing soil erosion, landslides, a rise in sea levels, extreme weather events, increasing aridity and drought, and changes in flood patterns. Most local communities living in semi-arid environments are familiar with climate change and weather induced vulnerability. They have generations of experience in coping with climate change, and can thus be considered capable experts, who have the knowledge to undertake and maintain systematic long-term climate observation and analysis of climate information.

These experts are normally the elders, who have depended on centuries of traditional knowledge and oral history to monitor and model weather changes. The local communities have thus, using IK, depended on diverse resources from the natural ecosystems and biodiversity to observe climate change. Most of the rural communities around the world have already reported some adverse impacts from changing climatic conditions within the ecosystems on which they depend. Such reports include visible indicators like warming weather, the disappearance of snow in mountains, changes in the distribution of plants and animals leading to the disappearance of essential food sources and, of particular concern, negatively impacting species that have special cultural significance to communities (Kirsty, 2010). Extreme weather events highlight the importance of indigenous weather prediction knowledge to give timely warning of such impending events and help to mitigate the impacts.

The notion of IK has gained in popularity over the past few decades. The current interest in IK has been motivated by an appreciation of its importance, as well as by its perceived loss due to the lack of documentation. Rural people's IK is defined as the set of concepts, meanings, skills and routines that emerge actively over time (Brouwers, 1993,). The knowledge systems of rural people derive from the interaction of individuals in a particular society with the local environment, and are formed and transformed by the society (Chambers and Jiggins, 1986). Researchers are not making adequate use of this abundant knowledge to advance the social and economic development of rural communities. Among the reasons for the limited acknowledgement of local knowledge is the lack of documentation (Hillbur, 1998,). Since the aim of this chapter is to better understand how people living in harsh dryland conditions adapt, it is important to take into consideration rural people's knowledge as a factor influencing their adaptation.

Another aspect to take into consideration is that IK is not static, but exists in a dynamic relationship with their socio-economic and political environment, and is in constant evolution over time (Brouwers, 1993). As they interact with their surroundings, local people continually adjust their livelihoods to the existing environment, or try to change it to meet their needs. This involves a process of experimentation, adoption and propagation of new ideas about the environment and its management. In adapting to changes in their environments, local people not only modify the products that they use, but also the practices they employ and the amount of labour they expend, as well as other socio-economic factors. The sources of the changes that affect them are frequently from 'outside pressures' or influences, but also derive from changes arising from the subsistence activities and experimentation employed by the local people themselves (Brouwers, 1993). Human agency, or the capacity to devise ways of coping with life, plays a central role in the way rural people create new livelihood possibilities.

Local knowledge, as it relates to food security, refers to a wide range of accumulated local experience concerning the ecosystem and natural resources, and how they are used and managed in the context of local organisational and institutional arrangements (Kauzeni, 2000,). It also includes the beliefs and value systems of the people. In this study, the contribution of local knowledge to agricultural production is explored in order to understand how people in Mvumi adapt to semi-arid conditions by depending on farming (Liwenga, 2003).

The relevance of IK in exploiting seasonality, diversity and flexibility

Agro-pastoral and pastoral communities worldwide have in-depth knowledge of the traditional methods of rangeland assessment, which influence their patterns of land use (Mills *et al.*, 2002). It has been established that on a daily basis, herders monitor the status of rangelands (Homewood and Rodgers, 1991) and determine the best grazing areas for their multi-livestock species (Cotton, 1996). However, the herder knowledge of the landscape in East Africa has been poorly documented (Oba & Kaitira, 2006). According to studies conducted in East Africa by Oba & Kaitira (2006), the Maasai herders classified seasonally grazed landscapes using socio-cultural folk systems, soils, topography and vegetation, management knowledge and seasons of grazing. Herders characterised the landscapes of grazing lands as degradable (*orpora*) or non-degradable (*orkojita*) in response to heavy grazing pressure, with reference to soil (*ngulupo*) and vegetation type. This categorisation is used for regulating seasonal grazing across heterogeneous landscapes. Likewise, studies undertaken by Egeru *et al.*, (2015) have shown that in semi-arid areas, such as Karamoja in Uganda, there is variability in the forage availability for different livestock species. The availability is differentiated across various locations in the Karamoja livelihood zones, leading to the heterogeneity of grazing landscapes. In the different livelihood zones, forage availability deficit gaps vary with respect to livestock species.

It is apparent that local communities harbour important information on valuable plants and vegetation dynamics; their knowledge is fundamental for management strategies aimed at the sustainable use and conservation of natural vegetation (Lykke, 2000). This is especially

Mushroom farmer Gorreti Asiimwe working inside her mushroom farm.

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the case when other historical and ecological information is not available (Sulieman *et al.*, 2012). Pastoralists in eastern Sudan, for instance, established a comprehensive list of plant species in the region, providing detailed biological and associated ecological descriptions (Sulieman & Ahmad, 2013). These descriptions provide an indication that the pastoralists are aware of the environmental changes taking place in their surroundings. Based on studies undertaken in the Sudan, for instance, it is known that local knowledge-based management strategies could ensure a focus on the species and vegetation types that are most valuable to local communities (Sulieman *et al.*, 2012). Table 1, presents the adaptation measures used among the transhumant pastoralists in eastern Sudan.

According to studies conducted in semi-arid areas of Tanzania, it has been established that agro-pastoralists are faced with a number of constraints, such as low and unreliable rainfall, poor soils, and labour and capital shortages (Liwenga, 2003). These agro-pastoral groups, such as the Gogo, have over a long period of time developed certain agricultural practices to adapt to these harsh conditions. It is this accumulated experience from communities who have lived for generations in a hostile environment, like the semi-arid zone of Tanzania, which provides a fundamental source of knowledge for the future. There is much to be learned from farmers' adaptation concerning the degree to which they react to changes occurring within their socio-economic and physical environment.
Regarding patterns of movement, agro-pastoral communities in the semi-

Table 1: Adaptation measures followed by transhumant pastoralists

Adaptation mesure	number	Percent
Renting agricultural to benefit from crop residue	50	100
Utilizing more than one camping area and longer roaming distances	44	88
Partial transhumance and sedentarization	36	72
Destocking	18	36
Changing grazing time	12	24
Transbounday grazing (i.e. Ethiopia)	8	16
Supplementary water transpoting using tankers	5	10
Do nothing	1	2

Source: Sulieman and Ahmad (2013)

arid areas of central Tanzania, analysis of the seasonal calendars revealed that different farm and non-farm activities were carried out. For instance, it was evident that villagers in the study area start clearing their fields approximately three months before the on-set of the rains (Liwenga, 2003). Land preparations for farming activities are undertaken early enough to avoid it all having to be completed in a very short period of time, and to effectively time the rains. Early land preparation also helps to avoid an unnecessarily heavy competition for labour to carry out other agricultural tasks, especially during the peak agricultural periods.

It was further established that in carrying out different livelihood activities, people in the semi-arid areas of central Tanzania try to ensure the proper timing of these different activities, based on the exploitation of the seasonality, diversity and flexibility of the available resources (Liwenga, 2003). Accordingly, agricultural production activities are normally concentrated during the wet season because agriculture in Mvumi is mainly rain-fed. The crucial agricultural activities, involving high labour demands, are carried out immediately following the first rains, in late November or early December. The peak agricultural period normally coincides with food insecurity for some households, particularly those that experienced poor harvests in the previous season, which implies that some livelihood strategies have to be adjusted to ensure household food security.

The use of IK in weather forecasting

Discussions with villagers in Mvumi revealed that indicators used for the timing of different operations vary between farmers (Table 2). In many parts of the Mvumi area, plant phenology was found to be the most used indicator in predicting rainfall events. Other indicators mentioned include the behaviour and movement of birds, insects and animals. The plants that have been used for weather forecasts include mango trees (*Mangifera indica*) and fig trees *Mikuyu* (*Ficus sycomorus*). Astronomical indicators, such as the arrangement of stars, were also found to be in use. Regarding meteorological indicators, local communities reported that they use the direction and variation of wind patterns to monitor rainfall as well.

Indicators of good and bad years in terms of rainfall in the Mvumi area varied based on local experiences and knowledge generated over the years. Hoeing is ideally carried out upon the appearance of the *Plaidaes* in the night sky and planting begins only after the baobab trees develop

Table 2: Some local indicators for weather forecasting

Type of indicator	Explanations
Stars	When a group of stars locally known as *nyelezi* are seen shining in the western side of Mvumi Division in the months of August/September the farmers predict good rains.
Fog	Appearance of fog locally known as *hungulyosi* on the mountains surrounding the villages in August/September is an indicator of good rains.
Fruit trees	If baobab and mango trees produce many flowers and fruits, this is regarded as an indicator of insufficient rains.
Wind	Frequen winds during the daytime resulting in whirlwinds and dusty conditions locally known as *chiffulafumbi* in the months of August/September is associated with good rains.
Onset of rains	Starting of rains in November is regarded as a sign that there will be adequate rainfall. If the first rains only fall during the daytime, then the speculation is that the rainfall period is likely to be short.

Source: Liwenga (2003)

green leaves (Mascarenhas, 1977). This kind of knowledge is passed from generation to generation. It has been noted that the proper observance of these various natural signs is key to successful farming and adaptation in a changing climate. If good rains are predicted then farmers can increase the areas of land under cultivation in anticipation of a good harvest. If, however, the signs indicate poor rains, then they concentrate on off-farm activities in order to generate income. Due to the unpredictability and variability of rainfall, predictions of rainfall are not always correct. This is particularly the case in relation to the duration of the dry spell that sometimes occurs in February for about two or three weeks. If the dry spell is prolonged then farmers predict a poorer harvest.

Integrating conventional science and IKS

In most societies, different worldviews related to environmental knowledge interact (Grange, 2007). It is explained that what one learns from life experience in one's immediate environment is different from what one is taught in class, thus, the essence of proper knowledge is an integration of both of these knowledge sources (Mercer *et al.*, 2009). It has been reported that since the 1970s a growing body of literature has emphasised the importance of incorporating local knowledge and practices into development and conservation projects, as well as in policies on an international and national level, both in countries that are industrialised and those that have a developing status (Catherine and Hoppers, 2002; Payton *et al.*, 2003). This comes at a time when the world, especially the developing world, is experiencing many environmental changes, including climate change and variability (Raymond *et al.*, 2010).

While in theory the importance of such integration of knowledge systems has been recognised within the international community, the practical application of this generally only occurs on a small scale within communities of developing countries, such as in areas of East Africa (Payton *et al.*, 2003). Studies conducted on indigenous-based weather forecasts in many parts of Africa (Mapara, 2009; Risiro, 2012; Chang'a *et al.*, 2010; and Makwara, 2013) conclude that both modern and traditional methods have got some advantages and weaknesses, and therefore, can be used together to produce more comprehensive reports of weather forecasts for end users. For example, in September 2008, through a Climate Change Adaptation in Africa-supported project focusing on IK in western Kenya, the Intergovernmental Authority on Development's Climate Prediction and Applications Centre brought meteorologists and Nganyi IK forecasters together to produce a further downscaled consensus forecast. The points of departure were thoroughly considered and reasons for the differences explored. An agreement was then reached on a harmonised forecast (Chagonda *et al.*, 2012).

Due to the oral nature of IK, little has been published on the process of integrating it into environmental conservation, management of natural disasters, or indicators of and responses to climate variability (Stigter *et al.*, 2005). Knowledge, both scientific and indigenous, is intertwined with power and human relationships including social, political, technical and economic. IK is oppressed in a number of ways as a result of the marginalisation, exploitation, powerlessness, cultural imperialism, violence and denial of the existing knowledge placed upon its bearers, and hence, contributes to the suppression of IKFs where Seasonal Climate Forecasts (SCFs) are dominant (Mercer *et al.*, 2009).

It is worth noting that, while a number of frameworks on how to integrate IKFs and SCFs have been developed, there is still a lack of consensus among scientists and policy makers on the best framework, and this is partly due to the fact that IKFs are linked to social values within a specific environment, thus, most of the frameworks developed do not preclude their use elsewhere (Dickens, 2007). External processes, such as globalisation, environmental pressures, marginalisation, racism, and economic and health inequity (Edwards and Heinrich, 2006), impact on the loss of IKFs internally (intrinsic factors) through, for example, agricultural changes, migration and behavioural changes (Mercer *et al.*, 2009).

It is clear that IKFs and SCFs both have strengths and weaknesses; a major challenge remains regarding how to bring them together in a way that respects their different values and builds on their strengths. To integrate the different forecasts, detailed information about both IKFs and SCFs must be available (Chagonda *et al.*, 2012), and this demands more research into the discourse that brings together meteorologist, non-governmental organisation representatives, extension officers, researchers, input suppliers, and indigenous weather forecasting groups to understand the devisable mechanism that could blend the two sources of information (Makwara, 2013).

Conclusion and recommendations

In understanding the function of agro-pastoral IKS in adaptation to climate change and variability, it can be concluded that IK is relevant for the survival of agro-pastoralists in semi-arid environments. This chapter has demonstrated how IK contributes to the survival of agro-pastoral and pastoral communities within the semi-arid areas of the Eastern African region, including, Kenya, Sudan, Tanzania and Uganda. IK appears to have played a considerable role in determining how such communities develop their traditional agricultural and herding practices to suit the semi-arid conditions, and hence, cope with the dryland environment.

The exploitation of 'seasonality' and diversity of soils for farming activities provides possibilities for adaptation to climatic changes under dryland conditions. The seasonal calendar provides guidance for agro-pastoralists as to when different livelihood activities should be carried out.

It is apparent that IK is essential in order to sustain agro-pastoral systems in semi-arid areas. The reliability of IK, however, is under threat due to the effects of climate change, nevertheless, the question remains – to what extent is IK relevant in a changing climate? Ways in which IKS can be integrated with modern methods to further increase the flexibility of pastoralist communities in adjusting to climatic change impacts need to be explored. It is recommended that land use planners incorporate herder knowledge with scientific methods to explore how this could promote participatory rangeland management, and overall, increase the adaption capacity of agro-pastoralists and pastoralists in a changing climate.

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CHAPTER 14 - Indigenous knowledge in weather and seasonal rainfall prediction in Zambia

D.H. Nanja

Abstract

In Zambia, rain-fed agriculture has long been the main stay of most rural smallholder farmers' livelihoods. The timing and management of the cropping calendar requires knowledge regarding the weather and seasonal changes. An understanding of local weather parameters, which is a complex matter, has been developed over a long time by smallholder farmers. It involves understanding the nature of, amongst others, elements such as rainfall, temperature, wind speed, humidity and radiation. This knowledge today is called indigenous knowledge (IK).

This paper highlights the use of IK in weather and seasonal rainfall prediction in Zambia from reviewed literature. It reveals that weather predictions can be made through observations of the wind systems; positions of the moon; movements of animals; and tree phonological stages. For example, wind systems, moon phases, and the presence of moon halos are the indicators used for forecasting rains. The movements of animals and tree phonology stages are used to indicate the quality of the seasonal rainfall. IK is therefore demonstrably applied in weather and seasonal rainfall prediction to determine the timing and management of rain-fed agriculture. It is hereby recommended that the use of IK in weather and seasonal rainfall quality predictions in Zambia, should be promoted and further investigated. Meteorological scientists should also consider integrating IK in contemporary weather and climate forecasting.

Introduction

Knowledge regarding the performance of weather parameters is important for smallholder farmers, particularly those dependent on rain-fed agriculture. In the absence of modern weather forecasting facilities

– considered as a new concept by indigenous smallholder farmers – they have developed their own methods of understanding and predicting weather patterns and seasonal rainfall quality. Through the observations of weather parameter performance, tree phenology, and animal behaviour over a long time, a form of knowledge called indigenous knowledge (IK) has been developed. This knowledge is not written or recorded within documents kept by communities, but shared over generations via family stories, community gatherings, ceremonies and rituals. IK or IK systems (IKS) refer to knowledge and knowledge systems that are unique and distinct to a given culture or society. The main function of IKS is to developed strategies for the survival of rural communities in response to environmental and resource challenges. These strategies are imbedded in the human beings who diligently use them to address the related problems (Tharakan, 2015).

IKS acknowledges three main functional frames: 1 – human beings, who are the knowledge holders; 2 – the knowledge itself; and 3 – the problem or risks being managed.

- **Human beings:** This frame refers to the human being benefiting or being negatively impacted by climate change (Jiri et al., 2015). He/she is the carrier of the knowledge, the one to fully understand it, and the decision-maker. The same is the principle weather observer, researcher of every new phenomenon and data analyst.

- **Knowledge:** contemporary scientific forecasting is a relatively new phenomenon compared to IKS and thus, its credibility still requires much to be appreciated by most communities in Africa, especially for those in remote rural areas (Chagonda et al., 2014; Jiri et al., 2015; Tharakan, 2015). Such areas are hardly reached by most service providers, including meteorological and agrometeorological extension services. Access by these communities to written and electronic media sources such as newspapers, the internet, and television and radio is therefore limited. The climate risk information that does reach these areas is usually via word-of-mouth and is out dated, misleading and not suitable for decision-making. The poor communication systems in these areas further disadvantages the suitability of contemporary scientific forecasting in addressing climate risks among rural communities. However, local people have never been, at any time, without climate and forecasting knowledge. They have used IK since time immemorial and still depending upon it. This knowledge was not formed in isolation but links to other relevant information such as soil quality for holistic livelihood risk management, and has hence been depended upon since its development (Chagonda et al., 2014). It has been the sustainer and maker of what most African communities are today in terms of culture and agricultural production systems. Through the observation and analysis of weather parameters over time, smallholders have been able to interpret and use such information, and have disseminated the results to the benefit of the community and further. Significant knowledge on every aspect of agricultural systems has been developed for enhanced livelihoods. This knowledge may have had some limitations for effective management of all risks, but has been sufficient enough to sustain indigenous communities for decades.

- **Risks:** Climate risks are expected to become more complex in nature due to climate change, however, it is important to appreciate that according to available knowledge, there have always been climate challenges. For example, flooding and drought challenges have always existed, although the magnitude and frequencies of which are now quite different, and the duration and occurrence of droughts in semi-arid areas is only expected to intensify (Lasage et al., 2008). According

A young widow farmer cultivating the soil for the planting of her crops.


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to Chagonda et al. (2014), a case study in Zambia and Zimbabwe revealed that farmers perceive climate change as seriously detrimental to their agricultural activities – mainly through droughts, flooding, prolonged dry spells and wet spells. Each phenomenon had its own associated effects such as excessive rains leading to the breakdown of dam walls, increased livestock disease, reduced yields and river siltation. On the other hand, droughts bring prolonged dry spells, perennial low flows of big rivers, reduced yields and the drying up of wells (Chagonda et al., 2014).

According to an in-depth literature review of studies undertaken in Africa regarding IKS for weather forecasting, IK can be considered as a highly complex knowledge system. From long-term observation and experience, rural communities have come to recognise some bird species, insects and plants as weather sensitive and responsive to changes in atmospheric conditions. Indicators extend to phases of the sun and moon, and trade winds and their direction (Svotwa et al., 2013). Using this knowledge system, communities have developed climate risk management initiatives. It is for this reason that farmers in Zambia have an inclination towards utilising indigenous forecast information as opposed to that of scientific forecasts (Jiri et al., 2015; Kolawole et al., 2014; Roudier et al., 2014).

This weather and seasonal rainfall quality prediction system which involves observed indicators is complex, and the components of which when combined together or used in isolation, have proven to sustain smallholder farmers' agricultural production. Therefore, farmers' confidence in IK is high.

Classifying forecast indicators

Forecast indicators of climate and changes in atmospheric conditions such as animal behaviour, tree phenology, and moon phases and appearance, can be classified into two categories for weather and seasonal quality predictions. Some indicators prove more helpful in determining the occurrence of imminent rains, while others are used in determining the quality of the season for the next 4-6 months.

Weather forecasting

Good indicators are required to confidently forecast imminent weather patterns or those of a few days ahead. Just like in contemporary weather forecasting, weather instruments and equipment are required. However, the absence of these instruments among smallholder farmers has contributed to their limited confidence in modern weather forecasts (Chagonda et al., 2014).

The observation of moon phases is a practice generally used for determining the likelihood or absence of rainfall over an area in Zambia. The practice divides the moon sky path – both the visible and invisible – into four equal parts of 90 degrees each. The Zambian practice is that of having the two horizontal 90 degree quadrants on the eastern and western sides being subdivided into two equal sectors of 45 degrees by the horizons. One of the remaining quadrants will be between the two 45 degree quadrants above the horizon and is referred to as the full moon phase, while the other will be directly opposite in the invisible

Table 1: Atmospheric IK indicators for weather and rainfall forecasting in Zambia

Weather and rainfall forecasting				
Category	**Indicator**	**Significance**	**Country**	**References**
Atmospheric	Moon phases (horizon phases) The 3 days before and 4 days of the moon's appearance on the western horizon, as well as on the eastern horizon in the early part of the evening	Rains are about to come	Zambia	Mugabe *et al.*, 2010 Zuma-Netshiukhwi *et al.*, 2013 Svotwa *et al.*, 2013 Nkomwa *et al.*, 2013 Chagonda *et al.*, 2014
	The other moon phases Full moon	Dry, windy and mainly cloudless periods		Chagonda *et al.*, 2014 Nkomwa *et al.*, 2013 Mugabe *et al.*, 2010
	Halo of the moon	Coming of rains is imminent		Mugabe *et al.*, 2010 Zuma-Netshiukhwi *et al.*, 2013 Svotwa *et al.*, 2013
	Wind patterns – southerly and south easterly winds	Dry periods coming	Zambia	Mugabe *et al.*, 2010 Zuma-Netshiukhwi *et al.*, 2013 Svotwa *et al.*, 2013
	Northerly and north westerly winds	Rains are coming soon	Zambia	Mugabe *et al.*, 2010 Zuma-Netshiukhwi *et al.*, 2013 Svotwa *et al.*, 2013
Movement of animals	Cicadas	Coming of rains is imminent	Zambia	Mugabe *et al.*, 2010 Zuma-Netshiukhwi *et al.*, 2013
	Presence of many butterflies	Coming of rains is imminent	Zambia	Mugabe *et al.*, 2010 Zuma-Netshiukhwi *et al.*, 2013
	Flock of swallows	Coming of rains is imminent	Zambia	Jiri *et al.*, 2015 Mugabe *et al.*, 2010
	High temperatures Chickens moving with spanned wings	Coming of rains is imminent	Zambia	Mugabe *et al.*, 2010 Zuma-Netshiukhwi *et al.*, 2013

path of the moon. IK indicates that these moon phases do not bring rains. However, the moon phases on the eastern and western quadrants are associated with clouds, humidity, high temperatures, calm winds and rainy conditions, while the vertical and bottom quadrants are mainly associated with clear skies, lower temperatures, high wind speeds and dry conditions.

As the moon phases change within the season, farmers are generally expectant of the long-term weather patterns associated with each phase. This practice is common among smallholder farmers whose access to contemporary scientific forecast information is limited. Although, it is also practiced amongst those that do have access to meteorological forecasts.

The scientific explanation for the eastern and western moon phases being associated with the conditions as mentioned above, is because the synoptic systems of the moist Zaire Air Boundary, Inter tropical Convergence Zone (ITCZ) and the normal thermal lows over Zambia, have their presence during these phases, causing precipitation. The dry periods are equally due to the general presence of the semi-permanent high pressures during vertical and bottom quadrants phases. The

V A farmer using oxen and plough to prepare land for planting

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average period of one moon is about 7 days, similar to that of general global circulation systems. This is the very reason why the weather for the moon phases appears to be consistent with IK predictions.

It is important to note however that generally, the weather in winter during the same moon phases, is almost the opposite of that during summer. The eastern and western moon phases are associated with high pressures, clear skies and high wind speeds, while the others are associated with lower pressures, cloudy conditions and reduced wind speeds. The synergies between IK and contemporary weather forecasts are notable (Nkomwa. et al., 2013). However, it is important to note that at different latitudinal locations, the weather systems will vary during moon phases.

IK relating to moon phases is still relevant under contemporary situations as it complements scientific forecasting information, enhancing its credibility among rural communities (Chagonda et al., 2014). With the availability of both IK and scientific forecasting information, decision-making regarding climate risk management is enhanced for communities. However, such knowledge and practices may face future challenges if practitioners of contemporary forecasting and policy makers continue to disregard IK, and develop inhibiting policies for its integration.

According to IK, the sudden presence of a flock of swallows to an area is associated with the likelihood of afternoon showers and thunderstorms (Jiri et al., 2015). The swallows are usually seen continuously flying over the same area in an aerobatic style for approximately 30 minutes, due to the arrival of flying insects to the area. Indeed, showers or thunderstorms generally commence later that afternoon. The scientific knowledge to support this IK is that when low pressure develops over an area, trade winds move in to fill the low pressure and bring with them many insects, which are then eaten by the swallows. Through long-term observations, farmers have come to associate this occurrence with imminent rains that tend to ensue (Hill, 2001). A synergy between IK and scientific forecasting is evident here, and calls for scientists to explain their knowledge to smallholder farmers to increase their utilisation of scientific information.

Smallholder farmers celebrate the presence of swallows because this represents one of the last remaining reliable indicators of weather. According to IK, the accuracy of other forecasting indicators as a sign of incoming trade winds, such as phases of the moon, the halo of the sun and moon and the high noise of cicadas – or nyenze – during high temperatures, is complemented by the swallows' presence. Among smallholder farmers, the use of modern scientific information in forecasting showers and thunderstorms is best complemented when IK indicators, such as the presence of swallows, can also be considered. The use of IK indicators within scientific forecasting methods would increase smallholder farmers' perceptions of their credibility. The example of swallows as an indicator of weather events is not likely threatened by modern forecasts, since low pressures cannot be perceived by the human eye, therefore the presence of swallows will continue to be used by smallholders as a sign of imminent showers and thunderstorms.

Smallholder farmers in Africa also make use of the prevailing trade winds for short-term weather forecasts. Some trade winds are known to be dry, while others are wet during the summer months and their presence indicates the likelihood of precipitation. The northerly and north westerly winds in Zambia are a good example of this. In summer, they are generally associated with high moisture contents and move towards low thermal pressure areas or the southern hemisphere ITCZs that are formed, and keep oscillating from the northern to the southern parts of the country. Their southward movement is generally associated with precipitation (Zambia Meteorological Department, 2016).

When the moisture content in northerly/north westerly trade winds is normal or high, precipitation generally starts within the first or second day of their detection by farmers. The presence and absence of these winds helps smallholders plan more accurately in regards to the timing of agricultural activities, such as when to plant, apply fertilisers or weed their crops. In regards to the southerly and south easterly winds, smallholder farmers consider them to be characterised by high winds and clear weather conditions. Because they mainly originate from the continental high pressure systems over Mozambique and South Africa, they are generally drier and bring about little or no precipitation at all to Zambia in summer. High and low pressure systems cannot be seen, but their wind movements can be felt hence, they are best explained to smallholder farmers in relation to the prevailing trade winds.

The movements of trade winds are associated with general circulation systems of the semi-permanent continental high and low pressure systems over the southern hemisphere. The presence of these pressure systems' over a particular area lasts for about 1 week. Smallholder farmers consider the moon phases to last for a similar length of time.

From their IKS, smallholder farmers have come to recognise the general behaviour of trade winds and are able to forecast the likelihood of imminent precipitation to their area. In this way, they are able to more effectively manage agricultural-related risks throughout the year. Thus, the reliance of trade wind movements as an indication of weather events is very common in Zambia.

The scientific support for their use lies in the understanding of low pressure areas that draw both moist and dry trade winds. The trade winds in their vertical movements span from the earth surface, through middle levels and higher – up to 30,000 ft. Trade winds tend to move faster towards a low pressure area in the higher and middle levels than at the surface area due to friction with ground surfaces. The moisture contents of the trade winds depict a halo around the sun or moon in the higher levels when their rays pass through the cirrus clouds. It is through the presence of the halo that smallholder farmers and scientists can confirm the increased presence of moisture in the atmosphere, and plan for

A maize field partially flattened by rains and wind.

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expected precipitation. Depending on the speed, the middle and lower levels of windsoon reach an area where precipitation commences within about 24 hours.

Observations of cloud types in the sky represent another IKS tool for farmers to use within their climate risk management strategies (Roncoli et al., 2001). Such observations over time are what initially led farmers to discover the relationship between the presence of a halo around the sun and moon, and the subsequent weather conditions. They noted that some precipitation followed within 2 to 3 days of the appearance of the halo, and long-term observations of this phenomenon confirmed the trend. Further observations revealed a connection between the occurrence of the halo and the presence of swallows to an area – and both are associated with rainy conditions. The appearance of the two indicators at once therefore increases the accuracy of IKS in forecasting the likelihood of precipitation to an area.

Smallholder farmers have practiced this form of weather forecasting for years, even in the absence of contemporary weather information. With this knowledge, they are able plan and manage for climate risks more effectively. Explaining the relationship of the halo with scientific weather synoptic systems would enhance the credibility of modern scientific forecasting among smallholder farmers.

Table 2: Tree phenology IK indicators for weather forecasting in Zambia

Seasonal quality				
Category	**Indicator**	**Significance**	**Country**	**References**
Tree phenology	Plenty of fruits on Masuku trees (Uapaca kirkiana)	Plenty of rains	Zambia	Matsa and Mukoni, 2013; Nkomwa et al., 2013 Zuma-Netshiukhwi et al., 2013 Mugabe et al., 2010, Risiro et al., 2012 LEAD SEA, 2011
	Unstable mango (Mangifera indica) season. Trees flowering more than once in a season	Dry, windy and mainly cloudless periods	Zambia	Risiro et al., 2012 LEAD SEA, 2011
	Untimely dropping of mango flowers	Unstable season	Zambia	UNEP, 2008;
Movement of animals	Abundance of butterflies in October	Sign of good season	Zambia	UNEP, 2008
	Delayed butterflies presence in November	Sign of bad season	Zambia	UNEP, 2008

Low pressure systems are associated with high temperatures. Summer afternoons in Zambia under calm conditions can reach 40°C or more in certain locations. During such times, people seek relief from the blazing heat under the shade of trees. This process led communities to discover that cicadas, or nyenze, make sharp noises when temperatures reach highs of 38°C and above (Risiro et al., 2012). This is because when cicadas fan themselves in the heat, it produces a loud noise (Risiro et al., 2012). Further, they found that this occurrence was usually followed by precipitation – in particular showers and thunderstorms – soon afterwards. Following long-term observations, the sharp noise of cicadas has become associated with the likelihood of precipitation to an area. Contemporary forecasters should provide the scientific explanations of such occurrences to rural communities as well as make weather information easily accessible alongside this, in order to increase the appreciation and uptake of such knowledge among smallholder farmers (Challinor, 2008; McCrea et al., 2005).

This chapter has discussed how African smallholder farmers use and rely upon IKS (historical patterns, weather observations and signs) to formulate expectations on weather and climate (Jiri et al., 2015; Orlove et al., 2010). The main challenge to IKS in modern times is the advent of climate change and population growth. The depletion of certain fruit trees through deforestation and agricultural development also complicates seasonal forecasting of IKS, as some indicators are no longer available. Adaptation of current IKS is going to be required to meet the challenges associated with global climate change.

In Zambia, 75% of agriculture is rain-fed – a system that requires farmers to have a good understanding of the climate for every season. Farmers' knowledge regarding the coming season's forecast is important for decision-making regarding crop and farm management choices. Using their IK, farmers are able to forecast with some accuracy a good or bad season in regards to rainfall. A good season can be indicated through the presence of high yields on fruit trees such as masuku, locally known as wapaka kikiana, before the start of the growing season (Matsa and Mukoni, 2013; Nkomwa et al., 2013). On the contrary, a bad season can be anticipated in the absence of fruits on the same trees before the start of the growing season. This knowledge and information is widely used by farmers for planning seasonal cropping and management strategies.

Fruit production on fruit trees is related to the attainment of a certain temperature threshold. A conducive root temperature condition, amongst other factors, enables a plant to produce more fruit. This optimum root temperature is only achieved when the air temperature reaches certain thresholds related to the level of rainfall – which must be normal or above normal. Synergies of this IK with contemporary rainfall forecasting information is recommended in the literature, since plant phenology is related to temperature – a parameter used in weather monitoring and forecasting (Matsa and Mukoni, 2013). A future challenge to this IK practice will be population growth, which spurs deforestation that continues to reduce fruit tree numbers.

Another indicator used by smallholder farmers in Zambia for long-term seasonal forecasting is the presence of butterflies seen in the month of October flying from north to south (Chagonda et al., 2014). This is a sign of the development of semi-permanent low pressure areas in the southern hemisphere associated with the ITCZ. When the butterflies are absent at this time of year or are delayed to November, it is an indication of a bad season.

V **Extension workers answer questions during a field day for women farmers.**

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Conclusion

Smallholder farmers' agriculture risk management in Zambia is mainly dependent on their IK regarding weather prediction. This knowledge is the result of long-time observations of certain indicators that have shown a relationship with climate occurrences. Observations of certain animal behaviours and tree phenology stages provide smallholders with the capacity to predict weather and seasonal quality, without contributions from modern scientific forecasts. Agricultural losses associated with climate extremes are minimised due to this knowledge. Contemporary scientific forecasting knowledge, which is new amongst indigenous smallholder farmers, is perceived by farmers to be less credible, not fully explained, difficult to understand and interpret, untimely, mostly inaccessible and hence, inappropriate for climate risk management. Conversely, the use of IK in weather forecasting and seasonal rainfall prediction for supporting agricultural development in Zambia, has proven to be a sustainable system and is deeply rooted in indigenous farming communities.

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CHAPTER 15 - The future of indigenous knowledge systems and climate sciences

P.L. Mafongoya and O.C. Ajayi

Conclusion

The resilience of agro-ecosystems is rooted in the indigenous knowledge (IK) of smallholder farmers. The inherent dynamism of IK systems (IKS) lies at the heart of their ability to adapt. IKS are constantly evolving, learning through experimentation and knowledge building – processes that allow knowledge holders to adjust and modify their actions in response to environmental change. As global climate change and its emerging challenges and unknowns continue to affect southern Africa, it is essential that decisions, policies and actions are based on the best knowledge available. Biophysical and socio-sciences contribute significantly to the collective understanding of earth's systems, social systems and their integration. However, in recent years, it has become increasingly evident that scientific knowledge can benefit from the IK of farmers who directly bear the burden of climate-induced crises, and are the ultimate beneficiaries of efforts to solve such crises. The knowledge of local and indigenous people, often referred to as local, indigenous or traditional knowledge, is increasingly recognised as an important source of climate change knowledge and adaptation strategies.

IK is already seen as pivotal in various fields, such as sustainable development, traditional medicine, agroforestry, biodiversity conservation and natural resource management. Many are expecting this knowledge to play a prominent role in climate science and in facilitating adaptation to climate variability and change, as shown by many of the chapters in this book.

Knowledge co-production: Integrating indigenous and scientific knowledge

How robust are IKS in contemporary times, and how best can IKS be integrated with scientific knowledge are two important questions facing indigenous communities. Modern science is more acceptable to indigenous communities if it is integrated with, and presented within, the context of what they already know. Scientific weather forecasts are more credible to communities when they are integrated with IKS, a knowledge they have relied on for generations to predict and cope with droughts, floods and other natural hazards. Many chapters in this volume have demonstrated this point. Many chapters also explain that even when smallholder farmers listen to weather forecasts from meteorological departments over the radio, they still sometimes rely on their own traditional knowledge (Mpandeli *et al.*, this volume). The more scientific forecasts are reinforced with traditional knowledge, the more it will be used for planning purposes by indigenous communities.

The challenges brought about by global climate change are beyond the level of experience of knowledge holders, whether scientific or indigenous (Huntington *et al.*, 2005). Effective adaptation planning requires access to all the best available knowledge, whatever the source. In the face of uncertain and unpredictable risks and impacts due to climate change, there is a growing need for policies and actions that foster the co-production of knowledge, based upon collaborative efforts involving community based knowledge holders and natural and social scientists. Knowledge co-production is the collaborative process of bringing together populistic knowledge sources to address a defined process (Armigate *et al.*, 2011). This builds an integrated system oriented towards understanding a particular problem. Cross-scale and cross-cultural methodologies provide an important framework for adaptation action on the ground (Berkes, 2012). In the USA, the Swinomish climate change initiative combined Coast Salish cultural knowledge with US government scientific expertise, which resulted in the identification of the extent of impacts of climate change, and areas of concern for water quality (SITC, 2010). In the arctic, remote sensing through the use of fertilised research systems and other methods, such as meteorology and modeling, are being combined with IKS of Sami and Nenets reindeer herders to co-produce data sets to improve decision-making, herd management and adaptation strategies (Maynard *et al.*, 2005). In Africa, rain makers in the Nganyi communities of western Kenya (Guthiga and Newsham, 2011) and farmers in Nessa village in southern Malawi (Kalanda-Joshua *et al.*, 2011), have collaborated with meteorological scientists to provide integrated forecasts that are being disseminated by both indigenous and conventional methods to enhance community resilience to climate impacts.

Berkes *et al.* (2007) underlined the capacity of indigenous observations to make sense of complex changes in the environment through qualitative analysis of numerous variables, as opposed to scientific quantitative assessment of a few variables (Mafongoya *et al.*, this volume). This holistic approach to IK is akin to fuzz logic, which though different from scientific observation is complementary to it (Peloquin and Berkes, 2009). Such results point to the benefits of combining indigenous and scientific observation systems, as they may provide insights for climate change monitoring efforts.

Conservation of IKS

Many scholars have advocated for the protection of IKS through ex situ conservation – meaning isolation, documentation and storage of the information within international, regional and national archives (Warren *et al.*, 1993). *Ex situ* conservation is the least technical strategy and the most convenient politically. However, there are serious shortcomings with this strategy because IK is inherently scattered and local in nature. IK gains its vitality from being deeply integrated within people's lives, hence, an attempt to isolate, archive and transfer such knowledge can seem contradictory to its function. If western science is condemned for being none-responsive to local demands and divorced from people's lives, then centralised storage and management of IK lends itself to the same criticism. IK is a dynamic knowledge system that evolves and adapts with the changing needs of its people, thus ex-situ conservation seems a particularly ill-suited strategy for its preservation. The same strategy has been used for the conservation of plant germplasm and biodiversity, and has been considered inadequate and unsatisfactory. If *ex-situ* conservation has failed to conserve physically distinguishable entities such as seeds, it should not be expected to conserve a knowledge that is integrally linked to people's lives, and is therefore constantly changing.

Ex situ conservation may be justified on the grounds that IK is a public good or a global patrimony, and should therefore be made available to all interested individuals. National archives of IK materials and information should be made accessible to nationals and foreigners. However, access to centralised, bureaucratised data systems will always remain inequitable, disadvantaging the small users and farmers because of their centralised location, mostly in towns and cities.

Indigenous people are vulnerable to the impacts of global climate change, not only because they depend on climate sensitive resources, but also because they are often marginalised from decision-making processes and political power. It has been said that smallholder farmers are in general, politically passive; when conversely, they actively engage with and are experienced observers of their environment, and have accumulated sizeable and sophisticated bodies of knowledge and practices about the variability and transformation potential of their environment. This knowledge and know-how provides the basis of people's livelihoods, which are in turn at the centre of societal efforts to adapt to variability and change. IK therefore, provides important insights into processes of adaptation. The significance of IK becomes all the more evident once it is acknowledged that people and local communities have faced environmental variability and unpredictability for centuries. Hence, they have developed a range of technical, social and economic solutions, which form the basis of resilience in the context of climate change and variability. The challenges brought about by global climate change will surpass the experience of humankind, necessitating that adaptation and mitigation strategies should be formed using a combination of available knowledge. In this regard, a case should be made for the recognition of IK resilience, which has been evolving and adapting to new challenges for centuries.

Government policies and programmes should preserve and enhance indigenous resilience by supporting IK practices in natural resource management. Boosting IK resilience can also be achieved by fostering the diversity of indigenous crops and animals. Policies need to be planned and formulated through interdisciplinary research that brings together IK holders with scientists from various fields. This will allow efforts to build a mutual understanding among stakeholders, and reinforce trust between them. Recent efforts and partnerships between indigenous people and scientists are producing new knowledge in response to the emerging challenges of climate change. This co-creation and co-production of knowledge benefits and builds synergies between different knowledge systems, and is a good way to address the complexity of climate change and adaptation strategies.

Recommendations

The studies in southern Africa and parts of sub-Saharan Africa (SSA) have shown that the IKS of rural communities cover aspects of food production and processing, nature conservation and natural disaster management. IKS are culture specific and evolve over time to cope with environmental challenges. While the systems differ in detail, depending on the local culture and environment, they share similarities and common challenges. Some of the similarities are:

- IK relies on informal rules for its application
- IK faces a serious threat of being lost
- IK is neither pseudo-science nor anti-science, it is just another form of knowledge
- IK influences millions of people' lives in SSA without acknowledgement or recognition by formal government in most cases

New challenges

IK practices of natural resource conservation, disaster management and climate change management have worked well within the power structures of traditional communities. However, fast population growth and new socio-economic impacts, including science and technology developments, pose challenges to IKS. It is clear that a form of hybrid knowledge incorporating IKS and modern science is required to meet these challenges, as noted within the various chapters presented in this book.

Recommendation to address challenges

1. IKS should be documented in databases
2. IKS should be documented urgently to prevent any further loss of information.
3. IKS should be incorporated into national policy and development documents
4. Laws to safeguard intellectual property rights relating to IK should be enacted
5. IKS should be integrated with modern or scientific knowledge
6. IKS should be taught in schools, colleges and universities to become part of education curriculums
7. IKS should be popularised amongst members of the public

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