HOUSEHOLD VULNERABILITIES AND RESPONSES TO CLIMATIC AND SOCIO-ECONOMIC STRESSORS IN SOUTHERN AFRICAN DRY FORESTS AND WOODLANDS

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DECLARATION

I declare that this thesis is my own, unaided work, unless otherwise noted in the text. It is being submitted for the Degree of Doctor of Philosophy, at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination to any other University.

(Fiona Paumgarten)

12 day of DECEMBER 2019 at the University of the Witwatersrand, Johannesburg, South Africa

ABSTRACT

Rural households in the dry forests and woodlands of southern Africa face significant challenges to securing a sustainable livelihood. Climate change will likely exacerbate existing vulnerabilities in these dryland systems, particularly where households depend on climate-sensitive livelihoods and ecosystem services. In line with global goals to reduce and manage the risk of climate change, and to increase the likelihood of achieving the Sustainable Development Goals, there is the need to enhance rural households' adaptive capacity. Given the southern African region's broader development challenges, including the existing funding and capacity constraints, adaptation interventions need to be effectively targeted.

Although adaptation is described as a multi-dimensional and multi-scale process, the Intergovernmental Panel on Climate Change (IPCC) suggests that national commitments are often undermined by limited understanding of local level responses. A review of the existing literature from across southern Africa indicates limited local-level assessments of the climate-related risk of rural households in the region. A better understanding of the local context, guided by scientific research and local knowledge, is therefore important, particularly to support the design and implementation of appropriate interventions. These adaptation interventions should be cognisant of the heterogeneity of rural communities, acknowledge households' broader vulnerability context, recognise those groups most likely to be worst affected by climate change, and support households' existing capacity to respond to stresses and shocks.

With the aim of contributing towards an improved understanding of the local context, this thesis explores household vulnerabilities and responses to climatic and socio-economic stressors in southern African dry forests and woodlands. Focusing on two rural communities in South Africa's Limpopo Province, and taking a livelihoods approach, the study explored various aspects related to the climate-related risk of rural households, local perceptions and experiences of climate change and variability, households' broader vulnerability context (focusing on a range of stressors, including natural hazards), and their existing coping options (including the safety-net role of natural resources). With respect to the latter, it was assumed that households' existing coping strategies (and their access to assets) are indicative of households' adaptive capacity. For each of these aspects the influence of a number of factors, including location, various household characteristics, and households' existing capital

portfolio, was considered. Data were collected through a mixed-method approach, which included household surveys and a detailed Participatory Rural Appraisal.

South Africa’s Limpopo Province, one of the country’s poorest provinces, comprises predominantly rural areas, many of which are located in underdeveloped, former homeland areas. Households in these areas continue to rely on climate-sensitive livelihoods and have low adaptive capacity given limited assets and poor access to economic development opportunities. We considered rural households in the villages of Bennde Mutale and Vondo. Although both villages fall within the same district municipality, sites were selected in different agro-ecological zones, with notable differences in mean annual precipitation. Bennde Mutale falls within a dry agro-ecological zone, while Vondo is located in a semi-arid zone, receiving almost three times Bennde Mutale’s annual precipitation. Households in both villages continue to rely on land-based livelihoods and ecosystem services, including the use and sale of non-timber forest products (NTFPs).

Given the heterogeneity of rural households, differential climate change impacts are likely, both within and between communities. To better understand households’ climate-related risk a cluster-based approach was used to identify archetypical climate-risk profiles based on the core components of risk, as defined by the IPCC. The identification of six archetypical profiles allowed for the systematic interpretation of the nature of households’ climate-related risk. The profiles highlight the extent and heterogeneity of risk, with differences noted in the experience of natural hazards, in households’ exposure, the impacts faced, and in households’ adaptive capacity. Two high-, two moderate-, and two low-risk profiles were identified, with almost a third of households categorised as high-risk. These high-risk households continue to rely on land-based livelihoods, have poor access to secure shelter, and have low adaptive capacity, with the exception of access to natural capital. A clear site-related distinction in the profiles suggests adaptation interventions need to be site-specific, with households’ livelihood strategies and capital endowments shaped by the agro-ecological zone. However, the influence of factors such as household age and the gender of the household head, indicates that interventions aimed at improving households’ adaptive capacity need to also account for socio-demographic characteristics. These insights provide lessons for the development and targeting of interventions aimed at supporting local-level adaptation. The profiles provide a baseline against which interventions can be monitored.

The identification of distinct climate-risk profiles supports the design and implementation of adaptation interventions however questions remain on how best to cultivate local-level adaptation. Concerns include that households' willingness to adapt, and their adaptation responses, may be influenced more by the changes perceived, than the actual climate trends, with the risk of maladaptation. Understanding what factors shape perceptions may help in the design and targeting of more applicable climate change communications and interventions for the development of climate-resilient communities. Within this context, local experiences and perceptions of climate change were explored. Using existing meteorological datasets, the mean, trend and variability in precipitation and temperature as well as the occurrence of significant natural hazards were described. Local perceptions were assessed to determine whether these reflect the data and whether they are consistent, within and between the communities. While changes in precipitation and temperature were widely perceived, these perceptions tended to differ from the meteorological data, with respondents inclined to perceive more challenging conditions. Natural hazards were well remembered, with compelling oral narratives associated with these. These natural hazards result in cognitive biases which influence perceptions, with the risk that future adaptation responses may account only for the extremes not the trends. As with the climate-risk profiles, perceptions diverge by location although they are not uniform within each site. At the site-level, perceptions diverge, influenced by households' engagement in land-based livelihoods, their access to irrigation equipment and weather information, and their experience of climate-related challenges Although lessons can be learnt from these nuanced perceptions, the intra- and inter-site differences suggest the need for caution in using perception-based studies for one location or group to guide broader adaptation planning. The divergent perceptions intimate the need for targeted climate change communications which support households' ability to make strategic, long-term adaption decisions.

Within the context of climate change and given the need for households to improve their adaptive capacity, there has been renewed interest in households' existing coping strategies, including the safety-net function of NTFPs. It has been suggested that strengthening households' existing coping portfolio is a means of facilitating adaptation, and important given households' broader vulnerability context. Better understanding households' past responses to climate-related and other shocks, their existing coping options, how households combine and protect these options, and the opportunities and constraints associated with these, may provide insights into enhancing households' adaptive capacity. Within this context the range and prevalence of unanticipated shocks experienced by rural households, and the coping strategies used in response to these, was considered. Using mosaic plots to highlight associations between the shocks experienced and strategies used, it was investigated whether households apply coping strategies arbitrarily or not. A multivariate analysis was used to explore the influence of site and/or household characteristics on the adoption of a strategy. Households are exposed to various unanticipated production, human and financial shocks, as well as natural hazards, with production shocks being the most common. Although they rely on various informal coping strategies, these are applied selectively depending on the shock and on households' intent to manage their future options. Households' coping choices are also influenced by their access to human and financial capital. Households rely on social and natural capital to protect their alternative coping options, suggesting that a reliance on these capitals is not necessarily an indicator of limited alternatives. Households' informal, *ex-post* coping strategies appear to be limited for natural hazards, with households relying instead on external assistance or on *ex-ante* household savings. More vulnerable households were less likely to rely on external assistance, suggesting barriers to these social safety-nets. Households' reliance on savings is concerning. Increasingly frequent and intense natural hazards may hinder the accumulation of savings, undermining households' efforts to secure a sustainable livelihood, and reducing their capacity to cope and adapt. Natural products (specifically NTFPs) were not often used to cope with natural hazards, suggesting limitations to this coping option for covariate, climate-related shocks.

Given increasing expectations of the contribution of NTFPs towards sustainable, climate-resilient livelihoods in these dryland areas, there is the need for a more nuanced understanding of this livelihood, coping, and adaptation option. Although households use and sell a diversity of NTFPs, the daily- and safety-net function of wild foods was examined in more detail. In more marginal areas, where crop failure and recurrent drought undermine food and nutritional security, climate-resilient wild foods may play a key role in adaptation. To better understand the potential and limitations of wild foods, households' consumption of wild edible herbs, fruits and bushmeat, both on a regular basis and in response to increasing food scarcity, was investigated. Wild food consumption is generally prevalent, implying widespread need or that these foods are consumed in response to availability, dietary preferences, and cultural traditions. The sale of wild foods is less prevalent than their consumption. Wild food use is not generic, varying by location, depending on households' size and existing livelihood strategies. The frequency of wild food consumption during three food availability periods: when food is generally plentiful (e.g. post-harvest); when food is scarce (e.g. during seasonal crop shortfalls); and during "hungry periods" (e.g. drought), was considered. Based on this, three archetypes (clusters) of wild food users were defined, indicating differential dependence on wild foods. Alarmingly, those households who consume wild foods regularly, who were therefore considered to be "wild food dependent", decreased their consumption frequency under conditions of increasing food scarcity. This suggests that for these "Dependence" households, wild foods constitute a poverty trap, not a safety-net. Seasonal variations in wild food availability, and decreased availability during natural hazards, suggest limitations to the safety-net function of wild foods. Under these conditions, "Dependence" households, characterised by labour-constraints, may struggle to maintain their usual consumption levels, particularly if other households turn to wild foods as a safety-net, increasing competition for limited resources. Although there is the need to recognise the opportunities associated with wild foods, as both a coping and adaptation option, it is also necessary to recognise that under certain circumstances the safety-net function of wild foods may be weak or detrimental to the livelihoods of the most vulnerable.

Rural livelihoods in the dry forests and woodlands of southern Africa are inherently vulnerable, particularly given their ongoing reliance on climate-sensitive, land-based livelihood strategies, and their low levels of adaptive capacity. Within the context of climate change, in order to avoid increasing levels of vulnerability and climate-related risk, there is the need to support households' efforts to cope and adapt. Adaptation and development interventions need to account for the heterogeneity of vulnerability and climate-related risk at the local level, recognising differences in exposure and in households' existing capacity to cope and adapt. Given the apparent influence of site (and potentially agro-ecological zone) on households' climate-related risk, their experiences and perceptions of climate variability and change, and on their existing capacity to cope and adapt, these interventions should be site-specific. This study considered two villages within the same district municipality, suggesting that even at the municipal-level, there is the need for nuanced interventions. Wider testing of the methods and frameworks used in this study is recommended to determine if the patterns identified here are repeated across a broader area. This would help in the wider targeting of appropriate interventions. Households' vulnerabilities and responses, and to a lesser degree, their perceptions of climate change, are also influenced by various socio-demographic and -economic characteristics, emphasising the heterogeneity of rural communities. Interventions need to account for this heterogeneity and recognise that certain households may face barriers to pursuing certain adaptation options. Natural capital is one of the few capital types available to poorer, more high-risk households, however their reliance on this may constitute a poverty trap in the case of natural hazards. This study contributes to our overall understanding of household vulnerabilities and responses to climatic and socio-economic stressors in the dry forests and woodlands of southern Africa. In doing so, it contributes towards addressing the current dearth of such local-level assessments in the region. It provides recommendations for future research, and for policy and practice interventions aimed at enhancing rural households' capacity to cope and adapt, with this improved capacity identified as a vital target of the Sustainable Development Goals.

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DISCLAIMER

This thesis consists of four content chapters which have been prepared for publication in different scientific journals. As such, the style and language of the different chapters varies. There is also some overlap between the chapters given the requirements for publication. The specific journals and author contributions have been detailed in Chapter 1 together with any other relevant outputs (e.g. conference presentations) related to the core chapters.

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LIST OF ABBREVIATIONS

AEZ	Agro-ecological zone
AGRIC	Agriculture
AIC	Akaike Information Criterion
AIDS	Acquired immunodeficiency syndrome[1]
ANOVA	Analysis of variance
APES	Animal, Plant and Environmental Sciences
BIC	Bayesian information criterion
BODATSA	Botanical Database of Southern Africa
CA	Correspondence analysis
CARE	Cooperative for Assistance and Relief Everywhere
CCG	Child care grant
CFS	Climate Forecast System
CHAL	Challenge
CHIRPS	Climate Hazards Group Infrared Precipitation with Station data
CHPClim	Climate Hazards Group's Precipitation Climatology
CIFOR	Center for International Forestry Research
CIRAD	Centre de coopération internationale en recherche agronomique pour le développement (The French Agricultural Research Centre for International Development)
CPC	Climate Prediction Center
CTHB	Centre of Excellence in Tree Health Biotechnology
CTICC	Cape Town International Convention Centre
DEAT	Department of Environmental Affairs and Tourism
DEVIL	Delivering Food Security on Limited Land
DF	Degrees of freedom
DFID	Department for International Development
DG	Disability grant

[1] Term is used together with HIV, and expressed as "HIV/Aids", "HIV/AIDS" or "HIV-Aids"

DNS	Department: National Treasury
DST	Department of Science and Technology
EBA	Ecosystem-based adaptation
EPWP	Extended Public Works Programme
ESM	Electronic supplementary material
ESP	Ecosystem Services Partnership
EVI	Enhanced Vegetation Index
FACCE-JPI	Joint Programming Initiative on Agriculture, Food Security and Climate Change
FAO	Food and Agriculture Organization
FEWS NET	Famine Early Warning Systems Network
FGD	Focus group discussion
FMA	February, March, April
GCI	Global Change Institute
GHCN	Global Historical Climatology Network
GOVT	Government
H_2O	Water
HH	Household
HHS	Household survey
HIV	Human immunodeficiency virus[2]
HSD	Honest Significant Differences (Tukey HSD)
HSRC	Human Sciences Research Council
IDS	Institute of Development Studies
IFPRI	International Food Policy Research Institute
IIED	International Institute for Environment and Development
INFO	Information
IODZM	Indian Ocean Dipole Zonal Mode
IOL	Independent Online
IPCC	Intergovernmental Panel on Climate Change

[2] See also "AIDS"

IPM	Integrated pest management
IUCN	International Union for Conservation of Nature
IUFRO	International Union of Forest Research Organizations
IV	Indigenous vegetable
KII	Key informant interview
LEDET	Department of Economic Development, Environment and Tourism Limpopo
LIVST	Livestock
LVI	Livelihood Vulnerability Index
MANOVA	Multivariate analysis of variance
MAP	Mean annual precipitation (in mm)
MAT	Mean annual temperature (in °C)
MSC	Master of Science
N/A (NA)	Non-applicable
NCCAS	National Climate Change Adaptation Strategy
NCCRP	National Climate Change Response White Paper
NCDC	National Climatic Data Center
NGO	Non-governmental organization
NMDS	Non-metric multidimensional scaling
NRF	National Research Foundation
NTFP	Non-timber forest product
OAP	Old age pension
OXFAM	Oxford Committee for Famine Relief
PBL	Netherlands Environmental Assessment Agency
PCA	Principal components analysis
PECS	Programme on Ecosystem Change and Society
PhD	Doctor of Philosophy
PIK	Potsdam Institute for Climate Impact Research
PRA	Participatory rural appraisal
R	Rand (South African)

SAAB	South African Association of Botanists
SADC	Southern African Development Community
SANBI	South African National Biodiversity Institute
SASSB	South African Society for Systematic Biology
SAVI	Southern Africa Vulnerability Initiative
SAWS	South African Weather Service
SDG	Sustainable Development Goals
SE	Standard error
SES	Social-ecological System
SLF	Sustainable Livelihoods Framework
SON	September, October, November
SM	Supplementary material
StepSA	Spatial Temporal Evidence for Planning in South Africa
SSA	Statistics South Africa
TEK	Traditional ecological knowledge
TEMP	Temperature
TRMM	Tropical Rainfall Measuring Mission
TV	Television
UN	United Nations
UNECA	United Nations Economic Commission for Africa
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States Dollar
VCD	Visualising categorical data
VIF	Variation Inflation Factor
WIRES	Wiley Interdisciplinary Reviews
WITS	University of the Witwatersrand, Johannesburg
ZAR	South African Rand (Zuid-Afrikaanse Rand)

LIST OF APPENDICES

(Note: The list below, includes those Appendices attached to the broader thesis. The respective results chapters (Chapters 3-6) have their own Appendices/Annexes/Online Resources and/or Supplementary Materials, depending on the requirements of the journal for which the chapters have been formatted (and in some cases, submitted))

CHAPTER 1

General Introduction

1.1. Literature Review

1.1.1. Climate challenges for rural households in the African drylands

Globally, the drylands cover about 40% of the earth's land surface and are home to approximately two billion people (Fraser et al. 2011; Sietz et al. 2017). Many of these dryland areas, which include arid, semi-arid, and dry sub-humid climatic zones, have been described as potential climate change "hot spots"; i.e. areas where a "strong climate change signal is combined with a large concentration of poor, vulnerable, and marginalised people" (De Souza et al. 2015: 747). Both the social and ecological systems in these areas are considered particularly vulnerable to climate change, given their high levels of sensitivity, and low adaptive capacity (Kotir 2011; Fraser et al. 2011; Niang et al. 2014; Abdi et al. 2016; Del Ninno et al. 2016; Van Wesenbeeck et al. 2016; Sietz et al. 2017). In the African drylands, climate change threatens to reverse the sustainable development gains made to date, including those related to poverty reduction, improved food and water security, reduced human health risks, improved infrastructure, and ecosystem protection, thereby endangering the drylands' social-ecological systems (SES) and undermining the overall achievement of the Sustainable Development Goals (SDGs) (Alcamo et al. 2008; Niang et al. 2014; UN 2019).

Social-ecological systems are "integrated complex adaptive systems in which social and ecological subsystems are coupled and interdependent, each a function of the other, expressed in a series of mutual feedback relationships" (Berkes & Folke 1998; Berkes 2017: 3). The global drylands have been described as one of the most diverse yet highly vulnerable socio-ecological systems (Reynolds et al. 2002; Huber-Sannwald et al. 2012). Although vulnerability determinants are often heterogeneously distributed (e.g. see Sietz et al. 2017), a number of assessments on vulnerability and livelihood security in the drylands indicate the recurrence of distinct vulnerability-creating mechanisms (e.g. Jäger et al. 2007; Reynolds et al. 2007; Safriel & Adeel 2008; Sietz et al. 2011, 2012, 2017; Kok et al. 2016). These include poor agro-ecological conditions, seasonal and unreliable rainfall, inadequate infrastructure, limited market opportunities, and weak governance (Safriel & Adeel 2008; Stafford Smith et al. 2009; Blackie et al. 2014; Sietz et al. 2017). Although dryland social-ecological systems are characterised by inherent uncertainty, climate change is expected to exacerbate these existing challenges and create new risks, threatening the ability of these systems to maintain their essential function and structure (Safriel & Adeel 2008; Huber-Sannwald et al. 2012;

IPCC 2014). This has implications for the people who reside in these areas, whose livelihoods have historically been sustained by the ecosystem goods and services these diverse ecosystems provide (Huber-Sannwald et al. 2012; Niang et al. 2014).

In these complex, dynamic, and risk-prone areas, the absolute and relative costs of climate change are likely to be particularly high for those groups who are already marginalised, whether economically, politically, socially, culturally, institutionally, or otherwise (Vincent 2007; IPCC 2014; Joakim et al. 2015; Depietri 2019). This includes poor, rural households in the dry forests and woodlands of Africa who continue to rely on climate-sensitive, land-based livelihoods and ecosystem services for their subsistence and income needs (IPCC 2014; Kok et al. 2016; Elum et al. 2017; Hänke & Barkmann 2017; Castells-Quintana et al. 2018). The dry forests and woodlands cover almost half of the continent's land area, and incorporate, based on the broad definition used by Chidumayo and Gumbo (2010; ix), "vegetation types commonly termed woodland, shrubland, thicket, savanna and wooded grassland, as well as dry forest in its strict sense". Over 40% of the continent's population resides in these dry forests and woodlands (White 1983; Petheram et al. 2006; Locatelli et al. 2008; Sunderland et al. 2015; Sietz et al. 2017). In southern Africa, the dry forest and woodland area includes four extensive vegetation types, including the mopane woodlands in northern South Africa (White 1983; Chidumayo & Gumbo 2010).

Rural households in these dry forests and woodlands, who already face challenges to securing sustainable livelihood outcomes, are likely to face increasing levels of vulnerability unless their capacity to cope with, and adapt to, both climate-related shocks and long-term changes in the average climatic conditions improves (Muller & Shackleton 2014; Ziervogel et al. 2014; Börner et al. 2015; Coulibaly et al. 2015; Amjath-Babu et al. 2016; Connolly-Boutin & Smit 2016; Sietz et al. 2017; Nyoni et al. 2019). Enhancing households' capacity to cope and adapt is in line with global goals to reduce and manage the risk of climate change and achieve sustainable development (Dáze et al. 2009; IPCC 2014; Vidal Merino et al. 2018) (Box 1). Better understanding climate risk at the local level, and within the context of households' broader vulnerability context, is a necessary step towards achieving this (Eriksen 2008; Kleine et al. 2010; Bunce et al. 2010; IPCC 2014; De Souza et al. 2015; Jurgilevich et al. 2017). This includes better understanding vulnerability and risk in local, social-ecological systems in the dry forests and woodlands of southern Africa. Within the context of accelerated global environmental change understanding, and promoting, the resilience of these social-ecological systems is of growing concern (De Souza et al. 2015; Schoon & van der Leeuw 2015; Berkes 2017; Lu et al. 2018; Colding & Barthel 2019; UN 2019; UNDP 2020).

1.1.2. Defining and understanding vulnerability and climate risk in social-ecological systems

Vulnerability is generally defined as a system's propensity to be adversely affected, which is influenced by the sensitivity and exposure of the system to stresses and shocks, and the system's capacity to cope with, and adapt to, these (Turner et al. 2003; Füssel & Klein 2006; Hahn et al. 2009; IPCC 2012). It is a complex, multidimensional phenomenon, which varies spatially and temporally, influenced by interacting and overlapping social, economic, political, and ecological processes (Adger & Kelly 1999; De Chazal et al. 2008; Birkmann et al. 2013; Ahsan & Warner 2014; Oppenheimer et al. 2014). Understanding this complexity, and the multidimensional ways in which both natural and human systems are vulnerable, is important for the design, implementation and monitoring of interventions aimed at vulnerability reduction (Downing & Patwardham 2004; Adger et al. 2005; Reid & Vogel 2006; Vincent 2007; IPCC 2014; Kok et al. 2016). In response to this need, various assessment studies have sought to identify and better understand the drivers and inherent heterogeneity of vulnerability, both generally and within the climate change space (e.g. Leichenko & O'Brien 2002; Metzger et al. 2005; Füssel & Klein 2006; Birkmann 2007; Sallu et al. 2010; Preston et al. 2011; Kok et al. 2016; Vidal Merino et al. 2018). Related to this, these studies have considered systems' capacity to cope and adapt, and the factors that facilitate or constrain this (Luers et al. 2003; Vincent 2007). Focusing at different scales, these assessments have proposed various conceptual frameworks and a suite of proxy indicators to describe the vulnerability and adaptive capacity of specific people and places (Füssel & Klein 2006; Polsky et al. 2007; Vincent 2007; Hahn et al. 2009; Hinkel 2011; McDowell et al. 2016; Gerlitz et al. 2017; Jurgilevich et al. 2017).

Box 1: Glossary of specific terms taken from the IPCC's Climate Change Synthesis Report of 2014 (IPCC 2014)

(Note: in each case, the terms are direct quotes from the Synthesis Report (see Pg. 118))

1. Adaptation: The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities.
2. Adaptive capacity: The ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences.
3. Exposure: The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected.
4. Hazard: The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources. In this context, hazard refers to climate-related physical events or trends or their physical impacts.
5. Impacts: The effects on natural and human systems of extreme weather and climate events, and of climate change. This includes effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services, and infrastructure due to the interaction of climate changes or hazardous climate events […] and the vulnerability of an exposed society or system.
6. Mitigation: A human intervention to reduce the sources or enhance the sinks of greenhouse gases.
7. Resilience: The capacity of social, economic and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure, while also maintaining the capacity for adaptation, learning and transformation.
8. Risk: The potential for consequences where something of value is at stake and where the outcome is uncertain, recognising the diversity of values. Risk is often represented as the probability or likelihood of the occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. Risk includes the potential for adverse consequences on lives, livelihoods, health, ecosystems and species, economic, social, and cultural assets, services (including environmental services) and infrastructure.
9. Vulnerability: The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.

Although these assessments might place emphasis on different components of vulnerability, they have increasingly taken a more holistic approach, recognising the interactions between these components, particularly in the case of social-ecological systems (Eakin & Luers 2006; Füssel & Klein 2006; Knutsson & Ostwald 2006; De Chazal et al. 2008; Locatelli et al. 2008; Hahn et al. 2009; Preston et al. 2011; Oppenheimer et al. 2014; Sietz et al. 2017; Depietri 2019). In dryland social-ecological systems, more recent studies have focused on identifying specific archetypes of vulnerability, based on indications of distinct, recurring vulnerability-creating processes (Jäger et al. 2007; Sietz et al. 2011; Kok et al. 2016). For example, Sietz et al. (2017) used a cluster analysis to identify eight broad archetypes of vulnerability in farming systems in the drylands of sub-Saharan Africa. Various assessments have emerged which focus on conceptualising systems' vulnerability to changing climatic conditions and natural hazards (e.g. Schröter et al. 2005; Preston et al. 2011; Sietz et al. 2012; Wang et al. 2014; McDowell et al. 2016; Jurgilevich et al. 2017; Depietri 2019). The conceptualisation of vulnerability to climate change in coupled social-ecological dryland systems has been described as a specific "intellectual challenge" (Fraser et al. 2011). Berrouet et al. (2018, 2019) provide an overview of the evolution of conceptual thinking on the vulnerability of social-ecological systems and present a framework aimed at addressing some of the gaps in the assessment of this vulnerability (Berrouet et al. 2018, 2019). They highlight the need to consider the implications of threats of a continuous character (e.g. climate change), as opposed to discreet hazards, particularly as the former may alter the availability of the ecosystem services on which social systems depend (Berrouet et al. 2018, 2019).

Four distinct approaches to understanding vulnerability and risk have been suggested (Birkmann et al. 2013). These include approaches that are rooted in: i.) political economy (e.g. DFID's Sustainable Livelihoods Framework); ii) social-ecology (i.e. studies focused on coupled social-ecological systems (e.g. Turner et al. 2003)); iii.) a holistic view of vulnerability and disaster risk (i.e. they consider exposure, susceptibility and adaptive capacity as integrated components of risk (e.g. Birkmann 2007)); and iv.) climate change systems science (i.e. they use the formulation of vulnerability described by the Intergovernmental Panel on Climate Change (IPCC), and have emerged in the context of climate change adaptation (e.g. Füssel & Klein 2006)). The third and fourth categories differ in that approaches in the fourth category pay greater attention to the rate and magnitude of change (Birkmann et al. 2013). The IPCC's definitions and approaches have played a key role in defining the current conceptual understanding of climate vulnerability and risk, with the most recent climate-risk framework having emerged from the growing understanding that the risk of impacts is a function of the interaction of climate hazards with the exposure and vulnerability of the system in question (see Fig 1) (Birkmann et al. 2013; Oppenheimer et al. 2014; Bennett et al. 2016). Based on a systematic review of empirical, sub-national climate risk and vulnerability assessments, Jurgilevich et al. (2017) argue that these assessments need to pay greater attention to the interactions between the components of risk as well as the variability in the different components. These complex interactions are likely to result in differential climate-related impacts, although certain areas, sectors, populations, households, and individuals are expected to be worse affected (Grothmann & Patt 2005; Vincent 2007; Dáze et al. 2009; Hahn et al. 2009; IPCC 2014; Kok et al. 2016; Vidal Merino et al. 2018).

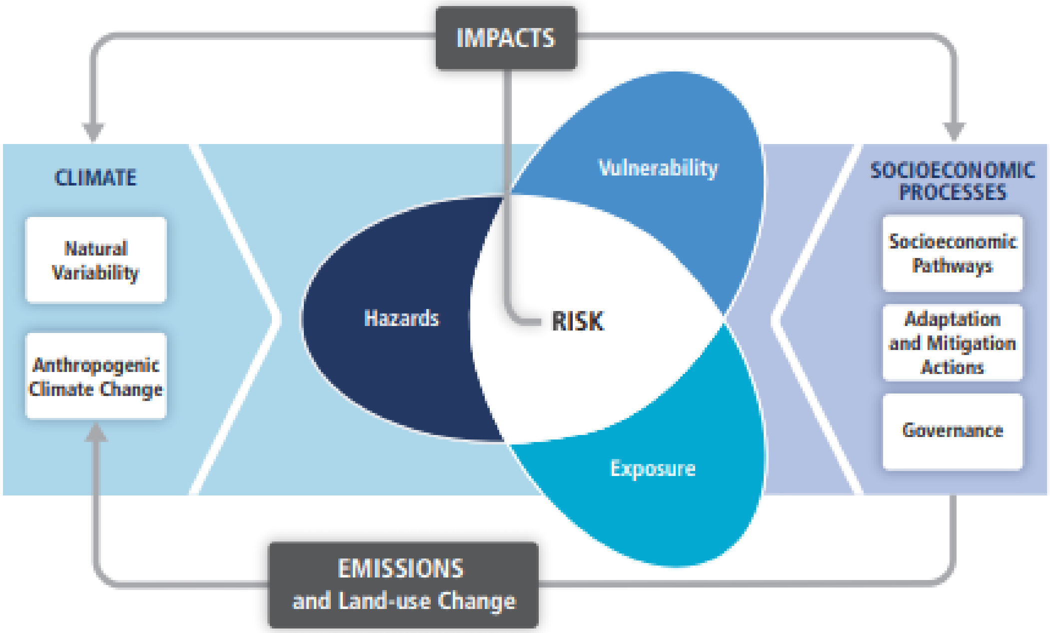

Fig. 1: The IPCC's revised climate risk framework (2014). The risk of climate-related impacts is a function of the interactions between climate hazards and the exposure and vulnerability of the system in question. Exposure (an external factor) is presented as a separate component to vulnerability (an internal factor, which incorporates the elements of sensitivity and adaptive capacity) (IPCC 2014) (see Box 1 for the IPCC's definitions of the core components). Variations in the climate system (left) and in socio-economic processes (right) compound the heterogeneity of risk (IPCC 2014).

Various authors highlight the challenges associated with the range of vulnerability conceptualisations used in these vulnerability and climate risk assessments (e.g. Birkmann et al. 2013; Joakim et al. 2015). Joakim et al. (2015) considered how different studies have used the term vulnerability, and based on this, suggest four different vulnerability categorisations: i.) vulnerability as a threshold; ii.) vulnerability as exposure to hazards; iii.) vulnerability as a pre-existing condition; and iv.) vulnerability as an outcome. They go on to suggest that understanding vulnerability as a pre-existing condition is the most appropriate for framing climate change adaptation (Joakim et al. 2015). According to Jurgilevich et al. (2017) publications that discuss these conceptual and methodological issues (e.g. Joakim et al. 2015), constitute one of three broad categories of the climate risk and vulnerability assessment literature. Other publications include those that present empirical case studies (e.g. Rød et al. 2015) or a ranking of regions/countries (e.g. Brooks et al. 2005); and publications that present studies that investigate the drivers of vulnerability (e.g. Luers 2005). In addition to ongoing questions on the conceptualisation of vulnerability, questions also remain on the appropriate scale at which to carry out vulnerability and climate risk assessments. While broader scale assessments allow for the identification of patterns in the drivers of vulnerability, they lack the sensitivity to differentiate at the local level (Vincent 2007; Van Wesenbeeck et al. 2016; Sietz et al. 2017). Local-level assessments, however, may fail to account for the influence of broader social, economic, and climatic processes (Vincent 2007; Eakin & Bojorquez-Tapia 2008; Hahn et al. 2009).

A number of assessments have sought to better understand various aspects of climate risk in the African drylands, through the development of various indices, at different scales. For example, to explore the vulnerability of African countries to climate change-induced variations in water availability, Adger and Vincent (2005) used an aggregated social vulnerability index of human sensitivity and adaptive capacity. The Livelihood Vulnerability Index (LVI) was developed by Hahn et al. (2009) to estimate differential climate change impacts at the district level, focusing on communities in Mozambique. Vincent (2007) developed adaptive capacity indices for use at different scales: i.) a national index for cross-country comparisons in Africa, and ii.) a household-level index, tested on rural households in South Africa. In order to explore differentiated vulnerability drivers between male and female-headed households in Uganda, Balikoowa et al. (2019) focused specifically on constructing a gender vulnerability index. Despite the development of these different indices, both Jurgilevich et al. (2017), who reviewed sub-national climate risk and vulnerability assessments, and McDowell et al. (2016), who considered local level assessments, indicate notably fewer assessment studies from sub-Saharan Africa than from developed nations.

Based on a systematic evaluation of community-level climate change vulnerability assessments published over the preceding 25 years, McDowell et al. (2016) identified a number of “keystone papers” published in the mid-2000s, which theorize on how best to study climate change vulnerability at the community-level (i.e. work by Turner et al. 2003, Adger 2006, Füssel & Klein 2006 and Smit & Wandel 2006). They note that despite growing consensus of the need to account for social-ecological interdependencies, few studies have significantly emphasised interlinked social-ecological systems, although this focus is more common in the African studies (McDowell et al. 2016). Although there has been an increase in community-level assessments, and despite advancements in the conceptual framing and methodological approaches, there are still key shortcomings in how vulnerability is studied at the community-level (Ribot 2014; Wang et al. 2014; McDowell et al. 2016). For example, the IPCC’s revised climate risk framework has, to date, rarely been applied at the local level (Karim 2018). In developing countries, the need for these community-level and sub-national assessments will continue to increase, particularly given the projected climate changes and the persistence of widespread socio-economic inequalities (McDowell et al. 2016; Gerlitz et al. 2017). Although the use of different methodologies, frameworks, and definitions, at different scales, creates challenges in terms of comparability and scalability, these different assessments have contributed towards an improved understanding of vulnerability, climate risk, and adaptive capacity, helping to define, prioritise and target risk-reduction interventions (Luers et al. 2003; Fussel & Klein 2006; Birkmann et al. 2013; Oppenheimer et al. 2014; Gerlitz et al. 2017; Jurgilevich et al. 2017; Vidal Merino et al. 2018).

1.1.3. Understanding vulnerability, climate risk, and adaptative capacity at the local level, with a focus on rural communities

Poor, rural households face multiple, often concurrent stressors that impact on the bio-physical, social and economic environments in which they exist, and which undermine households’ efforts to sustainably secure their livelihood outcomes (DFID 1999; Paumgarten & Shackleton 2011; Hänke & Barkmann 2017; FAO 2018). These stressors, which comprise shocks, trends, and seasonal variations, are described as a common feature of rural livelihoods, inextricably linked to the chronic poverty many households endure (DFID 1999; Pattanayak & Sills 2001; Wood 2003). Having said that, the complex nature of vulnerability together with the heterogeneous nature of rural communities implies that different individuals and groups are likely to experience varying degrees of vulnerability and climate risk (Adger & Kelly 1999; DFID 1999; Maxwell et al. 1999; Kasperson & Kasperson 2001; Dáze et al. 2009; Sietz et al. 2012; IPCC 2014; Castells- Quintana et al. 2018). Each household's vulnerability context is ultimately the result of a unique combination of crises, existing inequalities, the household's lifecycle stage and socio-demographic characteristics, its existing livelihood strategies, and its resource endowments (Block & Webb 2001; Pattanayak & Sills 2001; Few 2003; Berrouet et al. 2019). Therefore, although poor, rural households may be inherently vulnerable, not all households are equally vulnerable, with some households being less able to cope and adapt than others (DFID 1999; Berrouet et al. 2019). These include already marginalised households, such as those who are more dependent on ecosystem goods and services, those with a female-, child- or elderly head, younger households, those impacted by HIV/Aids, and those with limited social networks (Pattanayak & Sills 2001; Posel 2001; Vincent 2007; Gyampoh et al. 2008; Drimie & Gillespie 2010; Paumgarten & Shackleton 2011; Murugani et al. 2014; IPCC 2014; Börner et al. 2015; Djoudi et al. 2016).

Climate change is expected to exacerbate existing levels of vulnerability, uncertainty and inequality, threatening land-based livelihoods and the ecosystem goods and services that support them with a combination of disasters (Gyampoh et al. 2008; Berrang-Ford et al. 2010; IPCC 2014; De Souza et al. 2015; Kok et al. 2016). Poor, rural households will need to adapt to, at the very least, maintain their current levels of well-being (Muller & Shackleton 2014; De Souza et al. 2015). However, households' capacity to cope with, and adapt to, climate change is often constrained by limited resources, existing vulnerabilities, inadequate policies, and weak institutions (Agrawal et al. 2008; Bryan et al. 2009; Hahn et al. 2009; Pandey et al. 2018). Addressing these constraints, through the collaborative design, implementation and monitoring of appropriate measures, is necessary for the establishment and maintenance of more climate-resilient communities, in which households are able to engage in short-term coping strategies, and adapt to long-term risks (Eriksen & Silva 2009; Börner et al. 2015; Mehar et al. 2016). Although the variance in vulnerability patterns suggests no single option to reduce vulnerability, the complexity of vulnerability and climate-related risk of rural households needs to be better understood to enhance households' own efforts to increase their adaptive capacity (Turner et al. 2003; Downing & Parwardhan 2004; O'Brien et al. 2009; Kleine et al. 2010; Sietz et al. 2011; Quinn et al. 2011; Bennet et al.

2016). In developing countries, where funds and capacity are limited, the need for appropriate and well-targeted support is high. Measures aimed at reducing rural households' vulnerability and climate risk should be cognisant of the heterogeneity of rural communities, acknowledge households' broader vulnerability context, recognise those groups most likely to be worst affected by climate change, and understand and support households' own capacity to manage and reduce risk (Bunce et al. 2010; Adger et al. 2011; Brockhaus et al. 2013).

1.1.4. Responding to adversity – coping, adaptation, and adaptive capacity

Adaptation is now recognised as an equal and complementary approach to mitigation for reducing and managing the adverse impacts of climate change (IPCC 2014; Joakim et al. 2015). In human systems, adaptation, described as the "process of adjustment to actual climate and its effects", seeks to "moderate or avoid harm or exploit beneficial opportunities" (IPCC 2014: 118). Although adaptation is a complex, multi-dimensional, and multi-scale process, adaptation efforts have tended towards being top down, failing to account for local priorities, knowledge, and capacity (Bryan et al. 2009; IPCC 2014). Several studies have emphasised the importance of this local knowledge in decision making regarding climate risk (e.g. Vogel & O'Brien 2006; Thomas et al. 2007; Pandey et al. 2018), with the IPCC (2014) having described these existing local and traditional knowledge systems as a major resource for climate change adaptation. Having said that, although rural households and communities have a long history of coping with, and adapting to, climate variability and change, unprecedented climate shocks and long-term changes in the average climatic conditions are likely to strain existing capacities (Acosta-Michlik et al. 2008; Abdullah et al. 2009; Berrang-Ford et al. 2010; Paumgarten & Shackleton 2011; IPCC 2014; Castells-Quintana et al. 2018). To avoid increasing levels of vulnerability, there is the need to engender and support initiatives that cultivate resilience and build adaptive capacity (Smit & Wandel 2006; Füssel 2007; Birkmann et al. 2013; IPCC 2014). This process may benefit from better understanding households' past responses to climate-related and other shocks, their existing coping options, how households combine and protect these options, and the opportunities and constraints associated with these (Adger et al. 2003; Skoufias 2003; Vincent 2007; Cooper et al. 2008; Pandey et al. 2018). Strengthening households' existing coping portfolio has been proposed as a cost-effective means of facilitating early forms of adaptation, and important given households' broader vulnerability context (Skoufias 2003; Heemskerk et al. 2004; Takasaki et al. 2004; McSweeney 2005; Cooper et al. 2008; Günther & Harttgen 2009; Wunder et al. 2014; Börner et al. 2015; Castells-Quintana et al. 2018).

In many developing countries, where access to formal private insurance is limited and where public safety-nets are weak, rural households tend to rely on a diversity of informal insurance mechanism or coping strategies to endure adverse times (Dercon 2002; Skoufias 2003; Paumgarten & Shackleton 2011; Mehar et al. 2016). Within the context of climate change, households' existing coping strategies are receiving renewed attention, specifically with respect to where the distinction lies between coping and adapting (Thompson & Scoones 2009; Berrang-Ford et al. 2010; IPCC 2014; Mehar et al. 2016; Hänke & Barkmann 2017; Pandey et al. 2018). These coping strategies tend to be defined as short-term responses to immediate threats, although distinctions are made between strategies that are more reactive (*ex-post*) or proactive (*ex-ante*) in nature (Dekker 2004; Cooper et al. 2008; Berrang-Ford et al. 2010; Paumgarten & Shackleton 2011; Coulibaly et al. 2015; Mehar et al. 2016). Coping and adapting are often distinguished on the timescale of the response, with coping considered a short-term response while adaptation involves a more long-term adjustment (Osbahr et al. 2008; Eriksen & Silva 2009; Pelling 2010; Birkmann et al. 2013). Others suggest that the two are not clearly distinguishable, with existing coping strategies often morphing into adaptation responses (Fabricius et al. 2007). Birkmann et al. (2013) distinguish between coping, as the reactive component of resilience, and adaptation as the more proactive component. Tierney (2014) distinguishes between inherent and adaptive resilience, whereby inherent resilience refers to individuals'/households/communities' existing capacity to respond to crises, while adaptive resilience, refers to their ability to continue functioning on the basis of resourcefulness. Although adaptation promotes resilience, effecting adaptation requires some pre-existing level of resilience (Joakim et al. 2015).

The safety-net role of non-timber forest products (NTFPs) is one informal coping strategy receiving renewed attention, particularly in terms of the potential contribution of various products to households' adaptive capacity (Ofoegbu et al. 2016; Balama et al. 2017). As with households' other informal coping options, there are various opportunities associated with the safety-net function of NTFPs (Skoufias 2003; Hunter et al. 2007; Fisher et al. 2010; Paumgarten & Shackleton 2011; Ofoegbu et al. 2016; Balama et al. 2017; Mbiba et al. 2019). NTFPs are often easily accessible and therefore of particular importance to poor, rural households with limited alternative forms of insurance (Pattanayak & Sills 2001; Takasaki et al. 2004; Fisher et al. 2010; Paumgarten & Shackleton 2011; Angelsen et al. 2014; Ofoegbu et al. 2016; Mugido & Shackleton 2017). These households benefit through both the consumption and sale of a diversity of products and species. This contribution is a core aspect of this study, with a particular focus on the role of wild foods, which are already incorporated into the diet of an estimated one billion people (Burlingame 2000). In more marginal areas (including the African drylands), where crop failure and recurrent drought undermine food and nutritional security, more climate-resilient wild foods may play a key role in adaptation (Burlingame 2000; Delang 2006; Nasi et al. 2011; Pramova et al. 2012; Powell et al. 2015; Tibesigwa et al. 2016). Effective ecosystem management could therefore play a key role in helping households cope with, and adapt to, climate change (Vignola et al. 2010).

Despite the opportunities associated with this coping option, there are also a number of associated constraints , including seasonality, over-use, the opportunity costs associated with collection, etc. (Fisher at al. 2010; Baiyegunhi & Oppong 2016). Additionally, there is mixed evidence on the effectiveness of NTFPs in insuring households against large, covariate shocks (as opposed to smaller idiosyncratic shocks) (Wunder et al. 2014; Ofoegbu et al. 2016). While some studies indicate that NTFPs play an important role in buffering households against climate-related shocks (e.g. McSweeney 2005; Tibesigwa et al. 2016; Depietri 2019), others caution that this reliance may constitute a poverty trap in cases where the resource is limited, and demand is high (Levang et al. 2005). For vulnerable, natural resource-dependent households it may therefore be necessary to consider alternative insurance (Debela et al. 2012; Wunder et al. 2014; Hickey et al. 2016; Weyer et al. 2017). However, given increasing expectations of the contribution of NTFPs towards sustainable, climate-resilient livelihoods in the drylands, there is the need for a more nuanced understanding of this livelihood, coping, and adaptation option (Fisher et al. 2010; Ofoegbu et al. 2016).

Numerous commentators have explored both the idiosyncratic and covariate risks to which rural households are vulnerable, with a particular focus on how they respond and the factors that determine a household's ability to cope (Godoy et al. 1998; Block & Webb 2001; Dercon 2002; Skoufias 2003; Dekker 2004; Paumgarten & Shackleton 2011; Börner et al 2015). Given the multiple, often concurrent stressors households face, they often rely on a portfolio of strategies, turning to these either simultaneously or sequentially depending on the shock in question (Paumgarten & Shackleton 2011). Although some strategies may be more crisis-specific, others are employed in response to a range of crises, with certain more common strategies noted (e.g. relying on kinship networks, economic adjustments to household spending, selling assets, and relying on NTFPs) (Heemskerk et al. 2004; Paumgarten & Shackleton 2011; Mugido & Shackleton 2017). Households' socio-economic and socio-demographic characteristics influence the coping strategies used (DFID 1999; Skoufias 2003; Paumgarten & Shackleton 2011). For example, given their limited asset base and weaker economic position, poorer households are often more dependent social and natural capital to cope, while wealthier households draw from their available financial capital (DFID 1999; Paumgarten & Shackleton 2011; Ahsan & Warner 2014). Households with high human capital, often expressed as a function of available labour and skills, might rely on labour-intensive coping options, or use their skills to diversify into alternative livelihoods (Sietz et al. 2012). Coping responses may therefore vary both temporally and spatially, dependent not only on the nature and intensity of the shock but also on households' available asset base (Pattanayak & Sills 2001; Reid & Vogel 2006; Quinn et al. 2011; Börner et al. 2015; Bennett et al. 2016; Berrouet et al. 2019).

Similarly, various social, political, economic, technological, and institutional factors influence a system's adaptive capacity, with this capacity described as a precondition for adaptation (Adger & Vincent 2005; Vincent 2007; Deressa et al. 2009; Brown & Westaway 2011; IPCC 2014; Jurgilevich et al. 2017). According to Agrawal et al. (2008), local adaptation responses can be classified into five categories: mobility, storage, diversification, communal pooling, and market exchange. In the case of poor, rural communities, households' uptake of adaptation (whether autonomously, or in response to adaptation interventions) is likely to be influenced by their access to, and control over, the appropriate resources, including their existing natural, social, human, financial and physical capital (Adger et al. 1999; Bryan et al. 2009; Dáze et al. 2009; Hahn et al. 2009; de Jalón et al. 2018; Vidal Merino et al. 2018; Berrouet et al. 2019). Households' demographic structure; their socio-economic position; the livelihood strategies employed; households' access to land and output markets; their dependence on, and access to, natural resources; the existing agro-ecological conditions; the quality of housing (and other infrastructure); and households' awareness of, and access to, extension services, insurance products and credit can all either support or constrain adaptive capacity (Adger 1999; Pattanayak & Sills 2001; Skoufias 2003; Vincent 2007; Gyampoh et al. 2008; Bryan et al. 2009; Hart & Aliber 2012; Mpandeli et al. 2015 Ofoegbu et al. 2016). Levels of adaptive capacity can therefore vary both spatially and temporally (Birkmann et al. 2013). Better understanding different adaptive capacities, and ensuring vulnerable groups have access to and control over critical resources, is important for the targeting of adaptation support measures (Adger & Kelly 1999; Block & Webb 2001; Skoufias 2003; Vincent 2007; Gyampoh et al. 2008; Birkmann et al. 2013; Joakim et al. 2015).

Uncertainty exists on how to foster adaptation at the local level, with it having been suggested that households' willingness to adapt, and their actions, may be influenced more by the changes they perceive, than the actual climate trends (Bryan et al. 2009; Bryan et al. 2013; IPCC 2014; Devkota et al. 2016; Elum et al. 2017). Various studies explore the influence of households' perception of change on their decision to adapt, focusing on the factors that shape these perceptions (e.g. Vogel & O'Brien 2006; Vincent 2007; Simelton et al. 2013; Muller & Shackleton 2014; Hitayezu et al. 2017). Households' perceptions of climate change appear to be influenced by a number of factors including households' socio-demographic characteristics, their farming experience, experience of recent climate events and other climate factors; their available income; and their access to information (e.g. via extension services) and formal credit (Vogel & O'Brien 2006; Maddison 2007; Nhemachena & Hassan 2007; Thomas et al. 2007; Vincent 2007; Bryan et al. 2009; Simelton et al. 2013). Furthermore, recent climate events may have more influence on perceptions and behavioural responses, than long-term changes in average conditions (Thomas et al. 2007; Gbetibouo et al. 2010; Elum et al. 2017). Understanding what factors shape local perceptions may, i.) help identify households' primary concerns related to their local climate, climate change, and its impacts on their livelihoods; ii.) provide insights into households' existing responses as well as how households might adapt, and iii.) help in the design and targeting of more applicable climate change communications and actions for the development of climate-resilient communities. (Bryan et al. 2009; Simelton et al. 2013; Devkota et al. 2016). In their proposed conceptual framework for assessing the vulnerability of social-ecological systems, Berrouet et al. (2018) therefore highlight the importance of accounting for both households' understanding of climate change and the social-ecological systems' adaptive capacity.

1.2. Rationale for the Study

Although systems may adapt autonomously, strategic adaptation is advised to ensure more sustainable adaptation (Brockhaus et al. 2013). Effectively and sustainably reducing climate-related risk requires complementary responses across scales, with local efforts linked to global approaches (Brockhaus et al. 2013; IPCC 2014). Although climate hazards can have widespread consequences, as recently noted in Southern Africa (Box 2), impacts are often experienced most intensely at the local level (Vincent 2007; Sietz et al. 2017). Policies and practices geared towards reducing the climate-related risk of local social-ecological systems need to account for the complexity of these systems, the risks they face, and the factors that undermine or enable their ability to cope with, adapt to, and recover from stressors (Luers 2005; Vincent 2007; Berrrouet et al. 2018, 2019). Currently however, a limited understanding of local-level impacts, vulnerabilities and existing responses tends to undermine both national adaptation commitments and local-level interventions (Callaway 2004; Sietz 2011; IPCC 2014; Ford et al. 2015; Jurgilevich et al. 2017). To better support the design, implementation and monitoring of appropriate development and adaptation interventions, there is the need for more context-specific information on local vulnerabilities and capacity to cope and adapt (Dáze et al. 2009; Fisher et al. 2010; Brockhaus et al. 2013; IPCC 2014; De Souza et al. 2015; Kok et al. 2016). This includes better understanding household vulnerabilities and responses to climatic and socio-economic stressors in the dry forests and woodlands of Southern Africa. Focusing on rural households in two communities located in South Africa's north-eastern Limpopo Province (see Chapter 2), this study sought to contribute towards this improved understanding.

In line with the Paris Agreement, which defines a global goal to i.) enhance adaptive capacity and resilience and to ii.) reduce vulnerability, with the purpose of strengthening the global response to climate change and contributing to sustainable development (UNFCCC 2017), South Africa recently gazetted its Draft National Climate Change Adaptation Strategy (NCCAS) for public comment (DEA 2019). The NCCAS outlines a common vision for adaptation and climate resilience in South Africa, presenting four strategic objectives: i.) to build climate resilience and adaptive capacity to respond to climate change risk and vulnerability; ii.) to promote the integration of climate change adaptation response into development objectives, policy, planning and implementation; iii.) to improve the understanding of climate change impacts and capacity to respond to these impacts; and iv.) to ensure resources and systems are in place to enable implementation of climate changes responses (see Box 3). Together with various other South African policy documents and acts[3] related to climate change responses, the NCCAS highlights the need to better understand, and address, climate-related risk at the local level. According to these various documents and

[3] E.g. South Africa's National Climate Change Response White Paper (NCCRP) (RSA 2011)

acts, the design and implementation of responses should involve multiple stakeholders, across different sectors and scales; should be guided by both scientific research and local knowledge; be people-centred, equitable and gender-sensitive; and be cognisant of the most vulnerable groups (Elum et al. 2017; DEA 2019). Despite the recognition of the need for local-level data, a review of the existing literature from South Africa, and from Southern Africa more broadly, indicates limited availability of data on the climate-related risk of rural households in the region, supporting the findings of both McDowell et al (2016) and Jurgilevich et al. (2017) (Box 4; Appendix 1). Based on this literature review, for South Africa, only six research articles have been published over the last decade which include interviews with local stakeholders, of which only four include interviews at the household-level (Box 4). This study contributes towards addressing this gap.

Box 2: Recent climate disasters in Southern Africa

Southern Africa is expected to face increasing climate-related risk associated with decreasing and more unpredictable rainfall, increasing temperatures, and increasingly extreme natural hazards (Blignaut et al. 2009; Niang et al. 2014; Mpandeli et al. 2015; Rakgase & Norris 2015; Elum et al. 2017; Senyolo et al. 2018). Recent weather-related disasters have highlighted the climate-related risk of households in the region. The 2015/16 El Niño-induced drought left 26 million people in need of humanitarian assistance; the 2018/19 El Niño-induced drought has again severely affected regional food production; while close to 6 million people across Mozambique, Malawi and Zimbabwe face increased vulnerability in the wake of severe tropical cyclones experienced in March and April 2019 (SADC 2016; FAO 2018; Amnesty International 2019). These consecutive disasters have severely impacted already challenged, largely rain-fed, local food systems, with acute levels of food insecurity expected to persist until the 2020 agricultural season (DEVEX 2019; FEWS NET 2019). Given Southern Africa's broader development challenges, including the existing funding and capacity constraints, failing to improve the long-term resilience of the region's natural and human systems may ultimately impede the achievement of the Sustainable Development Goals (Blackie et al. 2014; Niang et al. 2014; UNECA 2015; FAO 2018).

Box 3: Linkages between South Africa's NCCAS's strategic objectives, interventions and outcomes (see NCCAS pg. 20) (DEA 2019). Objectives 1 and 3 specifically emphasise the need to better understand vulnerabilities and responses to climatic stressors. This study contributes towards these objectives by exploring "Household vulnerabilities and responses to climate and socio-economic stressors in Southern African dry forests and woodlands", using a local case study from South Africa's Limpopo Province

OBJECTIVE	INTERVENTION	OUTCOME
OBJECTIVE 1: Build climate resilience and adaptive capacity to respond to climate change risk and vulnerability.	**INTERVENTION 1:** Reduce human, economic, environment, physical and ecological infrastructure vulnerability and build adaptive capacity.	**Outcome 1.1:** Increased resilience and adaptive capacity achieved in human, economic, environment, physical and ecological infrastructure vulnerability.
	INTERVENTION 2: Develop a risk, early warning, vulnerability and adaptation monitoring system for key climate vulnerable sectors and geographic areas.	**Outcome 2.1:** An early warning and monitoring system for key climate vulnerable sectors and geographic areas developed and implemented.
OBJECTIVE 2: Promote the integration of climate change adaptation response into development objectives, policy, planning and implementation.	**INTERVENTION 3:** Develop vulnerability and resilience methodology framework that integrates biophysical and socio-economic aspects of vulnerability and resilience.	**Outcome 3.1:** An adaptation vulnerability and resilience framework developed and implemented across 100% of key adaptation sectors
	INTERVENTION 4: Facilitate mainstreaming of adaptation responses into sectoral planning and implementation.	**Outcome 4.1:** An effective adaptation planning that covers at least 80% of the South African sectors identified in the NCCAS.
		Outcome 4.2: Achieve a 100% coverage of climate change considerations in sectoral operational plans.
OBJECTIVE 3: Improve understanding of climate change impacts and capacity to respond to these impacts.	**INTERVENTION 5:** Promote research application, technology development, transfer and adoption to support planning and implementation.	**Outcome 5.1:** Increased research output and technology uptake to support planning and implementation.
	INTERVENTION 6: Build the necessary capacity and awareness for climate change response.	**Outcome 6.1:** Capacity building and awareness for climate change response enhanced.
OBJECTIVE 4: Ensure resources and systems are in place to enable implementation of climate changes responses.	**INTERVENTION 7:** Establish effective governance and legislative processes to integrate climate change in development planning.	**Outcome 7.1:** Adaptation governance defined and legislated through the Climate Change Act once approved by parliament.
		Outcome 7.2: Institutional support structures for climate change adaptation strengthened.
		Outcome 7.3: Enhanced public-private-civil society collaboration and stewardship.
	INTERVENTION 8: Enable substantial flows of climate change adaptation finance from various sources.	**Outcome 8.1:** Adequate financial resources of national adaptation priorities from national fiscus and international sources.
	INTERVENTION 9: Develop and implement an M&E system that tracks implementation of adaptation actions and their effectiveness.	**Outcome 9.1:** A national M&E system developed and implemented.

The study's primary aims are to i.) understand rural households' vulnerability to multiple stressors (with a focus on households' climate-related risk), and to ii.) understand households' responses to climate-related and other stressors, with a focus on the role provisioning services (specifically NTFPs) play. To gain further insights into rural households' vulnerabilities and responses, various aspects of rural livelihoods are considered, and the influence of a number of factors is explored, including location, household characteristics such as gender of the household head, and households' existing capital portfolio. Data were collected through a mixed-method approach, which included household surveys and a detailed Participatory Rural Appraisal. The methods and selected study sites are described in more detail in Chapter 2.

The specific objectives of the study are to:

1. Explore, and better understand, the heterogeneity of the climate-related risk of rural households, both within and between rural communities, based on the assumption that this improved understanding is important for the design, implementation and monitoring of interventions aimed at reducing this risk. This requires understanding the different components of climate-related risk, including the hazards experienced, households' exposure, and their vulnerability (i.e. their sensitivity and adaptive capacity).

2. Explore local perceptions and experiences of climate variability and change, based on the assumption that households' willingness to adapt and their adaptation responses may be influenced more by the changes they perceive than the actual climate trends, and that understanding households' perceptions, and the factors that shape them, may help in the design and targeting of climate change communications and interventions.

3. Investigate households' broader vulnerability context, specifically the nature and prevalence of unanticipated shocks experienced, including natural hazards, and to explore whether certain groups are more vulnerable than others.

4. Better understand households' existing capacity to respond to stressors, , taking households' past coping responses to unanticipated shocks, and their existing capital portfolio, as a reflection of their adaptive capacity. Related to this, the study seeks to determine whether households' existing coping strategies are implemented selectively or

arbitrarily, irrespective of the shock experienced, the location of the household, and the households' socio-economic and socio-demographic characteristics. It is assumed that this improved understanding of households' past responses, their existing coping options, and how they combine and protect these strategies, will provide insights into how best to enhance households' ability to cope and adapt.

5. Explore the safety-net function of provisioning services in relation to other coping strategies, and to assess whether these provisioning services are used by all households irrespective of their asset based because they are free and easily obtainable.

6. To explore the role of wild foods in rural livelihoods, particularly with respect to their role in supporting households on a daily basis compared to period of increased vulnerability. Given increasing evidence of widespread consumption of wild foods, and in light of expectations of the contribution of wild foods to sustainable and climate-resilient livelihoods, their contribution to household diets requires a more nuanced understanding. This includes better understanding the role of wild foods during periods of food scarcity related to seasonal shortfalls and climate-related shocks.

Box 4: Review of research articles addressing the climate-related risk of rural households in Southern Africa

Using Science Direct, a literature review was conducted of research articles published since the release of IPCC's 5th Assessment Report (i.e. from 2015 onwards). The search considered articles for each of the 10 Southern African countries, using the country name and the terms "IPCC", "climate change", "vulnerability", "adaptive capacity", "rural" and "household". The initial search revealed 177 articles, across the 10 countries (Table B4.1). See Appendix 1 for the detailed list.

Table B4.1: Number of research articles per country, with the number in brackets indicating the number of articles which include a local-level study in the country in question

Country	**# Research Articles**	**Country**	**# Research Articles**
Angola	7 (0)	Namibia	9 (1)
Botswana	19 (2)	South Africa	38 (4)
Lesotho	5 (1)	Swaziland	5 (0)
Malawi	20 (4)	Zimbabwe	28 (2)
Mozambique	30 (2)	Zambia	16 (4)
Total			**177**

Having compiled the initial list, the 177 papers were assessed to determine whether the study actually took place in at least one of the 10 countries and whether data were collected at the local level (i.e. the sample included interviews or focus group discussions (FDGs) with respondents at the local level). A number of papers were duplicated across the 10 countries. For example, the paper by Makondo et al. (2018) was listed in the searches for Botswana, Malawi, Mozambique, Namibia, South Africa, Zambia and Zimbabwe, with the research itself conducted in Zambia. Several articles mentioned these countries in-text but did not involve research in the countries themselves. For example, although the paper by Hasan & Kumar (2019) was listed in the search for Mozambique, the research took place in Bangladesh. Articles which included an urban sample (e.g. Mitchell et al. (2015)) or which did not include local-level data collection through household surveys, FGDs, etc. (e.g. Lin et al. (2016)) were also removed. Ultimately, all but 17 papers were removed from the list. See Table B4.1 as well as Appendix 1 (including Table A1-1) for details. Four of the 17 studies included local-level research in South Africa (Appendix 1).

For South Africa, the search was then expanded to include papers published since the release of the IPCC's 4th Assessment Report (i.e. from 2008 onwards). Again, each paper was assessed to determine whether the study sample included rural stakeholders. Two additional papers were identified. The six South African studies are detailed in Table B4.2. Of the six studies, only four include household survey data.

Box 4 continued…

Table B4.2: Research articles including the terms "South Africa", "IPCC", "climate change", "vulnerability", "adaptive capacity", "rural" and "household", published since the release of the IPCC's 4th Assessment Report in 2008. These are listed, in chronological order, from the most to least recent. Although all six studies included local-level data collection, the studies by Elum et al. (2017) and Senyolo et al. (2018) did not involve household interviews.

Article Details	Study Site, Sample & Data Collection Method
1. Radingoana, M.P., Dube, T., Mollel, M.H.N. & Letsoalo, J.M. (2019) Perceptions on greywater reuse for home gardening activities in two rural village of Fetakgomo Local Municipality, South Africa. *Physics and Chemistry of the Earth, Parts A/B/C*, 112: 21-27.	182 HH from 2 villages in Limpopo Province. Data collected via mixed-method approach, including HH surveys.
2. Senyolo, M.P., Long, T.B., Blok, V. & Omta, O. (2018) How the characteristics of innovations impact their adoption: An exploration of climate-smart agricultural innovations in South Africa. *Journal of Cleaner Production*, 172: 3825-3840.	Interviews with various climate-smart agriculture experts and stakeholders in South Africa
3. Elum, Z.A., Modise, D.M. & Marr, A. (2017) Farmer's perception of climate change and responsive strategies in three selected provinces of South Africa. *Climate Risk Management*, 16: 246-257.	150 randomly selected cabbage and potato farmers from various communities in Gauteng, Limpopo and Mpumalanga provinces. Data collected via a structured questionnaire.
4. Ofoegbu, C., Chirwa, P.W., Francis, J. & Babalola, F.D. (2016) Assessing forest-based rural communities' adaptive capacity and coping strategies for climate variability and change: The case of Vhembe district in South Africa. *Environmental Development*, 18: 36-51.	366 HH from 21 rural communities in the Vhembe District Municipality of Limpopo Province. Data collected via a HH survey.
5. Leyk, S., Maclaurin, G.J., Hunter, L.M., Nawrotzki, R., Twine, W., Collinson, M. & Erasmus, B. (2012) Spatially and temporally varying associations between temporary outmigration and natural resource availability in resource-dependent rural communities in South Africa: A modeling framework. *Applied Geography*, 34: 559-568.	9374 HH from 21 villages in Mpumalanga Province. Data collected via a demographic survey, at the HH-level.
6. Bryan, E., Deressa, T.T., Gbetibouo, G.A. & Ringler, C. (2009) Adaptation to climate change in Ethiopia and South Africa: options and constraints. *Environmental Science & Policy*, 12(4): 413-426.	800 HH from 19 districts across 4 provinces (Gauteng, Limpopo, Mpumalanga & Northwest). Data collected via a HH survey.

1.3. Structure and Outputs of the Thesis

Apart from the General Introduction (Chapter 1), General Methods and Description of the Study Sites (Chapter 2) and Synthesis and General Discussion (Chapter 7) chapters, the individual thesis chapters have been compiled with the intention of submitting them to scientific journals. Chapters 3-6 have been written as stand-alone papers and formatted differently, depending on the requirements of the selected journals. Chapter 3 has been submitted to the journal Weather, Climate, and Society. Chapter 4 has been formatted for Regional Environmental Change. Chapter 5 has been submitted to the Journal of Rural Studies while Chapter 6 has been published in the journal Human Ecology. With respect to the latter, the published article has been copied into this document, with the original formatting. Chapters 1, 2 and 7 have been formatted in accordance with the requirements of the University of the Witwatersrand's Faculty of Science. When writing a thesis by paper, repetition between the chapters is unavoidable, particularly with respect to those sections which describe the selected study areas and the methods used.

The section below provides an overview of the four results chapters (Chapters 3-6), outlining the context, and aims and objectives, of each chapter.

Chapter 3: Heterogeneity of climate risk profiles among households in two rural villages in Limpopo, South Africa

This chapter explores the heterogeneity of climate-related risk amongst rural households in dryland systems, based on the assumption that better understanding this risk, both within and between communities, is important for the design, implementation and monitoring of interventions aimed at reducing this risk (Kok et al. 2016). This includes interventions which support households' own efforts to manage and reduce climate-related risk. Using a cluster-based approach, this chapter identified differentiated, archetypical, household-level climate-risk profiles, based on combinations of indicators related to climate hazards, exposure, vulnerability, and impacts. The identified profiles were evaluated, based on the assumption that, i.) if they differ substantially between the two selected study sites, then adaptation interventions need to be site-specific, and ii.) if they are similar, then interventions can be applied more broadly across sites, but may have to be adjusted depending on specific household characteristics.

This chapter has been accepted for publication in the Journal of Rural Studies

Chapter 4: Perceptions of climate change in rural South Africa: Cognitive biases and the influence of household characteristics and location

This chapter considers local perceptions and experiences of climate change and variability in rural South Africa, based on the assumption that these perceptions, and the factors that shape them, may influence local adaptation responses. Understanding these perceptions and influencing factors, may support the design and targeting of climate change communications and interventions (Cooper et al. 2008; Hitayezu et al. 2017). To contribute towards this improved understanding, this chapter explores the experiences and perceptions of climate change of two rural communities, focusing on climate-related shocks and long-term precipitation and temperature trends. The specific objectives of the chapter are to, i.) assess whether local-level perceptions of climate change and variability reflect the meteorological data; ii.) explore whether these perceptions are uniform, or whether people within the same community, and between the two communities, perceive climate change and variability differently; and iii.) to consider possible explanations for any divergences, both between the perceptions and the meteorological data, and between the perceptions themselves.

Chapter 5: Prepare for the unanticipated: Portfolios of coping strategies of rural households facing diverse shocks

This chapter considers rural households' broader vulnerability context by investigating the nature and prevalence of unanticipated shocks. It explores the diversity of coping strategies used in response to these shocks based on the null hypothesis that households apply these strategies randomly, irrespective of the shock in question, the households' location, and their socio-demographic and economic characteristics. There has been a renewed interest in households' existing informal coping options, and the role they do, and can play, in enhancing households' adaptive capacity (Eriksen & Silva 2009; Hänke & Barkmann 2017; Castells-Quintana et al. 2018). Mosaic plots were used to highlight associations between the identified shocks and coping strategies. A multivariate analysis was used to explore whether the adoption of a particular strategy was influenced by explanatory variables related to site and/or household characteristics. The various coping strategies were considered in terms of their limitations to buffering households against covariate, climate-related shocks.

This chapter has been accepted for publication in the journal Weather, Climate, and Society.

Chapter 6: Wild Foods: Safety Net or Poverty Trap? A South African Case Study

This chapter focuses on the safety-net role of wild foods during periods of food scarcity, related to seasonal shortfalls and climate-related shocks. Given the expectations of the contribution of wild foods to sustainable and climate-resilient livelihoods, their contribution to households' diets requires a more nuanced understanding. Despite their widespread use, questions remain on the exact function of wild foods, particularly with respect to their role in supporting rural households on a daily basis compared to periods of increased vulnerability (Bharucha & Pretty 2010). To contribute towards this understanding, this chapter explores the extent of wild food consumption and sale and whether this is influenced by location and household characteristics. Archetypes of wild food users were defined by clustering households based on the frequency with which they consumed wild foods during three food availability periods: i.) when food is plentiful (e.g. after the harvest), ii.) when food is scarce (e.g. during seasonal crop shortfalls), and iii.) during "hungry periods" (e.g. during drought and unanticipated crop failure). Households' perceptions of the importance of the safety-net function of wild foods were explored.

This chapter has been published: Paumgarten, F., Locatelli, B. & Witkowski, E.T.F. 2018. Wild foods: Safety net or poverty trap? A South African case study. *Human Ecology* 46(2):183-195

Chapter 7 presents and discusses the key findings of each chapter, highlighting implications for policy and practice, and identifies areas for future research.

In terms of author contributions, each of the core content chapters have involved collaboration with, and guidance from, my two supervisors (Prof. Ed Witkowski and Dr. Bruno Locatelli). They are included as co-authors on all four papers. Additionally, Chapters 4 and 5 included collaborations with Dr. Catherine Van den Hoof (Chapter 4) and Prof. Coleen Vogel (Chapter 5). In terms of their specific contributions, Dr. Van den Hoof contributed towards the analysis of the meteorological data for Chapter 4. She also provided guidance and feedback on the chapter's draft versions. Prof. Vogel provided feedback on the draft version of Chapter 5.

In addition to the four results chapters outlined above, various preliminary findings were presented at the fora detailed below[4].

1. *Programme on Ecosystem Change and Society (PECS) 2015 Conference: Social-ecological dynamics in the Anthropocene*
   (3-5 November 2015, Spier Wine Estate, Stellenbosch)
   Oral presentation: Exploring the role of provisioning services in households' response to vulnerability in the dry woodlands of Venda, South Africa

2. *8th ESP (Ecosystem Services Partnership) World Conference: Ecosystem Services for Nature, People and Prosperity*
   (9-13 November 2015, Spier Wine Estate, Stellenbosch)
   Oral presentation: Exploring the role of provisioning services in households’ response to vulnerability in the dry woodlands of Venda, South Africa

3. *Joint SAAB/SASSB Conference 2016*
   (10-13 January 2016; University of the Free State, Bloemfontein)
   Oral presentation: Exploring the role of provisioning services in households' response to vulnerability in the dry woodlands of Venda, South Africa

4. *Sustainable Rural Development Network Colloquium*
   (25-26 April 2016, Wits Rural Facility, Mpumalanga - joint colloquium hosted by the Knowledge Hub for Rural Development (Wits Rural Facility) and the Institute for Rural Development (University of Venda))
   Oral presentation: Exploring the role of provisioning services in households' response to vulnerability in the dry woodlands of Venda, South Africa

5. *2nd Southern African Adaptation Colloquium: Solution Spaces and Futures, Learning Together in a Climate Challenged World*
   (7-8 July 2016, University of the Witwatersrand, Johannesburg)
   Oral presentation: Exploring the role of provisioning services in households’ response to vulnerability in dry woodlands of Venda, South Africa

6. *3rd International Conference on Global Food Security*

[4] Although the various presentations have the same title, different components of the research were presented in each case.

(3-6 December 2017, Cape Town International Convention Centre, Cape Town)
Oral presentation: Can land-based livelihood continue to contribute to household food security given current challenges and prospective climate change? A perception-based analysis
Poster presentation: Wild foods in Venda, South Africa. Improving rural food security or increasing households’ vulnerability to climate change?

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CHAPTER 2

General Methods and Description of the Study Sites

2.1. General Methods and Description of Study Sites

The research adopted a comparative case study approach using two villages located in South Africa's Limpopo Province, the country's northern-most province. Local case studies are recognised as a key form of social science inquiry, used because they generate valuable knowledge and an in-depth understanding of a limited number of cases (Sietz et al. 2011; Yin 2012). Yin 2012 (pg. 4) notes that "case study research assumes that examining the context and other complex conditions related to the case(s) being studied are integral to understanding the case(s)". For this reason, Sietz et al. (2011) suggest that local case studies are a valuable tool for understanding the vulnerability contexts of dryland social-ecological systems. A case study approach allows for an in-depth empirical inquiry into contemporary phenomena, within their real-life context, relying on multiple sources of evidence for the purpose of triangulation (Yin 2012). As with other research tools, there are disadvantages to a case study approach (Yin 2009). A key concern is that the findings of local case studies are specific to the selected context, making generalisations and upscaling difficult (Sietz et al. 2011). While there are advantages to the detailed focus on the local context, the influence of broader-scale factors receives less attention. There are also concerns over a lack of rigor and the potential biases of the researcher (Yin 2012). Although we recognise the limitations of this case study approach, it was considered appropriate for addressing our specific research objectives, whilst still providing more broadly relevant insights. Ultimately, each research tool has opportunities and constraints associated with it (Yin 2009).

This chapter gives an overview of the general methods and provides details on the selected study sites. Additional information on the methods and the study sites can be found in the respective results chapters (Chapters 3-6) and in the Appendices.

2.1.1. Methods

A range of methods was employed in an interdisciplinary approach, with each method intended to compliment the other, allowing for triangulation of the data. Both qualitative and quantitative data were collected. Traditionally, qualitative and quantitative methods have been seen as providing opposing viewpoints, however there are a number of advantages to a mixed-methods approach: i.) it gives a voice to the study's participants and allows for interaction between the researcher and the participants; ii.) it provides for the collection of comprehensive, contextual data; and iii. it allows for the triangulation of the results (Bryman

2012). Mixed-methods research does however have limitations. It can be complex, costly, and time-consuming. There is also the risk of discrepancies arising in the interpretation of the findings. This choice of methods was selected based on my previous experiences with mixed-methods research, and because to begin to understand household vulnerabilities and responses to climatic and socio-economic stressors, it is important to have as detailed an understanding of the local context as possible.

The field research consisted of two core components: a participatory rural appraisal (PRA), conducted through a series of community workshops, and semi-structured household interviews. These were complemented by key informant interviews, informal discussions and personal observations which added to our overall understanding of the context and supported our overall interpretation and presentation of the results. Before commencing with the fieldwork, an introduction and ground-proofing process was carried out. Permission to conduct the research was gained from the relevant authorities, including the chief of each village. The selection of the study sites was influenced by the communities' willingness to participate in the research. All ethical standards of the host institution were adhered to, including receiving free, prior, and informed consent from all participants. Prior to the initiation of the fieldwork, a team of enumerators/facilitators was selected and trained on the different methods. This team assisted with both the community workshops and the household interviews, which allowed for the PRA exercises and interviews to be conducted in the local language. Although there are advantages to being able to conduct research in the local language, there is the risk of information getting "lost in translation" and of introducing additional biases into the mix (i.e. not just any potential biases of the researcher). It also assumes that the translators themselves fully understand the research content.

Participatory Rural Appraisal (PRA) – Community Workshops

The research included a large PRA component, conducted through a series of voluntary community workshops. The community was informed of these workshops at an introductory meeting held prior to the initiation of the fieldwork. Participation was open to anyone in the community however the initial group of participants was encouraged to attend each of the subsequent workshops to allow us to build on discussions. The number of participants varied somewhat, depending on people's availability, but consisted, on average of 20 people in each village. The group included both men and women of different ages. The workshops were held in each village, with the support of the local leadership. They ran over several days but were not necessarily held on consecutive days, recognising the participants' other commitments. Only half-day workshops were organised to avoid participant fatigue.

The PRA included exercises designed to support discussion, reflection and interaction on local livelihoods, vulnerabilities, and the communities' existing capacity to cope and adapt (Kleine et al. 2010). The PRA guideline (Appendix 2) was compiled using existing participatory capacity and vulnerability analysis tools, including those developed by CARE (Dáze et al. 2009) and OXFAM (Turnbull & Turvill 2012). The exercises are described in detail in Appendix 2 and summarised below. Each exercise was followed by a discussion session to gain further insights into the respective communities (Fig. 1).

- A community mapping exercise was used to define the area of the respective villages and to generate insights into elements of peoples' lives. Participants were asked to draw their landscape, indicating areas used for settlement, arable agriculture, grazing and the collection of non-timber forest products (NTFPs); water collection points; existing services such as road networks and schools, and so forth (Appendix 3).
- A seasonal calendar exercise was used to gather information on seasonal variations in the main livelihood activities, and other opportunities and challenges which impact local livelihoods over the course of a year (Theis & Grady 1991) (Appendices 2 & 4). Seasonal calendars are useful tools for highlighting correlations between different variables (Theis & Grady 1991).
- A time trend exercise was conducted, using pre-selected variables related to climate, livelihoods, etc., to show changes over time (Theis & Grady 1991) (Appendix 2). The exercise focused on changes and trends experienced over the different decades since each village was established. This exercise allowed for discussions on (perceived) climate variability and change.
- Historical profiles were used to explore key historical events, including natural hazards, which have had a significant impact on livelihoods (Theis & Grady 1991) (Appendix 5). Although these profiles focused on isolated events, they were intended to complement the time trend exercise by highlighting any patterns, or changes, in the occurrence of extreme events (Dáze et al. 2009; Turnbull & Turvil 2012).
- An impact chain exercise was conducted to identify the direct and indirect impacts of natural hazards, specifically droughts and floods, on both the natural and human

systems (Dáze et al. 2009; Turnbull & Turvil 2012) (Appendix 6). Participants were asked to consider how their livelihood strategies and assets were impacted and whether certain groups were worse affected.

- A problem tree exercise was used to explore why the communities were negatively affected by droughts and floods, with the aim of identifying the root causes of vulnerability and poverty (Turnbull & Turvil 2012) (Appendix 7).

Although the seasonal calendar, time trend and historical profile exercises considered the communities' broader vulnerability context, they also allowed for more specific and detailed discussions on climate variability and change, the livelihood impacts associated with this, how households (and the broader community) have coped in the past, and what measures might reduce these impacts in the future. The impact chain and problem tree exercises focused more specifically on droughts and floods and allowed for more detailed discussions on how the communities have, and could, minimise the associated impacts. Participants were asked to discuss a range of response strategies, however the safety-net function of NTFPs was considered in greater detail. In particular, we explored the safety-net function of wild foods. The strengths and weaknesses of the respective response strategies were explored.

Household Survey

A semi-structured household survey was administered to 170 randomly selected households (Appendix 8). A household was classified as a unit of people residing together, sharing meals. Eighty-five households were interviewed per village, constituting a quarter of each villages' total number of households. Each village was subdivided into four sections, based on the community-mapping exercise conducted in the workshops, and an approximately equal number of households was interviewed in each section. Wherever possible, the household head was interviewed. Where the household head was unavailable, another well-informed, resident adult was interviewed. The interviews were voluntary. Those who participated were requested to sign a formal consent form, in which anonymity was assured. The interviews were conducted in the local language with the assistance of the trained enumerators. Given the length of the interview schedule, it was split into two parts, with each household interviewed twice. The second part of each interview was conducted on a different fieldtrip, which allowed the researcher to first assess each of the original interviews.

Following a livelihoods approach, the survey sought to gather data on households' socio-demographic and -economic characteristics, including their engagement in land-based and off-farm livelihood strategies; on households' capital portfolio (i.e. financial, physical, human, natural and social capital (DFID 1999)); on their experience of a range of shocks (including climate-related hazards); on households' perceptions of climate variability and change; and on households existing coping strategies.

The design of the survey drew from existing vulnerability assessments which propose a range of quantitative and semi-quantitative metrics and proxy indicators to describe different components of vulnerability in coupled social-ecological systems (e.g. Luers et al. 2003; Hahn et al. 2009). Bearing in mind that weak, or rosy, historical recall (retrospection) is a fundamental challenge when researching past events, the household survey only focused on the preceding five years. The PRA exercises were used to explore a longer timeframe.

Key Informant Interviews

Key informant interviews were conducted with local elders, traditional leaders, local farmers, livestock owners, traditional healers, and with the agricultural extension officers responsible for each site. The interviews were fairly informal, intended to support the household survey and PRA data, and to establish the overall context of the two sites.

Data Collation and Analysis

The various data were collated and analysed with the purpose of addressing the aims and objectives of the research. The quantitative data were entered into Excel and analysed using the programme "R" ("The R Project for Statistical Computing"). Where relevant, the qualitative data were coded and analysed. Each results' chapter provides more detail on the specific analysis tools used.

For Chapter 6 ("*Wild Foods: Safety Net or Poverty Trap? A South African Case Study*"), wild food species recorded in the local vernacular were translated into their botanical and English names using existing studies by Mabogo (1990), Nesamvuni et al. (2001) and Maanda and Bhat (2010).

Fig. 1: Various PRA exercises were conducted in community workshops in each village (a & d), including community mapping (b), seasonal calendar (c) and impact chain exercises (e & f)

2.1.2. The Study Sites

Description of the General Context

Two study sites were selected in South Africa's Limpopo Province (Fig. 2). The province is divided into five district municipalities, each of which is sub-divided into local municipalities (DNS 2011). The two study sites, located approximately 90 km apart, fall within the Vhembe District Municipality although they are in neighbouring local municipalities. Bennde Mutale (31°1'48"E; 22°24'14"S) is in the Mutale Local Municipality[5] while Vondo (30°21'60"E; 22°56'5"S) is in the Thulamela Local Municipality. More than 85% of the population of these local municipalities reside in "tribal areas", defined by Statistics South Africa (SSA) as non-urban areas which fall under the domain of a tribal authority (SSA 1998). Governance in these areas is therefore coordinated between the different tiers of government and the tribal authorities.

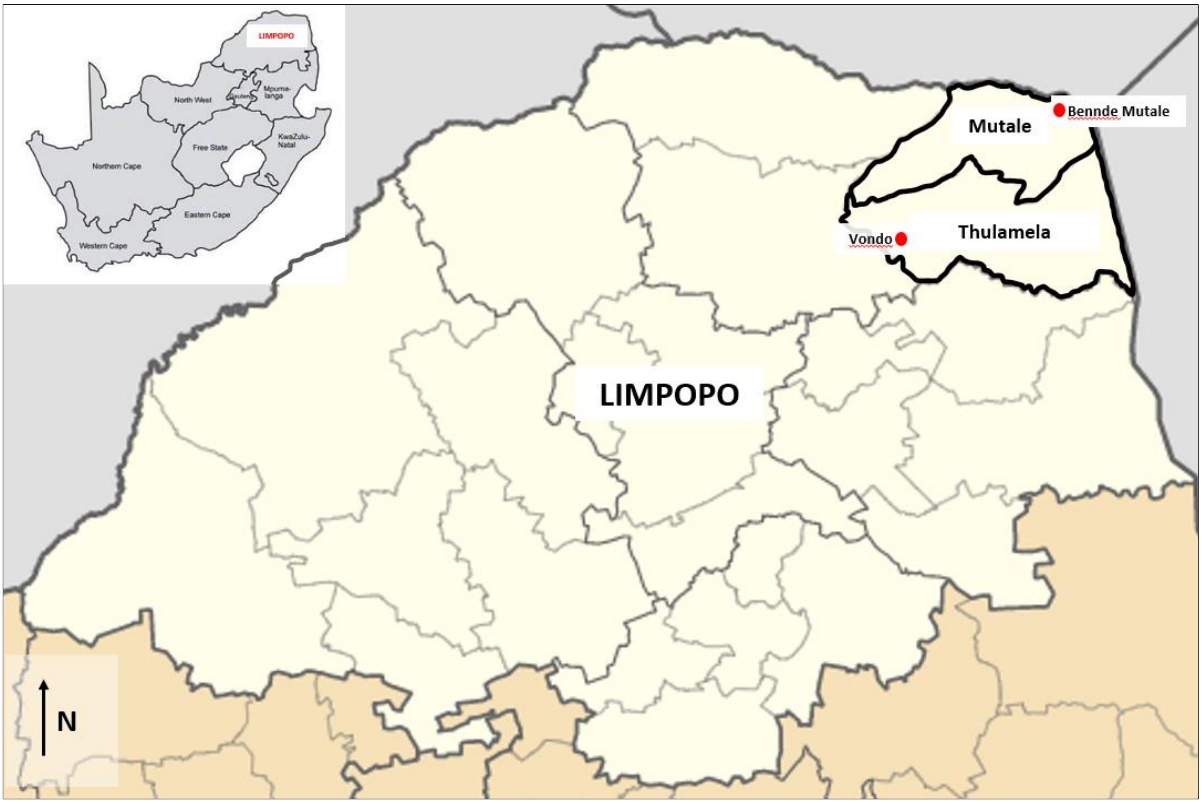

Fig. 2: Location of the study sites – Bennde Mutale and Vondo - located respectively in the Mutale and Thulamela local municipalities of South Africa's Limpopo Province

[5] The Mutale Local Municipality has subsequently been disestablished and merged into the Musina Local Municipality. I still refer to Mutale here, and present data for this previous local municipality, as the merger only occurred after South Africa's last national census (2011) and after the completion of the fieldwork.

Human systems are often “geographically heterogeneous”, with differences in exposure and vulnerability influenced by climatic and non-climatic factors, and by inequalities resulting from distorted development processes (IPCC 2014). In the South African context, this “geographical heterogeneity” has been influenced by the country’s historical Apartheid policies which established ten territories (“homelands”) for the re-settlement of black South Africans (Thornton 2002). Prior to South Africa’s demographic transition, most of the Vhembe District Municipality fell within the former Venda homeland[6]. These former homeland areas remain characterized by limited development, poor service provision, low education levels, high dependency ratios, and high unemployment rates (SSA 2014; Ofoegbu et al. 2016) (Table 1). Although the living conditions in both the Mutale and Thulamela local municipalities have improved post-Apartheid, including improved access to formal dwellings, electricity and potable water, fuelwood remains the primary source of energy for cooking, piped water inside the dwellings is limited, and pit toilets are still prevalent (Table 1). Lack of access to safe drinking water exacerbated a cholera outbreak in 2008/09, which spread from neighbouring Zimbabwe, and resulted in the provincial government declaring Vhembe District Municipality a disaster area (Mudau et al. 2017).

[6] These homeland areas were re-incorporated into South Africa in 1994 (https://www.sahistory.org.za/article/homelands)

Table 1: Profiles of the Mutale and Thulamela local municipalities (Source: SSA 2013)

Attribute	Mutale	Thulamela
Dependency ratio (per 100: 15-64)	79.9	70.1
Population under 15 years (youth) (%)	38.2	35.2
Population density (persons/km^2)	24	106
Average household size	3.8	3.9
Female-headed households (%)	54.8	54.4
Living conditions:		
Formal dwellings (%)	87.3	85.7
Electricity for lighting (%)	83.3	87.2
Fuelwood for cooking (%)	81.3	67.1
Piped water inside dwelling (%)	5.8	15.2
Pit toilet (%)	92.6	73.7
Highest education level (all ages):		
Some primary schooling (%)	45.5	42.7
Completed secondary school (%)	6.8	9.6
Higher education (%)	1.1	1.9
Unemployment rate (official) (%)	48.8	43.8
Youth unemployment rate (official) 15-34 (%)	62.2	58.3
Average household income (per annum):		
None (%)	13.2	11.9
R1 - R4,800 (%)	8.9	8.9
R4,801 - R9,600 (%)	17.5	16.4
R9,601 - R19,600 (%)	24.0	23.9
R19,601 - R38,200 (%)	19.1	19.8
>R38,201 (%)	17.3	19.1
Agricultural households:		
Livestock & poultry (%)	50.6	34.2
Vegetables & other crops (%)	45.1	61.1
Other (%)	4.3	4.7

Limpopo is one of South Africa's poorest provinces, with an economy driven by primary industries such as mining, forestry, agriculture, cattle ranching, and hunting (SSA 2014).

Almost 80% of the province's population, and over 80% of the households in the Mutale and Thulamela local municipalities, live below the poverty line[7] (LEDET n.d.). In both municipalities, most households are engaged in, or derive an income from, subsistence or commercial agriculture (SSA 2014; Maponya & Mpandeli 2015). However, many households diversify their livelihood strategies in an effort to secure their livelihood outcomes (Venter & Witkowski 2013; Ofoegbu et al. 2016). As local employment opportunities are limited, people migrate in search of work resulting in a high proportion of female-headed households (Table 1) (SSA 2014; Ofoegbu et al. 2016). State welfare grants also make a key contribution to household income (Venter & Witkowski 2013; Ofoegbu et al. 2016). Limited access to productive land and assets, variable (and often extreme) weather conditions, limited external support, increasing living costs, food insecurity, and a high incidence of HIV/Aids all undermine livelihood security (Drimie & Gillespie 2010; Venter & Witkowski 2013; Murugani et al. 2014; Maponya & Mpandeli 2015; Ofoegbu et al. 2016). Female-headed households face particular constraints, including cultural traditions which restrict women's access to and control over productive resources such as land, natural resources, etc. (Shackleton et al. 2011; Maponya & Mpandeli 2015). The younger generation face limited livelihood options (Maponya & Mpandeli 2015). Climate change is expected to exacerbate households' existing levels of uncertainty and vulnerability (Gbetibouo et al. 2010; IPCC 2014; Elum et al. 2017).

Climate change is likely to result in decreasing rainfall, an increasingly unpredictable rainy season, and increasing temperatures (Gbetibouo et al. 2010; Rakgase & Norris 2015). Projections for the Vhembe District include a 1-3°C increase in temperature and a 5-10% reduction in rainfall by the mid-21st century (Turpie & Visser 2013). Natural hazards, particularly droughts and floods, are expected to have increasingly adverse effects, particularly for small-scale, subsistence farmers (LEDET n.d; Maponya & Mpandeli 2015). Previous severe droughts, in 1981, 1988/89, 1991/92, 2004/05 and 2014/15 had significant negative impacts on crop and livestock production, and consequently on food security and livelihoods in general (Mpandeli et al. 2015; Elum et al. 2017; Senyolo et al. 2018). According to Limpopo's Provincial Climate Change Response Strategy (2016-2020), the province's rural areas face high levels of climate-related risk given their dependence on rain-fed agriculture, low economic development, poor infrastructure, and limited adaptive

[7] Based on the World Bank's international poverty line of USD 1.90/day

capacity (LEDET n.d). Low levels of human and physical capital are a particular challenge (LEDET n.d.). For poor, rural households in these areas, who depend, to a large extent, on land-based livelihoods and ecosystem goods and services, the risk of climate change impacts is particularly high (Shewmake 2008; Drimie & Gillespie 2010; Gbetibouo et al. 2010; Drimie & McLachlan 2013; Turpie & Visser 2013; Shisana et al. 2014; Thivhafuni 2015; Senyolo et al. 2018). Within these rural communities, already marginalised groups are likely to be worst affected.

Detailed Profiles of the Selected Sites

- *Biophysical characteristics*

The site selection was based primarily on differences in mean climate, particularly mean annual precipitation (MAP), and in the site's agro-ecological conditions (Funk et al. 2015; IFPRI 2015). The two sites, separated by the Soutpansberg Mountain Range, differ in terms of agro-ecological zone (AEZ), climate zone, mean annual precipitation, mean annual temperature, elevation, and dominant vegetation type. Bennde Mutale falls within an arid AEZ and in a climate zone described as "*Arid, Desert, Hot arid*" (see Fig. 3) (IFPRI 2015; StepSA 2015). Vondo falls within a semi-arid AEZ and in climate zone described as "*Warm temperate, Winter dry, Hot summer*" (see Fig. 3) (IFPRI 2015; StepSA 2015). Although both sites experience a summer rainy season, Bennde Mutale's MAP (for the period 1981-2014) was 402 ± 141mm compared to Vondo's 1108 ± 371mm (Funk et al. 2015). Bennde Mutale's mean annual temperature, for the same period, was 24.7°C compared to 19.0°C for Vondo (Funk et al. 2015). Both sites experience a cooler, dry winter. The elevation at Bennde is 308m. Vondo is considerably higher at 1022m.

The dominant vegetation type differs between the two sites. Bennde Mutale is characterised by a mix of *Musina Mopane Bushveld* and *Makuleke Sandy Bushveld* while Vondo is characterised by *Soutpansberg Mountain Bushveld* (Mucina & Rutherford 2011). The *Musina Mopane Bushveld* is dominated by *Combretum apiculatum,* by both *Terminalia prunioides* and T. *sericea,* and by *Colophospermum mopane,* with the latter being the primary food source of mopane worms (*Gonimbrasia belina*). Edible fruit-bearing trees, such as *Adansonia digitata* and *Sclerocarya birrea* subsp. *caffra* are important taxa in this vegetation type (Mucina & Rutherford 2011). The *Makuleke Sandy Bushveld* is dominated by species such as *Burkea africana* and *Kirkia acuminate* (Mucina & Rutherford 2011). Important taxa include species such as *Senna petersiana* and *Hexalobus monopetalus*, both of which have edible fruit. The *Soutpansberg Mountain Bushveld* comprises of a complex mosaic of vegetation (Mucina & Rutherford 2011) but includes important taxa such as *Strychnos madagascariensis* and *Englerophytum magalismontanum*, both of which have edible fruit.

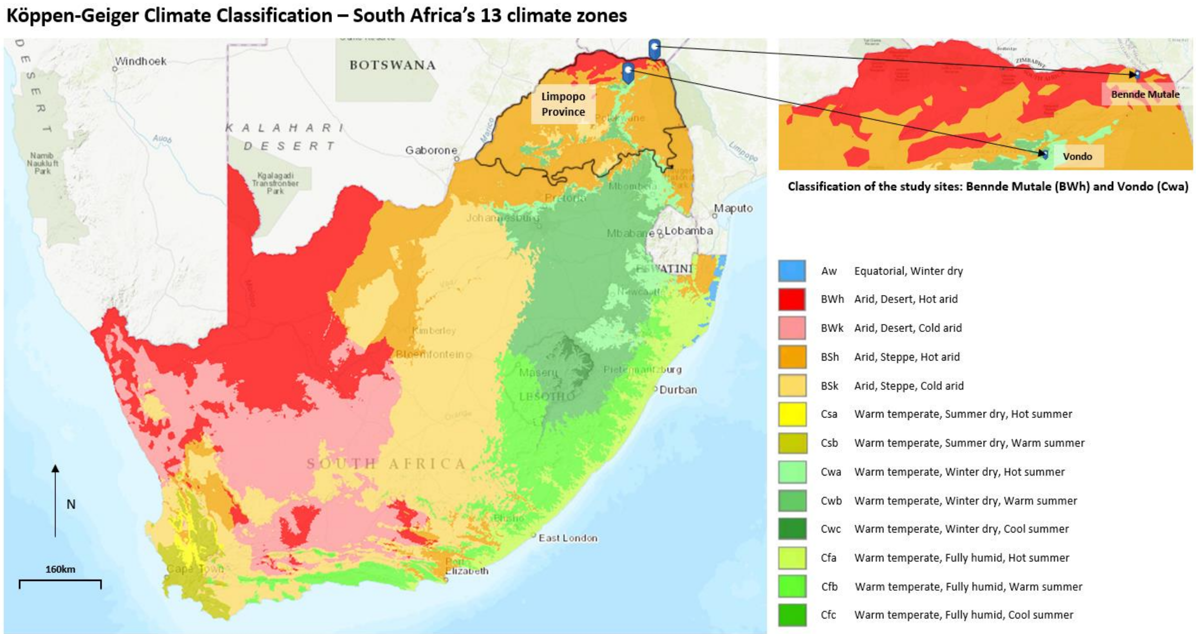

Fig. 3: Köppen-Geiger Climate Classification showing South Africa's 13 climate zones, and the location of the two study sites, with Bennde Mutale located in zone BWh and Vondo in zone Cwa (StepSA 2015)

The primary land uses also differ between the sites, with animal husbandry being more prevalent in drier Bennde Mutale and crop production in wetter Vondo (SSA 2014) (Table 2). Bennde Mutale is bordered by communal rangelands, neighbouring communities, the Kruger National Park, and the Madimbo military corridor, and is delineated by the Mutale River in the south (Appendix 3). The Madimbo corridor separates Bennde Mutale from the Limpopo River, South Africa's northern border with Zimbabwe. Both the establishment of the Kruger National Park and the Madimbo corridor were associated with a number of forced removals, and subsequent disputes over who has rights to the land (Steenkamp & Uhr 2000). Vondo is surrounded by pine and tea plantations, and neighbouring communities, with land set aside for settlement and for the cultivation of various cash and tree crops. Vondo is delineated by the Mutshindudi River in the south-east (Appendix 3). Given the area's better agro-ecological conditions, and the higher population density of the Thulamela Local Municipality, the residents of Vondo have less access to unconverted land. Vondo covers an approximate area of 4.4 km^2 while Bennde Mutale covers an area of 10.1 km^2. Land in both villages is communally owned.

Although the two sites fall within different climate zones (Fig. 3), both sites experience natural hazards, including floods and droughts, although respondents indicated that these are more severe in Bennde Mutale (workshops). Floods are associated with erosion and landslides, crop and livestock losses, and increases in water-borne diseases (e.g. malaria and cholera) (Appendices 6 & 7). Damage to infrastructure, including houses, fences, irrigation equipment, electricity poles, roads, and bridges, was also reported with respondents attributing this to poor spatial planning and the use of inferior construction materials. Drought is also associated with crop and livestock losses, resulting in hunger and malnutrition. Natural water sources dry up and NTFP availability declines. Negative impacts were also associated with heavy winds and hailstorms.

- *Socio-economic and political characteristics*

Bennde Mutale and Vondo are similarly sized villages, consisting of 327 and 340 households respectively (Figs. 4 & 5). Both villages are remote, particularly Bennde Mutale, and can be considered as representative of their neighbouring communities. This remoteness limits access to services (e.g. banks, formal credit institutions, extension support) and to both input and output markets. Residents of Bennde Mutale have to travel approximately 20 km to get to the nearest small town of Masisi. Larger commercial centres include Thohoyandou (95 km) and Musina (118 km). Vondo residents have access to the small town of Phiphidi (5 km), and to the larger centres of Sibasa (13 km) and Thohoyandou (15 km). Thohoyandou is the closest large commercial and administrative centre to both sites. Although the main route to both villages is tarred, the internal roads are dirt. Vondo can be difficult to access during the summer, when heavy rains make the village's steep, dirt roads impassable. Limited access to transport also restricts residents' ease of movement.

Households in both villages engage in a mix of off-farm and land-based livelihood strategies (Table 3). Over 80% of households in both sites receive at least one government grant (i.e. an old-age pension, a child-care grant, or a disability grant). Other sources of off-farm income include wages, migrant remittances, and money earned through self-employment, although for each of these, opportunities are limited. Employment opportunities include those offered by government work programmes (e.g. the Extended Public Works Programme).

Households’ ongoing engagement in land-based livelihoods, including the collection and sale of NTFPs, influenced the selection of the study sites. Agricultural practices, including the selection of crops and livestock types, are influenced by the respective site’s agro-ecological conditions. Livestock ownership is more prevalent in Bennde Mutale. Livestock fulfils multiple functions, including an important insurance function. Arable agriculture, including the cultivation of exotic fruit trees, is more widespread in Vondo. Households cultivate a mix of home-gardens and fields, predominantly for consumption. In both sites, arable agriculture is predominantly rainfed. In Bennde Mutale, households also cultivate small, winter gardens, which they irrigate by hand (Appendix 4). A greater proportion of Vondo farmers and livestock owners sell their produce. Households in both sites rely on NTFPs, including wild foods, medicinal plants, twig brushes, thatching grass, reeds, wooden building/fencing poles and other household items, and fuelwood. The sale of NTFPs is more prevalent in Bennde Mutale. Respondents in both sites indicated a decrease in the availability and use of these NTFPs. A livelihood ranking exercise, conducted during the community workshops, highlights the site-related differences in the land-based livelihood strategies (Table 4). Land, in both communities, falls under communal tenure. The younger generation is less interested in these land-based livelihoods.

Respondents in both sites noted a number of challenges to these land-based livelihoods, including limited land; limited water; limited access to, and money for, inputs; limited access to output markets; limited extension support; insufficient and unpredictable rainfall; and labour constraints. In both sites, crops and livestock are damaged/killed by wildlife. Unpredictable rains, temperature extremes, and natural hazards all present challenges to crop and livestock production, impacting household food security. Respondents in both sites indicated an increase in the cultivation of home-gardens, particularly after severe droughts in the 1980s and 1990s, with these gardens being easier to irrigate. These droughts were also associated with severe livestock losses, with residents in Bennde Mutale subsequently shifting to more drought-tolerant goats, while those in Vondo reduced their overall livestock ownership (workshops – time trend exercises). The availability of certain NTFPs is also influenced by climate variability (including seasonality) and extremes. Natural hazards were associated with a number of other impacts (Appendix 6).

Fig. 4: Arid woodland around Bennde Mutale (a), where animal husbandry dominates (b & c). Households rely on a system of community taps (d) for multiple uses, including irrigating small home-gardens (e). Traditional homes still dominate (f) although a decreasing availability of thatching grass is driving people to use alternative building materials (g). Households still rely on a diversity of NTFPs including wild fruits (e.g. marula (h)) and edible insects (e.g. mopane worms (i).

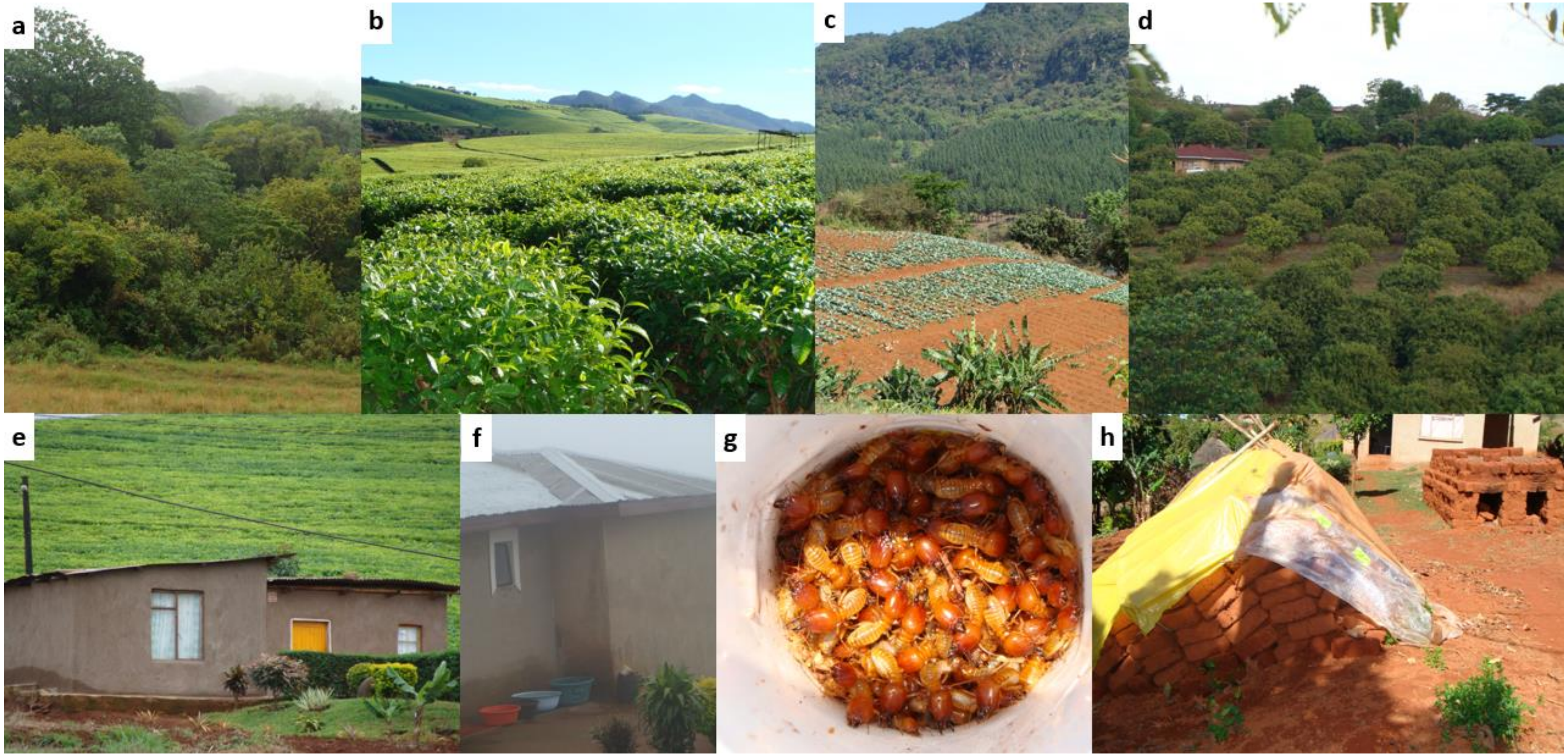

Fig. 5: *Soutpansberg Mountain Bushveld* is the dominant vegetation type in Vondo (a), however land conversion has been extensive given the good agro-ecological conditions, with land cultivated with tea (b), vegetables (c), exotic fruit trees (d), and timber (c). More modern houses allow for rainwater harvesting (e & f). Households continue to rely on natural resources including wild foods (e.g. termites) (g) and mud bricks (h).

Table 3: Village profiles - Bennde Mutale and Vondo, 85 households (HH) sampled/village

	Bennde Mutale	Vondo
Household (HH) details		
Av. HH age (years)	19.47	20.82
Av. HH size (excluding migrants)	5.33	4.71
Av. age of HH members (years)	26.26	27.43
Av. education of HH members (years)	6.22	7.17
Female-headed HH (%)	43.53	42.35
Access to infrastructure and services (% HH)		
HH with electricity	94.12	98.82
HH collecting water from communal taps	97.65	41.18
HH collecting river water	28.24	37.65
HH collecting spring water	1.18	67.06
HH storing water	97.65	95.29
HH with traditional structures (thatching grass roofs)	72.94	7.06
HH with traditional structures (mud walls)	71.76	55.29
Off-farm livelihood strategies (% HH)		
HH with formally employed members	29.41	16.47
HH with informally employed members	27.06	34.12
HH with self-employed members	9.41	9.41
HH with unemployed members	78.82	85.88
HH receiving migrant remittances	28.24	29.41
HH receiving a government grant	84.71	90.59
Land-based livelihood strategies (% HH)		
HH engaged in arable agriculture	63.53 (54 HH)	95.29 (81 HH)
HH cultivating for consumption (of farming HH)	100.00	100.00
HH cultivating for sale (of farming HH)	7.41	46.91
HH engaged in animal husbandry	61.18 (52 HH)	25.88 (22 HH)
HH keeping livestock for consumption (of livestock owners)	98.08	95.45
HH selling livestock (of livestock owners)	51.92	77.27
HH using NTFPs	100.00 (85 HH)	96.47 (82 HH)
HH selling NTFPs (of NTFP users)	65.88	3.66

Table 4: Livelihood ranking exercise

Rank	Bennde Mutale	Vondo
1st	Government grants	Fields
2nd	Local employment	Government grants
3rd	Migrant employment	Employment
4th	NTFPs	Self-employment
5th	Small stock	Gardens & migrant employment
6th	Cattle	---
7th	Self-employment	Small stock
8th	Gardens	Cattle
9th	Fields	NTFPs

Although most households in both sites have access to electricity (Table 3), fuelwood remains the primary source of energy, particularly for cooking. Neither village has a sewerage reticulation system with most households relying on pit toilets. There is no piped water within the dwellings, instead people rely on a system of communal taps and natural water sources for consumption, irrigation, and livestock. The amount and quality of water is affected by multiple users, the intermittent supply from the communal taps, and the seasonal availability of natural water sources. Although both villages lie along a river, the Mutale River, to which the Bennde Mutale's residents have access, is not perennial. Households in both sites harvest rainwater, however this is less common in Bennde Mutale, where more people still have traditionally constructed homes with grass roofs. Most households store water to ensure a more sustainable supply. The collection of both water and firewood have considerable labour costs, with respondents noting increasing challenges to finding sufficient quantities of both resources. Neither village has a clinic – people rely predominantly on mobile clinics and traditional healers. Poor access to healthcare, an increase in chronic diseases (e.g. diabetes and HIV/Aids), and food insecurity, were associated with a decline in people's health and well-being (workshops). Although both villages have a crèche and a primary school, neither has a secondary school. The leadership structures in both sites include a combination of traditional and government, with systems in place to ensure collaboration between the two. Bennde Mutale consists predominantly of people from the Tsonga and Venda tribes. Vondo consists predominantly of Vendas. More details on each site are provided in the relevant chapters and Appendices.

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CHAPTER 3

Heterogeneity of climate risk profiles among households in two rural villages in Limpopo, South Africa

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Heterogeneity of climate risk profiles among households in two rural villages in Limpopo, South Africa

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Abstract

More frequent and intense climate hazards, a predicted outcome of climate change, are likely to threaten existing livelihoods in rural communities, undermining households' capacity to cope and adapt. To support households' efforts to manage and reduce this risk, there is the need to better understand the heterogeneity of risk within and between communities. The Intergovernmental Panel on Climate Change revised their climate vulnerability framework to incorporate the concept of risk. By presenting a method for analyzing the climate-related risk of rural households, this study contributes towards the operationalization of this updated framework. Using a mixed-method approach, including a cluster analysis, it determined and assessed archetypical patterns of household risk. The approach was applied to 170 households in two villages, in different agro-ecological zones, in the Vhembe district municipality of South Africa's Limpopo Province. Six archetypical climate-risk profiles were identified based on differences in the core components of risk, namely the experience of climate hazards, the degree of exposure and vulnerability, and the associated impacts. The method's application is illustrated by interpreting the six profiles, with possible adaptation pathways suggested for each. The archetypes suggest that climate-related risk is heterogeneous, varying both between and within locations, influenced by households' livelihood strategies and capital endowments. There are clear site-related distinctions between the risk profiles however household age and gender of the household head also differentiate the profiles. These different profiles suggest the need for targeted interventions that account for these site-related differences, while still recognizing the heterogeneity of risk at the village level.

1. Introduction

Climate change impacts are expected to vary across regions, influenced by the hazards experienced, the degree of exposure, and the vulnerability of the natural and human systems exposed (IPCC 2014). Certain populations and sectors are likely to be harder hit, particularly where natural-resource-based systems support livelihoods (Kok et al. 2016). Dryland areas, including much of South and southern Africa, already face challenges which create vulnerable social-ecological systems (Safriel and Adeel 2008; Blackie et al. 2014). These include marginal ecosystems with low agro-ecological potential under pressure from multiple users; low, seasonal and unreliable rainfall; poor infrastructure and public services; poor governance; a marginalized population; limited opportunities for alternative livelihoods; low literacy rates; food insecurity, and the prevalence of chronic diseases (e.g. HIV/Aids) (Reynolds et al. 2007; Safriel and Adeel 2008; O'Brien et al. 2009; Sietz et al. 2011). Climate change is expected to exacerbate these vulnerability-creating mechanisms, undermining efforts to achieve the Sustainable Development Goals (IPCC 2014; Sietz et al. 2017). Rural households in these areas, who tend to be insufficiently insured, face the risk of increasing vulnerability unless their capacity to cope with, and adapt to, climate change improves (Günther and Harttgen 2009; IPCC 2014).

Vulnerability is multidimensional, varying temporally and spatially, affected by various environmental, economic, political, and institutional conditions (Skoufias 2003; Vogel and O'Brien 2004; Günther and Harttgen 2009; Ahsan and Warner 2014). This, and the fact that it is not directly observable, makes assessing vulnerability challenging (Luers et al. 2003). However, understanding the ways in which societies and ecosystems are vulnerable is important for the design, implementation and monitoring of interventions to reduce vulnerability (Adger et al. 2004; Reid and Vogel 2006; Vincent 2007; Kok et al. 2016).

Responding to this challenge, various assessment studies have sought to better understand the drivers and heterogeneity of vulnerability, generally and within the climate change space, with each approach's limitations guiding the methodology's refinement (e.g. Leichenko and O'Brien 2002; Füssel and Klein 2006; Birkmann 2007; Sallu et al. 2010; Kok et al. 2016). For example, while constructing single vulnerability and adaptive capacity indices, using an indicator-based approach, reduces complexity, it makes it difficult to draw conclusions on specific intervention points (e.g. Luers et al. 2003; Hahn et al. 2009; Gbetibouo et al. 2010; Ahsan and Warner 2014). Using disaggregated indicators maintains the data's richness but can result in too many indicator combinations to analyze systematically (Adger et al. 2004; Ahsan and Warner 2014; Kok et al. 2016). Recently, cluster-based approaches have been used to identify typical patterns of vulnerability, guided by indications of certain distinct, recurring vulnerability-creating mechanisms (Jäger et al. 2007; Reynolds et al. 2007; Safriel and Adeel 2008; Sietz et al. 2011, 2012, 2017; Kok et al. 2016; Vidal Merino et al. 2019).

As a method, cluster analysis reduces complexity by revealing a limited number of typical, recurrent indicator combinations, or units of analysis, which can be interpreted systematically (Sietz et al. 2011, 2012; Kok et al. 2010, 2016). By keeping the components discernible, rather than creating one index, the clusters provide differential insights, supporting the design of targeted interventions by allowing for discussions on each component's contribution (Kok et al. 2016; Sietz et al. 2017). Cluster-based approaches are used across domains, including earth and life sciences, social and behavioral sciences, information and policy sciences, and medicine and engineering (Anderberg 1973). At the rural household level, cluster analyses have been used, for example, to construct a typology of households participating in improved crop management in Malawi (Orr and Jere 1999), and to explore the poverty profiles of households in post-conflict Rwanda (Ansoms and McKay 2010). More recently, cluster-based approaches have been used to identify archetypes of vulnerability to weather extremes in Peru (Sietz et al. 2017; Vidal Merino et al. 2019) and to global change in dryland systems (Kok et al. 2010, 2016; Sietz et al. 2011, 2017). Our study aims to build on these analyses, using a cluster-based approach to assess climate-related vulnerability and risk at the household level, in two rural villages in different agro-ecological zones in South Africa.

Given the heterogeneity of rural communities, different households are likely to experience varying degrees of vulnerability to climate change, with their adaptive capacity influenced by the resources at their disposal (DFID 1999; Vogel and O'Brien 2004; Vincent 2007; Eakin and Bojórquez-Tapia 2008; Sietz et al. 2012). Using the IPCC's most recent framework on vulnerability and climate-related risk (2014), we apply a cluster analysis to determine whether there are differentiated, archetypical risk profiles, using combinations of indicators related to climate hazards, exposure, vulnerability, and impacts. By identifying and assessing these profiles, we aim to improve the understanding of the heterogeneity of the climate-related risk among rural households in dryland systems. We explore the profiles to determine if they provide lessons for the targeting of adaptation interventions, based on the assumptions that, i.) if the profiles differ substantially between the two sites, then interventions need to be site-specific, and ii.) if they are similar, then interventions can be applied more broadly across sites, but may have to be adjusted for specific household characteristics.

2. Study Area

The research was conducted in the Vhembe District Municipality of South Africa's Limpopo Province, one of the country's poorest provinces (SSA 2014). According to recent national census results (2011), this area faces ongoing challenges with poor service provision and development, high dependency ratios and youth unemployment rates, and low levels of education (SSA 2014). State welfare grants and migrant remittances make an important contribution to household income, with limited local employment opportunities (Venter and Witkowski 2013; SSA 2014; Ofoegbu et al. 2016). On average, 54% of households are female-headed, a legacy of South Africa's former homeland system and a reflection of the ongoing reliance on migrant labor (SSA 2014). Given the high levels of engagement in subsistence and commercial land-based livelihood strategies, climate change is likely to adversely affect the province's inhabitants (Turpie and Visser 2013; Thivhafuni 2015).

We considered rural households in the villages of Bennde Mutale and Vondo, located approximately 90 km apart, separated by the Soutpansberg mountain range (Figure 1). Bennde Mutale, in the Mutale local municipality, is separated from the Limpopo River (the border with Zimbabwe) by the Madimbo Military Corridor. The site is further delineated by the Kruger National Park (to the east), the Mutale River (south) and communal rangelands (west). Vondo, in the Thulamela local municipality, lies to the north of the Mutshindudi River and is surrounded by government-owned pine and tea plantations, and neighboring communities. The site selection was based primarily on differences in mean annual precipitation (MAP) and agro-ecological conditions, with Bennde Mutale located in an arid agro-ecological zone (AEZ) and Vondo in a semi-arid zone (IFPRI 2015). The dominant vegetation types in Bennde Mutale include Musina Mopane Bushveld and Makuleke Sandy Bushveld, while Soutpansberg Mountain Bushveld is dominant in Vondo (Mucina and Rutherford 2011). Both sites have a summer rainy season and a cooler, dry winter, but Vondo receives almost three times Bennde Mutale's annual precipitation and is about 5°C cooler (Funk et al. 2015) (Figure 1). Given these differences, Bennde Mutale is henceforth referred to as the "dry site", and Vondo as the "wet site".

In addition to these biophysical differences, communities were chosen where most households display some level of dependence on land-based livelihoods and natural resources. Willingness to participate in the research was another influencing factor.

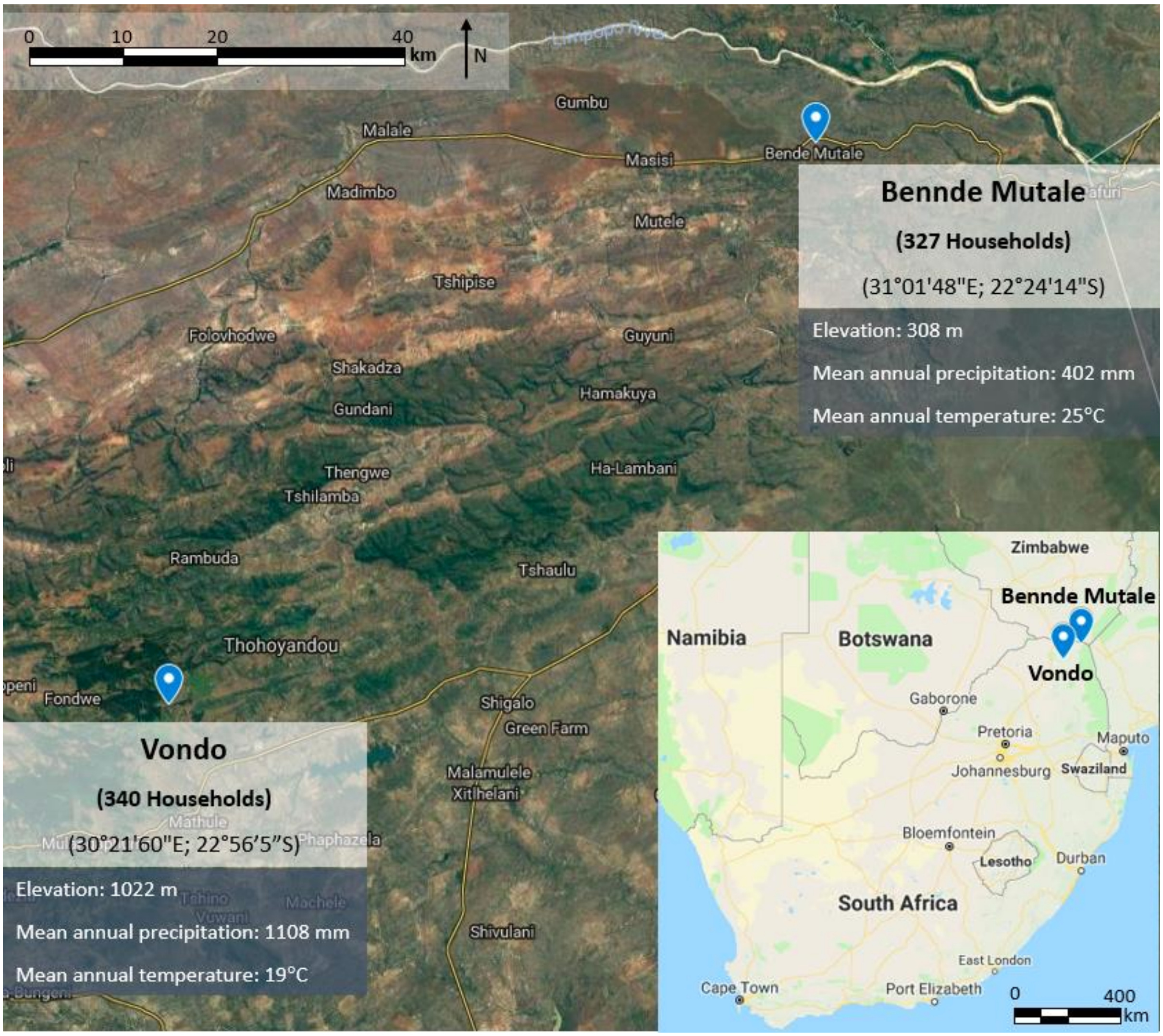

Fig. 1. Location and details of the two study sites, Vondo (wet site) and Bennde Mutale (dry site)

Households in both sites engage in arable agriculture, animal husbandry, and the use and sale of non-timber forest products (NTFPs). Arable agriculture is more prevalent in the wet site. According to respondents, there are constraints to these land-based livelihoods, including seasonality, climate hazards, pests, and diseases, overharvesting and overgrazing, limited land, and limited access to markets and extension support (workshops). These constraints, and households' increasing integration into the cash economy, make it difficult to depend exclusively on these subsistence-level, land-based livelihoods. Households seek to diversify although local employment opportunities are limited (workshops).

The nearest, large commercial and administrative center to both sites is Thohoyandou (15 km and 95 km from the wet and dry sites, respectively). This limits access to services (e.g. banks, formal credit institutions, extension support) and to input and output markets. The wet site is difficult to access during the summer when heavy rains make the village's steep, dirt roads impassable. Neither village has a secondary school or clinic. People rely on traditional healers and a mobile clinic for primary health care. Poor access to healthcare, an increase in chronic diseases (e.g. diabetes and HIV/Aids), and food insecurity, were associated with declining well-being (workshops). Households rely on communal taps and natural water sources for consumption, irrigation, and livestock. The amount and quality of water is affected by multiple users, the intermittent supply from the communal taps, and the seasonal availability of natural water sources. Most households have electricity, but fuelwood remains important for cooking, with overharvesting a concern for the residents (workshops).

Floods and drought are experienced in both sites (Chapter 4; Funk et al. 2015), although respondents indicated that these are more severe in the dry site (workshops). Floods are associated with erosion and landslides, crop, and livestock losses, and increases in water-borne diseases (e.g. malaria and cholera). Damage to infrastructure, including houses, fences, irrigation equipment, electricity poles, roads, and bridges, was also reported with respondents attributing this to poor planning and the use of inferior construction materials. Drought is also associated with crop and livestock losses, resulting in hunger and malnutrition. Natural water sources dry up and NTFP availability declines.

3. Methods

a. The conceptual framework

The IPCC's climate vulnerability framework has been modified to include the concept of risk, shifting from the previous focus on vulnerability and its core components (i.e. exposure, sensitivity, and adaptive capacity) (IPCC 2014; Kok et al. 2016). Risk involves the potential for impacts resulting from the interaction of climate-related hazards with the vulnerability and exposure of human and natural systems, with exposure now described as a separate component (IPCC 2014). This revised framework has rarely been applied at the household level (but see Karim 2018). Using a cluster analysis, we explore archetypical household-level climate risk profiles, first defining and measuring indicators for the framework's core components (Kok et al. 2016) (Figure 2, Table 1).

Regarding the core components, for hazards (i.e. natural or human-induced, climate-related physical events or trends which may result in impacts), we focused on floods and drought (IPCC 2014; Van Niekerk & Nemakonde 2017). For exposure, we considered households' involvement in arable agriculture and animal husbandry (i.e. climate-sensitive, land-based livelihoods), with exposure implying that households have livelihood activities and assets that could be adversely affected by hazards (IPCC 2014). We considered impacts on both agriculture and animal husbandry as well as those to household infrastructure and/or major assets, with the latter associated with the experience of floods (Vincent 2007). Vulnerability, defined as "the propensity to be adversely affected", encompasses households' susceptibility to harm and their capacity to cope and adapt (IPCC 2014, p. 128). Here we focused on households' access to capital endowments (as outlined in the Sustainable

Livelihoods Framework (SLF)) as an indicator of their ability to cope with and manage risk (Reid and Vogel 2006; IPCC 2014; de Jalón et al. 2018; Vidal Merino et al. 2019).

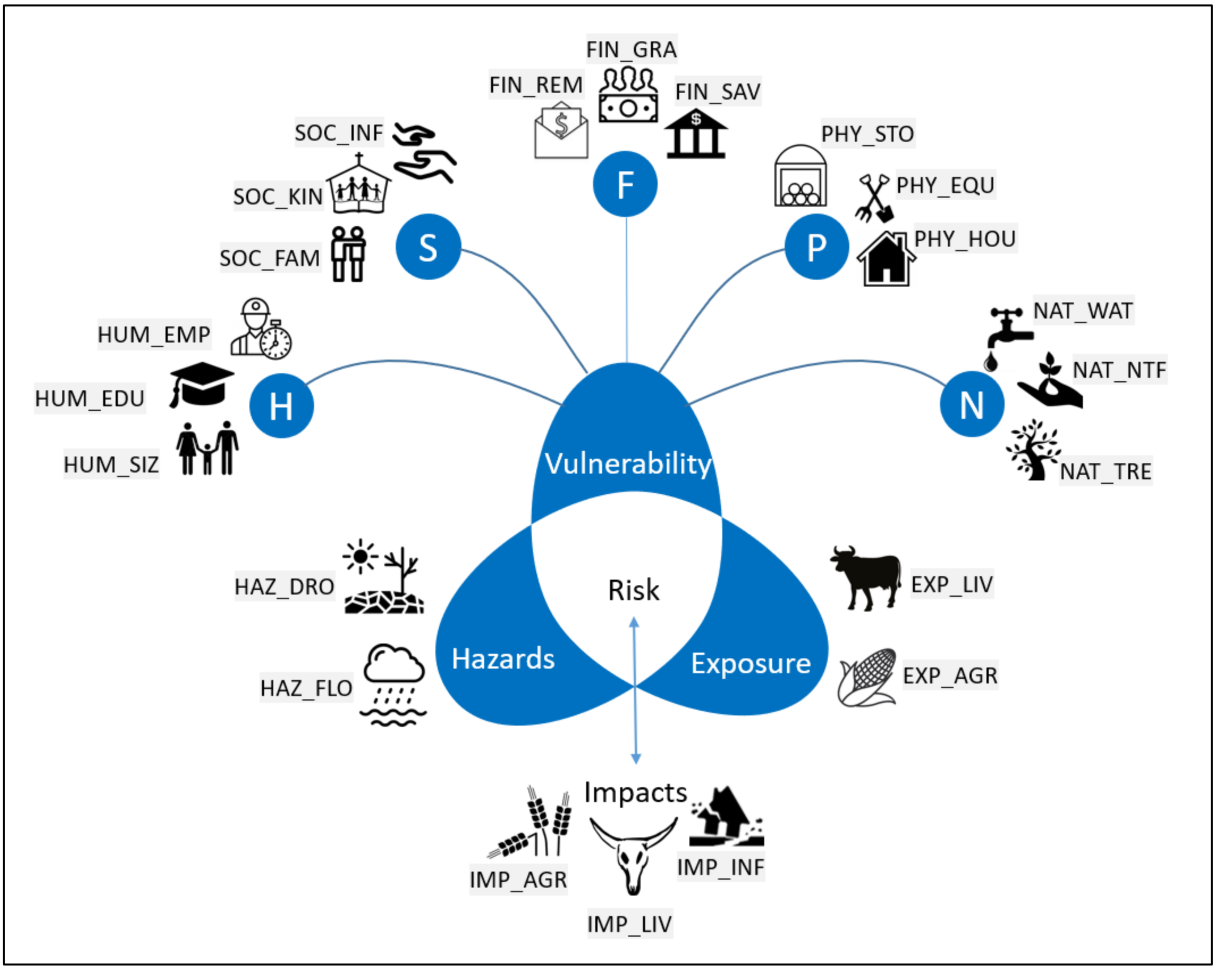

Fig. 2 Conceptual framework for the assessment of household-level climate-related risk, combining the IPCC (2014) framework (center) and the Sustainable Livelihoods Framework (DFID 1999) (top). See Table 1 for details on the variable codes (e.g. PHY_EQU = Physical capital: Equipment). H=Human Capital; S=Social Capital; F=Financial Capital; P=Physical Capital; N=Natural Capital.

b. Data collection

Data were collected using a mixed-methods approach, including a semi-structured household survey and a participatory rural appraisal (PRA). Key informant interviews were conducted with local elders, traditional leaders, local farmers, livestock owners, traditional healers, and the extension officers responsible for each site. These interviews and personal observations were intended to support the household survey and PRA data.

The survey was administered to 170 randomly selected households, 85 per village, a quarter of each village's total number of households. The interviews were conducted with a well-informed, adult household member, preferably the household head. For the survey design we drew from the SLF (DFID 1999), the Poverty Environment Network (Wunder et al. 2014), the Livelihood Vulnerability Index (Hahn et al. 2009), and similar vulnerability assessment studies (e.g. Vincent 2007; Eakin and Bojórquez-Tapia 2008; Ahsan and Warner 2014). Following a livelihoods approach, data were collected on households' socio-demographic and socio-economic characteristics, their engagement in off-farm and land-based livelihoods, their experience of multiple stressors (including climate-related hazards) and the coping strategies used in response to these.

The PRA was conducted to establish an understanding of the socio-economic environment and overall vulnerability context of the sites. Community members were invited to a series of workshops with the initial participants invited to subsequent workshops to build on discussions. The exercises conducted drew from the participatory vulnerability and capacity analysis methodologies developed by Dazé et al. (2009) and Turnbull and Turvil (2012). These apply a climate lens to livelihoods' analyses, allowing communities to identify and assess their vulnerabilities and adaptive capacity to climate-related hazards (Turnbull and Turvil 2012). The exercises explored annual cycles in livelihood strategies and resource availability and identified major events which have affected the communities. They aided discussions on the impacts of floods and drought, on how people coped with these previously, and on possible interventions to reduce future impacts.

Table 1. Description of indicators used in the cluster analysis, grouped by the risk dimensions of the IPCC's 2014 framework (see Figure 2). The measurements (range of observed values) are taken from the household survey

Risk dimension	Indicator description	Abbreviation	Measurement (range of observed values)
Hazards	Drought events faced by the household	HAZ_DRO	The number of major drought events reported when asked to mention the year the worst and second worst drought events were experienced (0 to 2)
	Flood events faced by the household	HAZ_FLO	The number of major flood events reported when asked to mention the year the worst and second worst flood events were experienced (0 to 2)
Exposure	Households' involvement in agriculture	EXP_AGR	The practice of agriculture in a home-garden or field (1) or both (2) (0 to 2)
	Households' involvement in livestock raising	EXP_LIV	The total number of livestock units owned (using equivalence factors between animals), log-transformed (FAO, 2003 (adapted by Chilonda and Otte 2006))
Impacts	Impacts on agriculture	IMP_AGR	The occurrence of crop failure (1), crop pests and disease (1) or both (2) in the last five years (0 to 2)
	Impacts on livestock	IMP_LIV	The occurrence of livestock loss (1), livestock pests and disease (1) or both (2) in the last five years (0 to 2)
	Impacts on infrastructure	IMP_INF	The occurrence of loss of/damage to infrastructure or major assets (e.g. house, agricultural implements, etc.) (1) or other damage from natural disasters (1) or both (2) in the last five years (0 to 2)
Vulnerability	Human capital: Household size	HUM_SIZ	The number of people in the household, full-time residents sharing a kitchen, excluding migrants (1 to 14)

Human capital: Education	HUM_EDU	The number of years of school education of the household head (0 to 13)
Human capital: Off-farm workforce	HUM_EMP	The number of types of off-farm jobs in the household, including formal and informal jobs and self-employment (0 to 2) (Vidal Merino et al. 2019)
Financial capital: Remittances	FIN_REM	The frequency of migrant remittances received (0=Never, 1=Infrequently (1-2 times/year or only when asked), 2=Every month). Households receiving regular remittances (i.e. off-farm income) are considered to have higher financial capital than those receiving intermittent support (DFID 1999).
Financial capital: Government social grants	FIN_GRA	The total monthly monetary value of government grants (i.e. old age, child care and disability grants), normalized by household size (i.e. divided by the number of household members: 1 for adult, 0.5 for child) (ZAR 0 to 1520), log-transformed.
Financial capital: Formal savings	FIN_SAV	The number of formal savings: bank or post office account, and crop and weather insurance (0 to 2). These savings provide a coping option and reflect households' ability to accumulate capital (Gautam and Andersen 2016; Vidal Merino et al. 2019).
Natural capital: Access to water	NAT_WAT	The number of water sources used for irrigation, livestock, and domestic uses (1 to 3). Access to a diversity of sources (including community and household taps, and natural water sources such as rivers and springs) may ensure supply.
Natural capital: Use of NTFPs	NAT_NTF	The number of activities related to NTFPs (i.e. either no activities (0) and/or the collection, use, and/or sale (1-3)). NTFPs included fuelwood, wild foods, medicinal plants, wood, and fibers. The use and sale of NTFPs reflects households' traditional ecological knowledge, access to labor, access to collection areas and markets, etc. (McSweeney 2005; Reid and Vogel 2006; Hunter et al. 2007; Paumgarten and Shackleton 2011).
Natural capital: Tree ownership	NAT_TRE	The number of categories of edible fruit trees cultivated and/or maintained in the household lands (i.e. either none, or only indigenous/exotic, or both indigenous and exotic (0 to 2)).

Physical capital: Storage capacity	PHY_STO	The number of resources (water, crops, seeds, NTFPs) that the household can store (1 to 4), reflecting households' ownership of storage facilities and their ability to produce/collect a surplus for when needed. E.g. wild foods can be stored as a buffer for seasonal crop shortfalls.
Physical capital: Equipment owned	PHY_EQU	The estimated value of equipment (i.e. disposable assets including stove, fridge, radio, cellphone, television, car, bike, tractor, wheelbarrow, cart, plough, chainsaw, water pump, solar panel) (ZAR 53k to 1830k), log-transformed. These assets reflect households' economic welfare (Vidal Merino et al. 2019). The equipment may contribute towards production activities (e.g. ploughs), improve households' access to information (e.g. cellphones), and could be sold as a coping strategy (DFID 1999; de Jalón et al. 2018).
Physical capital: House type	PHY_HOU	The resistance of house walls and roof reflected by the type of construction materials used (1 if concrete walls + 1 if non-reed/thatch/grass roof) (0 to 2). The use of modern (i.e. non-traditional) building materials reflects households' ability to construct homes that are more resistant to damage from floods, strong winds, etc. (Vincent 2007; Ahsan and Warner 2014).
Social capital: Extended family support in the village	SOC_FAM	The strength of family kinship networks in the village (1 if there is family support in the village + 1 if it has provided help in the last two years) (0 to 2)
Social capital: Membership in associations and groups	SOC_KIN	The number of memberships in local associations and groups (i.e. church, burial society, agricultural cooperative, or other (0 to 4))
Social capital: Membership in informal saving schemes	SOC_INF	The number of informal saving schemes: Savings from burial societies and/or stokvels and saving clubs (0 to 2)

Based on the results of the survey and the PRA, and taking the existing literature into consideration, we defined indicators for the components of the conceptual framework, selecting indicators that applied to both sites and for which we had the data (Figure 2, Table 1). The mix of quantitative household-level data and qualitative community-level data supported the interpretation of the results, providing a more comprehensive understanding of climate risk within and between the sites (Vidal Merino et al. 2019).

c. The selection and definition of indicators

We selected 22 indicators, and used data collected during the household survey, to represent the framework's core components (i.e. the risk dimensions) (Figure 2, Table 1). We selected two indicators for hazards related to households' self-reported experience of floods and drought. Given their proximity, the sites have experienced many of the same regional flood and drought events, although households may have experienced them differently. For example, tropical cyclones caused flooding in 2000 and 2013 while El Ninö caused droughts in the early 1980s and 1990s. South Africa's most recent drought occurred after the fieldwork. For the purposes of recall, and to ensure we captured more extreme hazards that were more likely to be experienced in both sites, we focused on the worst two flood and drought events experienced. For exposure, we also selected two indicators, namely households' involvement in arable agriculture and animal husbandry (i.e. livelihood activities that households reported were adversely affected by floods and drought). For impacts we selected three indicators related to the self-reported occurrence of impacts on agriculture, livestock, and/or household infrastructure and assets. We focused on impacts which required a response by the household, although the indicators reflect only the occurrence of an impact, not the degree of loss. The latter would require further research. Infrastructure damages, including damage to fences and livestock enclosures, irrigation equipment, and storage facilities and their contents (including seed stocks, food, etc.), may aggravate the direct impacts on agriculture and animal husbandry. The indicators for hazards, exposure and impacts were assumed to be positively correlated with risk.

For vulnerability, we selected 15 indicators grouped by capital type (i.e. human, financial, natural, physical, and social capital (DFID 1999)), with 3 indicators per type (Figure 2, Table 1). These capitals are assumed to reflect households' adaptive capacity and are therefore negatively correlated with risk if hazard and exposure remain constant (Ahsan and Warner 2014). We focused on household-level indicators, with households with limited capital considered to be more vulnerable (Cooper et al. 2008; Heltberg et al. 2009; Vidal Merino et al. 2019).

Households' human capital is expressed as a function of household size, education of the head, and members' engagement in local, off-farm employment. High human capital reflects households' labor and skills, and ability to diversify into less climate-sensitive, off-farm livelihoods (DFID 1999; Dercon 2002; Sietz et al. 2012). Labor availability has also been linked to households' ability to turn to labor-intensive coping options including the harvesting of NTFPs (e.g. as noted by McSweeney (2005) in response to hurricane-related losses in Honduras). Financial capital, often described as the capital type least available to the poor, is expressed as a function of households' access to migrant remittances, government social grants, and formal cash savings (DFID 1999; Reid and Vogel 2006; Paumgarten and Shackleton 2011). For natural capital, which provides livelihood and coping options, we used indicators related to households' access to multiple water sources, their use and sale of NTFPs, and their ownership of private tree crops (DFID 1999). Physical capital is reflected by households' capacity to store resources (including water, NTFPs, crops and seed), the estimated value of household equipment, and households' use of modern (i.e. non-traditional) building materials (DFID 1999; Ahsan and Warner 2014; Vidal Merino et al. 2019). Households' social capital is expressed by their available kinship networks, including family networks within the village, and households' membership in local associations and groups (Paumgarten and Shackleton 2011; Ahsan and Warner 2014). The latter is correlated with households' participation in informal savings schemes, the third selected indicator of social capital. The number of memberships held is taken as representative of the strength of the social capital (Vincent 2007). Social capital provides coping and adaptation options and allows for the accumulation of savings (particularly in the absence of formal savings institutions) (Paumgarten and Shackleton 2011). It is important for poor households with limited alternative insurance options (DFID 1999; Pelling and High 2005; Vincent 2007).

Variables related to the location of the household (i.e. site), the household's age, and the gender of the household head were not directly assigned indicators as they could not be directly linked to the household capital profiles. These variables were however considered when describing the clusters.

d. Cluster analysis

We applied a clustering procedure, as described by Janssen et al. (2012) and Kok et al. (2010, 2016), to identify archetypical patterns or profiles of risk, based on recurrent indicator combinations. This cluster-based approach was previously applied by Sietz et al. (2011, 2012, 2017), Kok et al. (2010, 2016) and Vidal Merino et al. (2019). The approach combines a hierarchical (h-clust) and partitioning (k-means) clustering algorithm, with the data first transformed to values between 0 and 1 with a min-max normalization (Appendix A). While the k-means algorithm efficiently partitions the data into k-groups, its outcome is sensitive to initialization. We used the h-clust algorithm (Ward's method) to define the initial conditions (i.e. the cluster centers) for the k-means. We resampled the initial dataset, randomly sampling the same number of observations with replacement, before re-running the algorithms. By repeating this process, we established a consistency measure enabling us to identify the optimal number of clusters for analysis (Appendix B) (Sietz et al. 2012). To interpret the six clusters, we observed the mean values of the selected indicators and compared pairs of clusters using Tukey Honest Significant Differences (Appendix C).

4. Results

Six clusters were categorized according to their respective risk profiles, and presented in the figure below, rather than in a comparative table (Figure 3). The figure uses different sized and colored dots to represent high/low levels of capital and high/low hazards, exposure, and impacts. Using the dots, we assign each cluster a risk score. Cluster 2 was the largest, representing 27% of the sampled households. This was followed by Cluster 4 (19%), then Cluster 1 (16%). Clusters 3 and 6 both represented 13% of households. Cluster 5 represented 12%. Each of the clusters is described in detail in the section below.

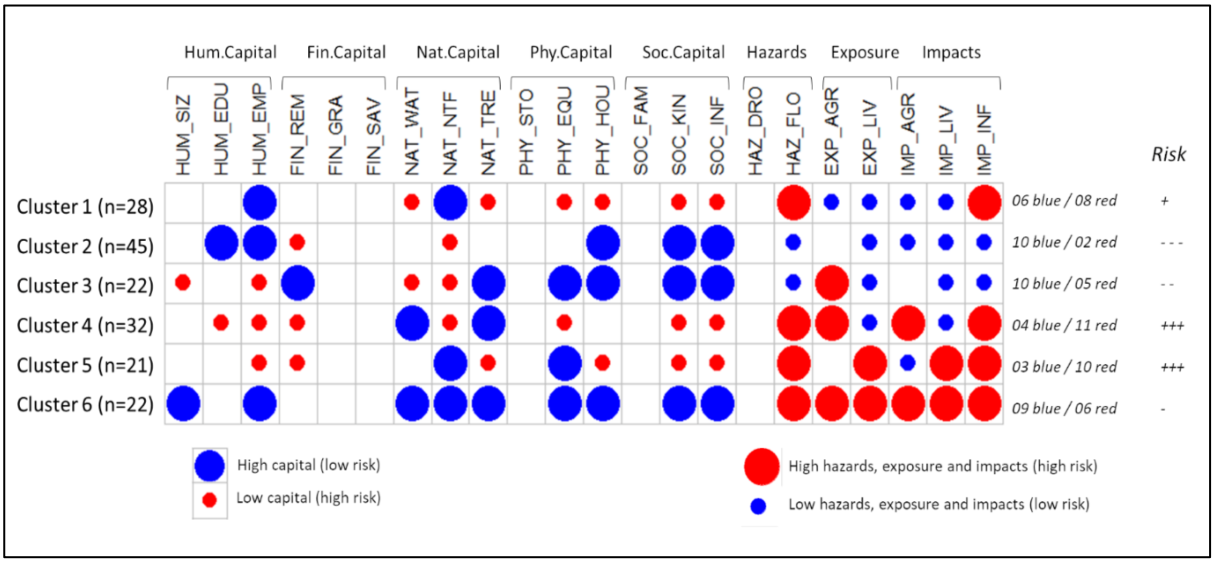

Fig. 3. Household clusters (rows) and indicators (columns), with large circles representing clusters with the largest means (or means not significantly different from the largest). The inverse applies to the small circles. White cells indicate a medium value. Assuming a negative correlation between capital and risk, the large, blue circles represent high capital and low risk. The small, red circles represent the inverse. For hazards, exposure and impact, the large, red circles represent indicators positively correlated with risk. The small, blue circles represent low risk. The risk scores, with "+++" reflecting the highest risk and "---", the lowest risk, represent the difference between the number of blue and red circles. See Table 1 for variable codes (e.g. PHY_EQU = Physical capital: Equipment).

a. Interpretation of households' climate risk profiles

Some indicators did not differ between the clusters (i.e. they had a medium value (see the white boxes in Figure 3)). These included households', i.) access to government social grants and formal savings (financial capital), ii.) available storage facilities (physical capital), and iii.) access to family-based kinship networks (social capital). Membership in associations and groups included informal savings schemes, with these social capital indicators therefore correlated. The experience of drought, as a hazard indicator, also had limited influence, with floods having been experienced more recently (in 2000 and 2013). Households established after the most recently reported drought (2008/09), would not have reported exposure to and impacts from this hazard (i.e. the hazards were self-reported).

The different clusters are described and interpreted in the following sections. This includes details related to site, the household's age, and the gender of the household head.

1) Cluster 1: Capital-constrained households with limited production impacts but moderate risk

Cluster 1 represented poor, off-farm households who faced moderate risk related to their capital constraints (vulnerability), despite low exposure and impacts given their limited involvement in land-based livelihoods (see blue and red dots in Figure 3). Most (86%) of these households were in the dry site. They were more recently established, possibly still building their capital portfolio.

These households had high human capital reflected in their access to employment, although this may involve unskilled work as laborers in government's Extended Public Works Program, and the nearby conservation areas and tourism facilities. Skilled positions existed as national park field rangers, but local opportunities were limited. These households had low natural capital related to the limited water sources used, although their water requirements may be lower given their limited involvement in land-based livelihoods. They had low natural capital in the form of private tree crops with the drier conditions hindering the cultivation of exotic fruit trees (e.g. *Mangifera indica*) (workshops).They had high natural capital related to NTFPs, however as households in both sites used NTFPs (e.g. over 80% used wild foods and fuelwood), the sale of NTFPs is probably the distinguishing factor here. These households had low physical capital, with more traditionally constructed homes and limited household equipment. Archetypical households had homes constructed from mud bricks and thatching grass. They owned cellphones and radios, not larger assets (e.g.

ploughs). Their low social capital included limited participation in community groups, including informal savings clubs.

These households had limited involvement in arable agriculture and animal husbandry, which they attributed to a lack of interest, insufficient rainfall, limited arable land, and insufficient income to purchase inputs. Given this limited involvement, they faced limited production risks. However, they faced infrastructure impacts, with their traditional homes being less resistant to damage from floods, strong winds, etc. They reported the experience of floods.

2) Cluster 2: Skilled, off-farm households with very low risk

Households in Cluster 2 had high human, social and physical capital, faced limited exposure and impacts, and therefore had very low risk (see blue and red dots in Figure 3). These were more recently established, male-headed households, most (87%) of which were in the wet site.

This cluster's high human capital was reflected in more educated household heads and the number of local, off-farm income sources. The wet site's neighboring tea and timber plantations provided some employment, with people also self-employed as local artisans, retailers, etc. These households do not receive remittances, an indicator of low financial capital. They had low natural capital, specifically related to NTFPs which were less available in the wet site. These younger households may also be less interested in, and knowledgeable of, the use and sale of NTFPs. These households had limited involvement in land-based livelihoods, with the archetypical households stating they "don't like livestock". Limited access to arable and grazing land may be a restriction, with the village chief having reallocated land for settlement (workshops). These households had good physical capital with more modern houses, suggesting the means to purchase building materials, aided by the site's proximity to urban centers. Participation in community-based groups and informal savings clubs contributed to households' social capital.

Given their limited involvement in land-based livelihoods, these households were less affected by production shocks. They also reported limited infrastructure damage, related to their sturdier homes. These newer households may be in areas with a gentler gradient (i.e. the recently reallocated land described above), making them less susceptible to damage from run-off (workshops - community maps (Appendix 3)). This may explain the limited reporting of floods.

3) Cluster 3: Capital diverse households with low risk

Cluster 3's households had a diverse capital portfolio, faced limited risk (see blue and red dots in Figure 3), were predominantly (77%) located in the wet site, and were mostly female-headed.

This cluster consisted of smaller households with labor constraints and limited involvement in local off-farm livelihoods, suggesting low human capital. Regular remittances indicated high financial capital. The male household head had most likely migrated, remitting regularly but leaving the de facto female-headed household labor-constrained. These labor constraints may explain this cluster's limited reliance on NTFPs and diverse water sources (i.e. low natural capital). These households may also have lower water requirements given their smaller size and limited involvement in land-based livelihoods. NTFPs were also less available in the wet site. These households have high natural capital in terms of private tree crops (i.e. exotic fruit trees) which grow well in the wet site and are possibly less labor-intensive than cash crops. These households owned higher value household assets (e.g. fridges, etc.) and had sturdier houses. Access to regular remittances and the wet site's proximity to urban centers may enable investments in physical capital. This cluster also had high social capital.

Although these households engaged in arable agriculture, with the archetypical households cultivating fields and home-gardens, this cluster was not defined by high or low agricultural impacts. Their tree crops may be less susceptible than cash crops to climatic variations and extremes. As they were not actively engaged in animal husbandry, these households faced limited exposure and impacts through livestock. They reported limited infrastructure impacts, probably linked to their sturdier houses and limited experience of floods.

4) Cluster 4: High-risk farming households with limited capital

The households in Cluster 4 were capital-constrained in most aspects other than natural capital (see blue and red dots in Figure 3). They were high-risk farming households, 66% of which were in the wet site, making this the most cross-cutting cluster in terms of the proportion of households per site.

The low levels of education of the household head and limited local employment suggested low human capital. These households tended not to have remitting migrants, with one archetypical household explaining that although members had migrated, they were still looking for work. They therefore had low financial capital. Their high natural capital was reflected in their use of diverse water sources for irrigation and household consumption, and their ownership of private tree crops. However, these households did not engage in the use and sale of NTFPs. These natural capital patterns were most likely related to the wet site which is better suited to the cultivation of exotic fruit trees, had more diverse water sources and lower NTFP availability. This cluster was also characterized by low physical and social capital. The former related specifically to limited household equipment, with archetypical households owning lower value equipment.

These households engaged in, and experienced impacts associated with, arable agriculture. They did not engage in animal husbandry, with archetypical households attributing this to money and time constraints. They reported no impacts related to livestock. These households reported infrastructure damage but were not noted for having informally constructed, less sturdy homes. This suggests the damage was to infrastructure such as fencing, irrigation equipment, etc. Flood experience was commonly reported, unlike the other wet site dominated clusters.

5) Cluster 5: High-risk pastoralist households with limited capital

Cluster 5 represented capital-constrained households who faced risks associated with their involvement in animal husbandry (see blue and red dots in Figure 3). These households were all in the dry site. The cluster showed no patterns related to household age or the gender of the household head.

This cluster had low human capital with limited engagement in local off-farm livelihoods. These households did not have remitting migrants (i.e. low financial capital), with one archetypical household explaining that migrant members were still seeking work. They had low private natural capital in terms of tree crops, related to the site's poor agro-ecological conditions (workshops). They had high natural capital related to NTFPs, with the dry site's communal rangelands providing access to NTFPs. Archetypical households reported selling bushmeat (particularly mopane worms) and medicinal plants. They owned higher value equipment (i.e. high physical capital) but had low physical capital related to their less resilient, traditionally constructed homes. This cluster had low social capital.

These pastoralist households faced impacts related to livestock. For example, during recent floods, animals grazing or drinking along the river were washed away. These households faced limited arable agriculture impacts. Although archetypical households cultivated small, winter home-gardens, these could be irrigated by hand, were unaffected by summer floods, and were easier to maintain. These households reported infrastructure losses related to flooding and their less-sturdy houses. Archetypical households also reported damage to their livestock enclosures.

6) Cluster 6: Moderate risk despite livelihood diversification and high capital

Cluster 6 represented households with diverse capitals, engaged in off-farm and land-based livelihoods (see blue and red dots in Figure 3). Despite exposure and impacts in arable agriculture and animal husbandry, their capital endowments reduced their overall risk. These were older, more established households mostly (82%) in the dry site.

These households had good human capital, consisting of larger households with locally employed (or self-employed) members. They had high natural capital including access to diverse water sources. They engaged in the use and sale of NTFPs with the archetypical households selling mopane worms, fuelwood, and thatching grass. Access to transportation assets allowed for the collection and sale of greater quantities of NTFPs. These households differed from those in the other dry site dominated clusters in terms of their access to private natural capital. This included indigenous fruit trees (e.g. *Sclerocarya birrea* and *Adansonia digitata*) that households had maintained on their land, with the dry site being unconducive to the cultivation of exotic fruit trees. These households had good physical capital, owning higher value equipment and more sturdily constructed houses. Archetypical households reported owning bicycles, cars, ploughs, and wheelbarrows, in addition to household and communications equipment (e.g. fridges and cellphones). They had high social capital.

These households engaged in mixed livestock-farming systems, with the archetypical households reporting the cultivation of fields and home-gardens and the ownership of various livestock types, including more high-value livestock (i.e. cattle, donkeys, and goats). They faced impacts in both arable agriculture and animal husbandry and reported infrastructure damage. Given their sturdier homes, the latter included flood damage to fences, irrigation equipment, etc. The dry site's larger tracts of arable land were along the river, increasing the risk of flood damage. These older, more established agricultural households may have better access to this limited riverfront land.

5. Discussion

We identified six archetypical patterns of household-level, climate-related risk, based on recurrent combinations of indicators related to the core components of risk, as defined by the IPCC (IPCC 2014). The identification of these distinct risk profiles allowed for the more systematic interpretation of the climate-related risk of rural households in dryland systems, contributing towards an improved understanding of the heterogeneity of this risk (Sietz et al. 2012; Kok et al. 2016; Vidal Merino et al. 2019). Key insights relate to patterns which emerge, with the most notable being a clear site-related division in the profiles. Socio-demographic characteristics, specifically household age and the gender of the household head, also distinguish some of the profiles. These insights provide lessons on the possible pathways, and implications, for adaptation, indicating areas where interventions could be targeted (Reid and Vogel 2006; Vincent 2007).

High-risk households rely on land-based livelihoods, have limited access to off-farm income, and limited adaptive capacity. Other studies have similarly identified agriculture-oriented, resource-constrained households as more vulnerable (Sietz et al. 2012; Vidal Merino et al. 2019). Additionally, the two high-risk clusters, one per site, reported flood-related impacts to household infrastructure and assets supporting Vincent's (2007) findings of an inverse relationship between the quality of peoples' homes and vulnerability. These high-risk clusters represent almost a third of the sample, highlighting the need to address climate-related risk. Conversely, the two lowest risk clusters (both in the wet site) are less reliant on land-based livelihoods, have a source of off-farm income, and good physical and social capital. Although these households face low climate-related risk, they may be adversely affected by other shocks (Dercon 2002; Vincent 2007; Sietz et al. 2012; Vidal Merino et al. 2019). Our results also suggest cases where households' limited engagement in land-based livelihoods is not a function of choice, but rather a reflection of weak access to land and resources (i.e. as noted in one of the mid-risk clusters) (Skoufias 2003). This distinction needs to be better understood for the targeting of adaptation interventions, with households who are marginalized from land-based options possibly requiring different support to those who prefer off-farm livelihoods. Our second mid-risk cluster suggests the need to better understand whether diversification is a source of resilience or vulnerability. These households reported high hazards, exposure, and impacts, but lower risk given their diverse capital portfolio. Understanding the trade-offs between specialization and diversification, would help determine whether diversification strategies should be encouraged or whether there is the need to support specific, climate-resilient activities (Sietz et al. 2012; Kok et al. 2016).

The identified climate-risk profiles are spatially distributed, with three clusters dominated by households from the dry site and three, by households from the wet site. Certain indicators, representing the core components of risk, differ notably between the sites. For example, i.) high natural capital related to NTFPs was reported by all the dry-site clusters, whereas private tree crops are common in the wet site; ii) exposure through animal husbandry was only reported in the dry site; iii.) infrastructural impacts were reported by all the dry-site clusters, related to their traditionally constructed homes; and iv.) the experience of flooding was reported by all the dry-site clusters, but only one wet-site cluster, consisting of arable farming households with poor physical capital. The AEZ in which each village is located is most likely a key determinant of these indicator differences, and therefore of the spatial distribution of the risk profiles. Applying this cluster-based approach to more villages within the same AEZs would clarify whether the profiles are consistent across each zone, or specific to the selected sites. Other studies have noted the influence of the AEZ on patterns of vulnerability, with higher vulnerability levels associated with harsher conditions (Kok et al. 2016; Vidal Merino et al. 2019). If wider testing reveals that the profiles are specific to the site, not the AEZ, then the influence of other contextual factors needs to be explored further, with Ahsan and Warner (2014) describing vulnerability as both place and context specific. For example, while the wet site households have better access to urban centers (and the resources and services they provide), the dry site's neighboring conservation areas provide local employment opportunities, with these factors possibly influencing the risk profiles. Applying this cluster-based approach across a spectrum of AEZs would provide useful insights into the approach's broader applicability.

The climate-risk profiles show distinctions related to the age of the household, although these are more noticeable in the dry site where the more well-established households face lower risk. Although these older households face greater exposure through their diverse livelihood strategies, their overall risk is lower given their stronger, more diverse capital portfolio (i.e. higher adaptive capacity). In their South African study, Paumgarten and Shackleton (2011) similarly noted newer households as poorer than their more well-established counterparts. Conversely, in the wet site, more recently established households face the lowest risk, both in the site and overall. Although the newer households in both sites have access to an off-farm income and limited involvement in land-based livelihoods (i.e. limited exposure and impacts), they face different levels of risk given their different capital portfolios. Possible explanations for these differences, include i.) that newer households in the wet site have more educated household heads allowing them to engage in more rewarding, less climate-sensitive employment, and to invest in their capital portfolios (i.e. their adaptive capacity), ii). that newer households in the dry site struggle to establish a livelihood and capital portfolio due to the site's remoteness and harsher conditions, iii.) that the dry site's harsher conditions hamper the inter-generational accumulation and transfer of wealth, limiting the strength of both family and community-based kinship networks, and iv.) that the newer households in the dry site consist of Zimbabwean immigrants who may face barriers to accessing resources such as land and social grants (Sietz et al. 2011, 2012; Vidal Merino et al. 2019).

Gender of the household head is a distinguishing characteristic of the two lowest risk clusters, both in the wet site. None of the higher risk clusters are distinguished by this characteristic. The lowest risk cluster includes households with a more educated, male household head. These are more recently established households with access to an off-farm income and a limited engagement in land-based livelihoods. The second lowest risk cluster consists of female-headed households, a group which is generally considered to be more vulnerable, with limited access to assets and alternative livelihoods (DFID 1999; Posel 2001). Here, these female-headed households face lower risk given their access to regular remittances, despite exposure through their engagement in arable agriculture. Although both these clusters face low climate-related risk, they may be vulnerable to income shocks, with the female-headed households being susceptible to risks affecting the remitting migrant. It is unclear why the gender of the household head is only a distinguishing characteristic in the wet site. This requires further investigation, including why regular remittances, an indicator of high financial capital, are only a distinguishing factor in the wet site. Households in the dry site may face barriers to migration, which need to be explored.

Patterns in the clusters' capital endowments provide insights into households' existing adaptive capacity and suggest where interventions could be targeted, either to address specific gaps or to build existing capacity. Although Vincent (2007) also identified differences in households' adaptive capacity in her South African study, the identification of broader patterns is useful. For example, our findings suggest a link between lower risk, and i.) the education of the household head, and ii.) households' access to an off-farm income, calling for interventions that improve human capital (Dercon 2002). These lower risk clusters have a diverse capital portfolio, as noted by Vidal Merino et al. (2019), but specifically have high physical and social capital. While the link between off-farm income and high physical capital is intuitive, the link between this income and improved social capital is worth exploring. Social capital is generally considered the capital most accessible to the poor (DFID 1999), however our findings indicate improved social capital with access to an off-farm income. The ability of poor households to participate in community groups is limited where groups require a membership fee (Vincent 2007). How to support these informal, savings groups to enable them to provide a diversity of households with increased adaptive and coping capacity, requires further investigation (Hahn et al. 2009). Although poor households may still benefit from family networks, reciprocity, etc., increasing natural hazards may strain social capital at a community level, leaving these households with limited alternatives. In the dry site, NTFP-related adaptation strategies may provide an alternative, particularly given the existing role of NTFPs in this site. Households would benefit from sustainable harvesting practices, to avoid overharvesting in response to covariate natural hazards, as well as from the development of existing and new NTFP markets (Paumgarten ad Shackleton 2011).

a. Implications for adaptation interventions

Understanding the characteristics of the risk profiles, and how these differ in terms of the core components of risk, provides insights into where adaptation interventions could be targeted to reduce household-level, climate-related risk. The profiles highlight those households requiring more immediate support, but also indicate that, given the heterogeneity of climate-related risk both within and between sites, there is the need for nuanced, strategically targeted interventions (Tschakert 2007; Sietz et al. 2011; Kok et al., 2016; Vidal Merino et al. 2019). The identification of archetypes addresses some concerns related to local, case-study-based, vulnerability assessments; i.e. that the specificities of each case make it difficult to draw broader conclusions (Hahn et al. 2009; Sallu et al. 2010; Kok et al. 2016). Five key implications and lessons for adaptation interventions are discussed below.

First, high levels of climate-related risk are associated with households' engagement in land-based livelihoods. With limited options to diversify off-farm, interventions are needed to reduce this risk (see Supplementary Material (Table S.1) for adaptation interventions proposed by the workshop participants) (Sietz et al. 2012; Vidal Merino et al. 2019). These interventions need to account for site-related differences in exposure (i.e. exposure in the dry site relates to animal husbandry versus arable agriculture in the wet site). For example, arable farmers need technical assistance and information on measures to reduce flood damage while livestock owners require interventions that support resilient pastoral systems (Table S.1). Respondents suggested establishing grazing camps, with water points, to prevent free-roaming livestock being washed away by floods.

Second, given the potential contribution of off-farm employment to reducing climate-related risk, households would benefit from interventions that support economic integration, skills development, and the creation of local, climate-resilient jobs (Sietz et al. 2011; Kok et al. 2016). This would benefit those households currently dependent on climate-sensitive land-based livelihoods, as well as those already engaged in off-farm activities.

Third, improved settlement planning, access to better building materials, and advice on the construction of flood-resilient infrastructure would reduce the climate-related risk of several clusters, particularly those facing higher risk due to low physical capital (Vincent 2007).

Fourth, the clear spatial distribution of the risk profiles highlights the need to understand and address climate-related risk (and its components) at a finer resolution than the municipal-level (Reid and Vogel 2006; Ahsan and Warner 2014; IPCC 2014; Kok et al. 2016; Sietz et al. 2017; Vidal Merino et al. 2019). Policy and practice interventions are typically designed at a broader level however our results suggest that even municipal-level interventions may not be sufficiently nuanced if they do not account for local-level differences (Jäger et al. 2007; Sietz et al. 2011). Categorizing locations, which show similarities in the core components of climate-related risk, would help target interventions.

Finally, interventions aimed at reducing household-level risk should adjust their activities according to certain household characteristics, including the age of the household and the gender of the household head. Households' demographic structure can affect their adaptive capacity (Pattanayak and Sills 2001; Vincent 2007). For example, female-headed households would benefit from interventions that reduce their reliance on remittances however, given their household and child-care responsibilities, these interventions should be gender-sensitive, acknowledging the specific challenges women and female-headed households face (Eriksen et al. 2005; Sietz et al. 2012).

6. Conclusion

We explored the heterogeneity of climate-related risk among rural households in two distinct agro-ecological zones in South Africa's Limpopo Province. Using a cluster-based approach, we identified distinct patterns of climate-related risk, associated with households' experience of climate hazards, their degree of exposure and vulnerability, and the associated impacts. The identification of a limited number of distinct, archetypical risk profiles allowed for the more systematic interpretation of the climate-related risk faced by these rural households. The resulting insights provide lessons for the development and targeting of policy and practice interventions aimed at supporting local-level, climate change adaptation. The clear site-related distinction between the profiles suggests that site-specific adaptation interventions may be needed. Having said this, household age and gender of the household head also distinguish some profiles, indicating that interventions need to account for socio-demographic characteristics. Based on these insights, limited resources can be more appropriately allocated, priorities can be set, and the relevant stakeholders can be identified.

By presenting a structured way to analyze the heterogeneity of climate-related risk at the local level, this approach provides rich detail without getting caught up in the intricacies of the individual household. The identified profiles set a baseline against which adaptation interventions can be monitored, while the use of selected indicators allows for cross-case comparisons. Applying this approach to a greater number of households, across a broader range of agro-ecological zones (and contexts), experiencing a different set of climate-related hazards, would help test the approach's broader applicability. This would help establish whether the six identified archetypes, and the associated adaptation recommendations, apply to a broader set of circumstances. Overall, this paper contributes towards the refinement of archetype analyses, particularly at the household level, and contributes to ongoing discussions on climate-related risk and adaptation. Finally, it presents a way to operationalize the IPCC’s revised, risk-focused, climate change framework at the local level.

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Compliance with Ethical Standards

The Research Office of the University of the Witwatersrand granted the ethical clearance to conduct the research (H120803). The relevant local authorities granted permission to conduct the research and formal, free, prior, and informed consent was obtained from all participants. Anonymity was assured. All ethical standards were adhered to.

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Appendices

APPENDIX A

Distribution of the Indicators

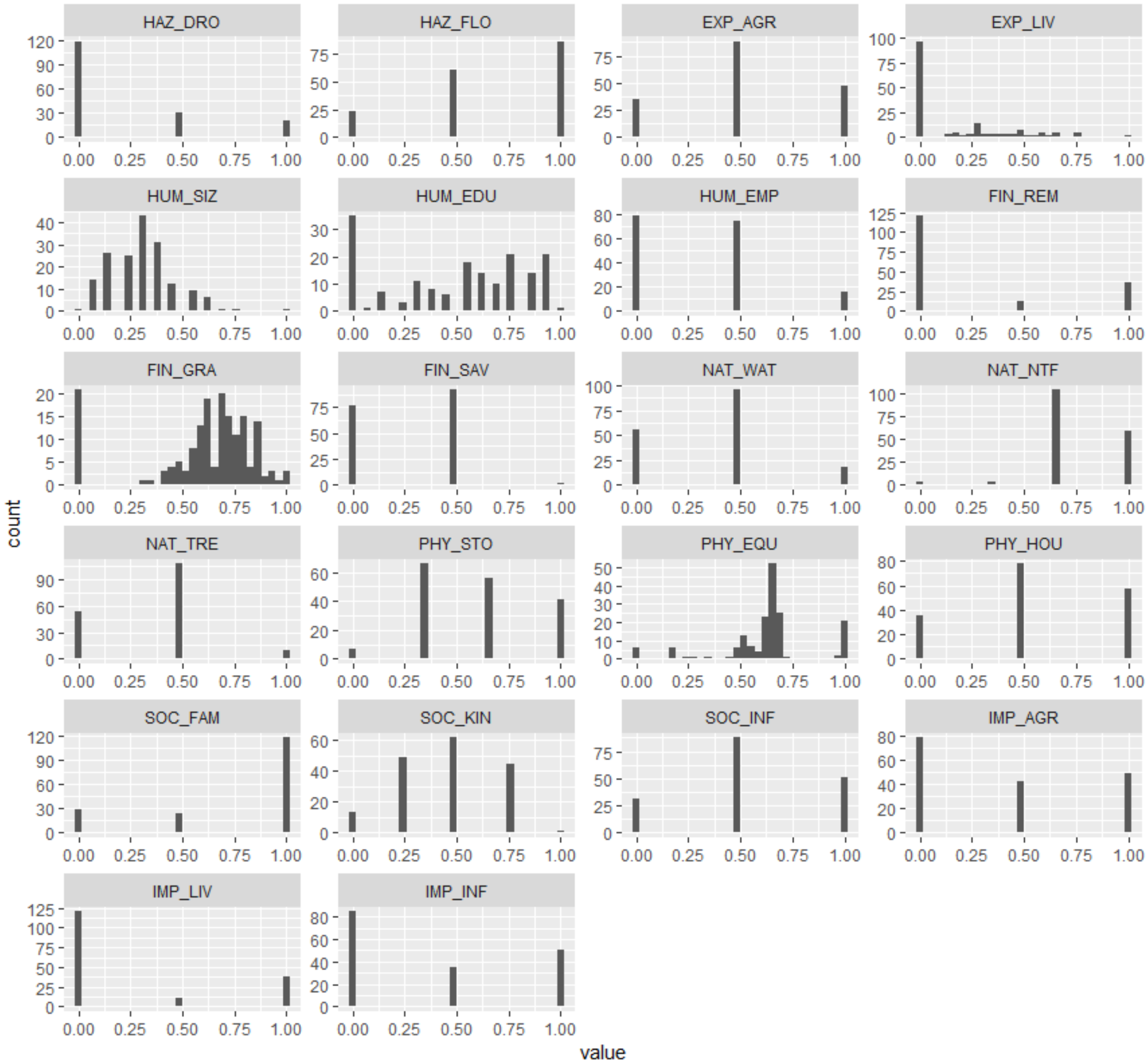

Fig. A.1. Histograms showing the distribution of the indicators normalized between 0 and 1. See Table 1 for variable codes.

APPENDIX B

Method for Determining the Optimal Number of Clusters

Although partitions with three clusters yielded the highest consistency measure (88%), this was not very informative, with the clusters possibly aggregating too diverse a selection of households (Figure B.1). For partitions of 5 to 10 clusters, the consistency measure varied between 60% and 65% with no marked local maximum. Therefore, using the MClust function in R, we applied hierarchical clustering for parameterized Gaussian mixture models, obtaining two optima at k=6 and k=11 (Figure B.2). After building partitions for k=3 to 7 clusters, we found the interpretation of 6 clusters to be the most informative.

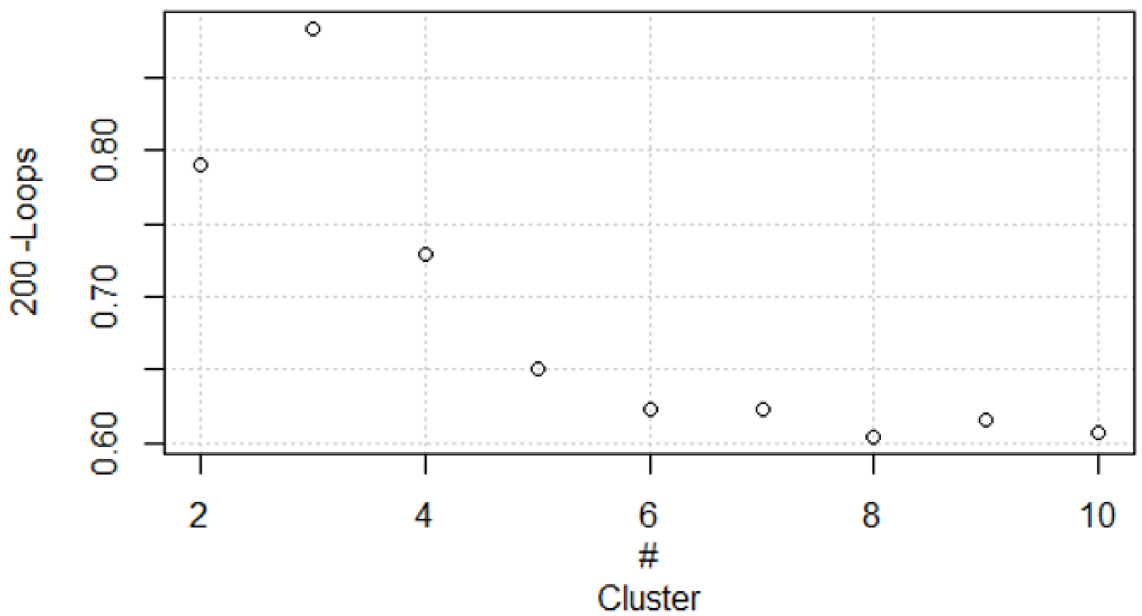

Fig. B.1. Consistency measure for partitions with 2-10 clusters

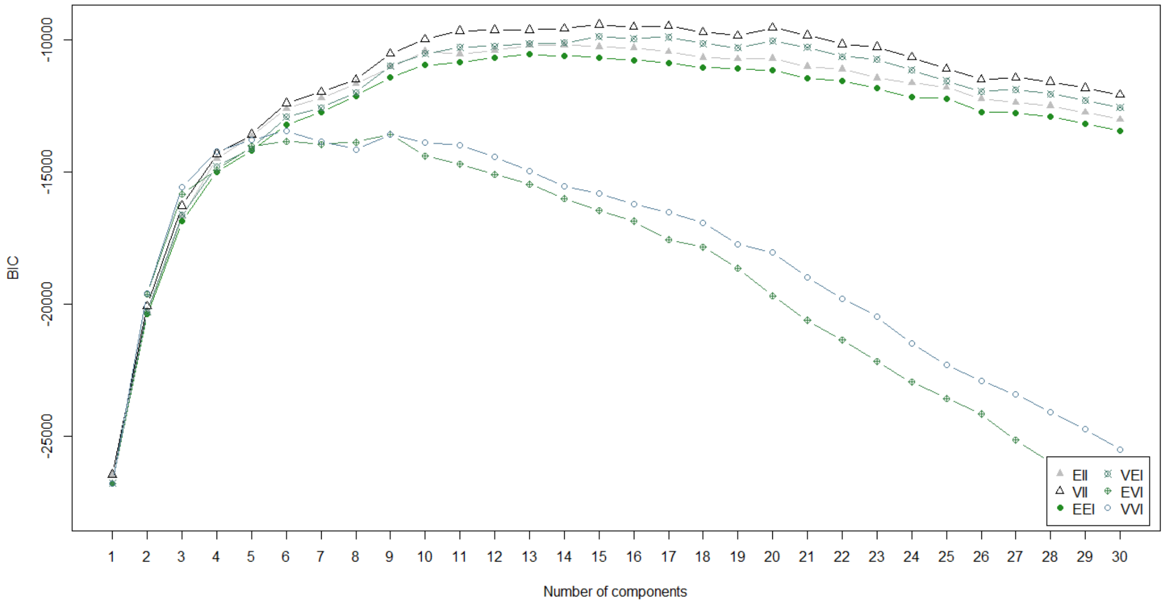

Fig. B.2. Bayesian information criterion (BIC) as a function of the number of clusters, calculated with the MClust package. Optimum at k=6 (for EVI and VVI models) or at k=11 for the other models.

APPENDIX C

Details of the Clustering Results

To interpret the 6 clusters, we observed the mean values of the selected indicators and compared pairs of clusters using Tukey Honest Significant Differences (TukeyHSD function in R). For each indicator, we identified the clusters with the largest and smallest means, or a mean value that did not differ significantly from the largest or smallest (Figure C.1).

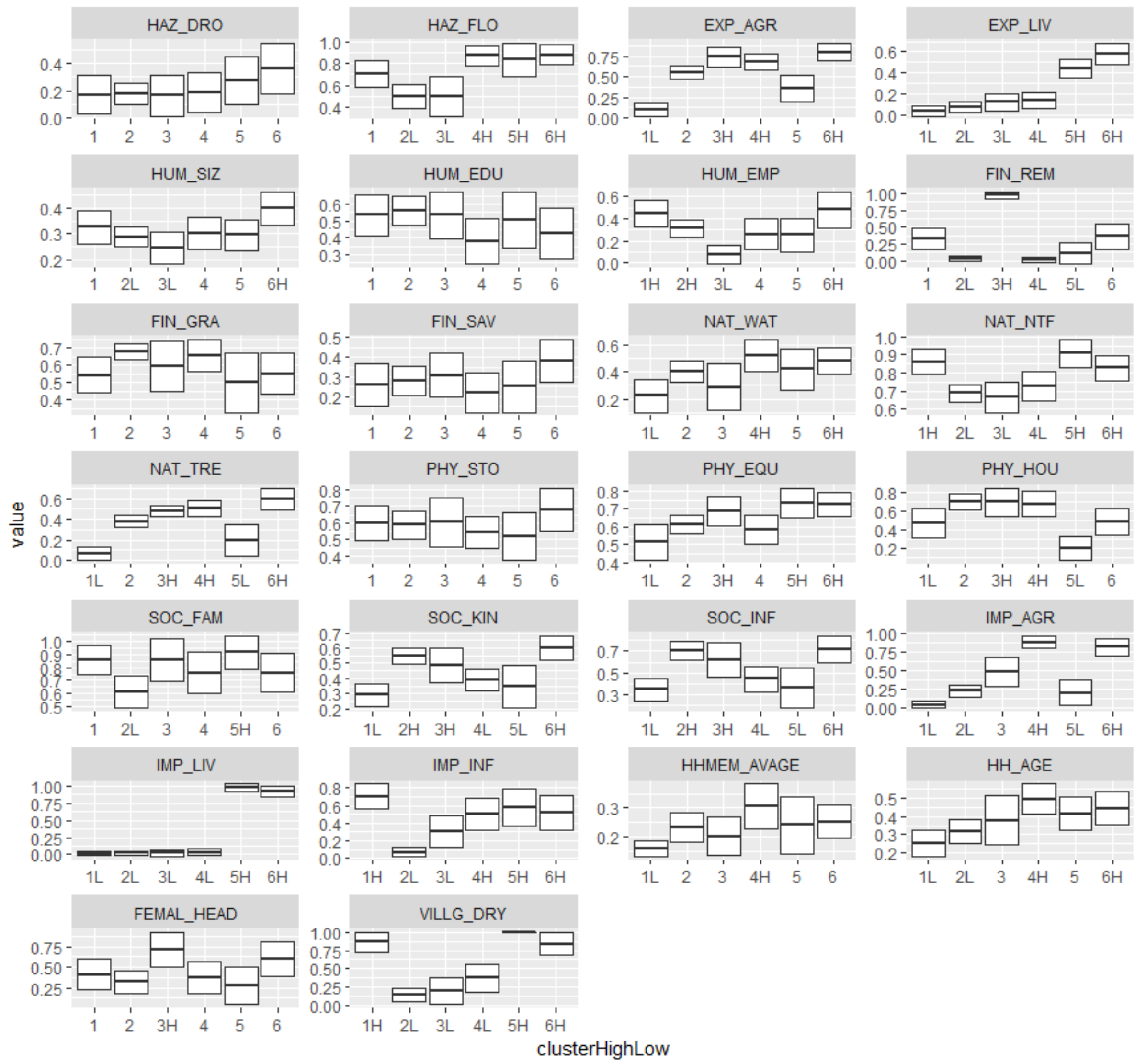

Fig. C.1. Mean values and confidence intervals (95%) of the variables for the 6 clusters (1-6). (When the letters L and H are attached to the cluster number (X axis labels), it shows whether the mean value of this cluster is the highest or lowest or is not significantly different from the highest or lowest). See Table 1 for variable codes (e.g. PHY_EQU = Physical capital: Equipment).

The clusters were interpreted qualitatively, using results from the household survey, PRA, key informant interviews and personal observations. The limited number of representative indicator combinations makes this qualitative interpretation possible (Sietz *et al.*, 2011[8]).

[8] Sietz, D., M.K.B. Lüdeke, and C. Walther, 2011: Categorisation of typical vulnerability patterns in global drylands. *Global Environmental Change*, **21**, 431-440, https://doi.org/10.1016/j.gloenvcha.2010.11.005

Supplementary Material

ESM 1: Possible Adaptation Measures

Workshop participants in both communities suggested possible measures to reduce the impacts of droughts and floods, based on previous experiences and responses (Table S.1).

Table S.1. Possible measures to reduce the impacts of droughts and floods

Adaptation need	Suggested measures
Improved water supply and storage infrastructure	Government should install infrastructure to pump and store water (e.g. boreholes, windmills, generators, and reservoirs) The community should dig communal wells, harvest rainwater, and use water sparingly
Improved access to healthcare	Government should improve access to healthcare facilities Healthcare providers and community members need first-aid training and information on treating illnesses exacerbated by drought (e.g. malnutrition, bilharzia, etc.) and floods (e.g. malaria, cholera, etc.) Traditional healers and households should collect, possibly cultivate, and store medicinal plants for future use
Improved infrastructure	Households need better construction materials and information on building flood-resistant homes, livestock enclosures, fences, etc. Government needs to improve the design, construction and placement of roads, bridges, electricity poles, government houses, etc., with community feedback, to reduce possible flood-damage
Improved access to extension services and information	The community needs information on measures to reduce drought and flood impacts (e.g. on drought-resistant crops and livestock, on constructing sturdier homes, on erosion control measures (including the prevention of vegetation-cover losses), etc.) Improved early warning systems are needed Government-sponsored, community-level groups/programs such as the government's Extended Public Works Program and Home-based Care need capacity-building

Improved land-use planning and management	Settlement planning should involve a community consultation process that considers previous flood levels and areas prone to waterlogging and landslides Grazing camps, with water points, should be established to manage grazing and prevent free-roaming livestock from being washed away along the river Sustainable rangeland management is needed to reduce the risk of conflict with the national park. During previous droughts, cattle-owners moved their livestock into the park for grazing. This would also improve NTFP availability. The community needs to account for floods and drought when planning where to cultivate. E.g. to reduce flood-related crop losses, people should avoid cultivating on steep slopes or along the river. However, cultivating along the river may reduce drought-related crop losses as the land is more fertile and irrigation is easier. Erosion control/flood prevention measures are needed (e.g. run-off channels, donga management, tree planting, etc.)
Improved/adjusted animal husbandry practices	Livestock numbers should be managed to avoid over-grazing and drought-related losses. Extra livestock should be i.) slaughtered, and the meat dried for future consumption, or ii.) sold, allowing for reinvestment and savings. Addressing barriers to livestock sales would encourage better herd management, allow households to accumulate savings, and limit drought-related losses Livestock health should be maintained, requiring improved access to inputs and veterinary support Government should provide fodder and/or livestock owners should cultivate, collect, and store grass/stover for feed Grazing land management - see section above
Improved/adjusted arable agriculture practices	Farmers should diversify their crops, planting drought-resistant species and those which can be processed (e.g. dried) and stored for future consumption Farmers should store seed, enabling them to replant in the event of flood- or drought-related crop failure Farmers should irrigate, fertilize, apply mulch, etc. to minimize drought-related crop failure Farmers should avoid cultivating land at risk of flooding, landslides, erosion, etc. and implement measures to avoid this damage (e.g. constructing run-off channels) The government should provide inputs such as shade nets, fertilizers, etc.
Improved food security (through storage)	Households should store food (including crops, meat, and wild foods) to buffer against drought-related shortages. This should be dried or canned as refrigeration is limited. Secure food storage facilities are required. Government should provide food parcels to vulnerable households

Improved management of natural resources	NTFPs should be sustainably harvested and stored for when needed (e.g. wild foods, traditional building materials and fencing poles) Vegetation cover should be maintained to protect natural water sources and avoid destructive run-off (i.e. overharvesting, overgrazing, wildfires, etc. should be avoided). The community should use water sparingly, re-using household grey-water for irrigation Government should minimize human-wildlife conflict by maintaining the fences with the national park, by managing wildlife numbers, by controlling problem animals, etc.
Livelihood diversification	Government should explore and support options for livelihood diversification, including off-farm livelihood strategies
Improved community institutions	The community should establish a community forum to monitor government construction projects to ensure they are well managed (e.g. engineers are aware of previous flood levels, proper materials are used, no corruption occurs, etc.)

CHAPTER 4

Perceptions of climate change in rural South Africa: Cognitive biases and the influence of household characteristics and location

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Perceptions of climate change in rural South Africa: Cognitive biases and the influence of household characteristics and location

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Abstract

Climate change is expected to challenge rural households' efforts to sustainably secure their livelihoods, making adaptation necessary. However, uncertainty exists regarding how best to promote local-level adaptation. Households' decision to adapt, and their adaptation responses, may be influenced more by the changes they perceive, than the actual climate trends. Understanding what factors shape these perceptions may provide insights into the measures needed to encourage and support successful adaptation. We explored local perceptions and experiences of climate change and variability in two rural villages, located in an arid and semi-arid region of South Africa's Limpopo Province. Using a mixed-method approach, including a participatory rural appraisal and household interviews, we explored the consistencies and divergences between the predominant perceptions and the meteorological data. Although the long-term precipitation and temperature trends may be too small to discern, climate change was widely perceived. These perceptions tended to diverge from the meteorological trends. They were not consistent across the sites, nor within each site. Households' engagement in land-based livelihoods, their experiences of local, climate-related challenges and extremes, and their access to irrigation and weather information influenced perceptions at the site-level. In the arid site, cognitive biases, related to previous drought-related losses, had an influence. These experience-based perceptions, combined with the fact that the climate trends are probably difficult to discern, may lead people to respond more to the climate extremes than to the trends. These findings suggest the need for locally-targeted climate change communications and support to ensure appropriate adaptation and climate-resilient communities.

Key words: Perceptions, climate change, participatory rural appraisal, rural livelihoods, South Africa

Introduction

Climate change is considered inevitable, with Africa's drier regions particularly vulnerable to impacts (Twomlow et al. 2008; Niang et al. 2014). For southern Africa, rainfall is generally expected to become more erratic, with a shorter rainy season, increases in inter- and intra-seasonal droughts, and more intense flood events, while mean annual temperatures are expected to increase (Cooper et al. 2008; Niang et al. 2014). Poor, rural communities in these areas, who rely on climate-sensitive livelihoods and ecosystem services, are expected to be worst affected (Reid and Vogel 2006; Twomlow et al. 2008). Climate change is likely to aggravate existing vulnerability levels, test households' resilience, and challenge their efforts to sustainably secure their livelihood outcomes (Ziervogel et al. 2008; Bunce et al. 2010; Connolly-Boutin and Smit 2016). Households will have to adapt to, at the very least, maintain their current levels of well-being (Muller and Shackleton 2014).

Adaptation, described as the "process of adjustment to actual climate and its effects" which, in human systems, seeks to "moderate harm or exploit beneficial opportunities", can be autonomous or externally driven (IPCC 2014: 118). Within the context of rural livelihoods, autonomous adaptation includes communities' and households' own adaptation responses to experienced or perceived climate change, whereas externally driven, or planned, adaptation includes programs driven by governments or other external parties, such as Ethiopia's Productive Safety Net Programme (PSNP) (Mersha and Van Laerhoven 2018). In either case, it has been suggested, that households' willingness to adapt is likely influenced by their identification, or at least perception, of climate change as a threat to their livelihoods (Brown & Westaway 2011; Bryan et al. 2013). For example, Mertz et al. (2009) found that Sahelian farmers who noticed a change in their local climate were more likely to change their agricultural practices. Some studies have proposed that households' perceptions may play a greater role in shaping their adaptation behavior than the actual climate patterns (Grothmann and Patt 2005; Keller et al. 2006; Leiserowitz 2006; Bryan et al. 2013). This has led to increasing efforts to better understand these perceptions, and the factors that shape them, with perceptions defined as the process by which people interpret and organize sensation to produce a meaningful experience of the world (Lindsay and Norman 1977).

Recent studies, including from South Africa (Thomas et al. 2007; Bryan et al. 2009; Gbetibouo 2009; Gandure et al. 2013; Muller and Shackleton 2014; Hitayezu et al. 2017), Zimbabwe (e.g. Moyo et al. 2012) and Botswana and Malawi (e.g. Simelton et al. 2013), suggest that although rural households perceive changes to their local climate, these perceptions often differ from the meteorological data. Concerns have been raised regarding this divergence and its implications on local-level adaptation, with possible explanations considered (Cooper et al. 2008; Slegers 2008; Rao et al. 2011). Although the local environment and its characteristics may influence perceptions (Muller and Shackleton 2014; Hitayezu et al. 2017), different groups within the same location may perceive climate change differently (Simelton et al. 2013). Influencing factors may include households' engagement in climate-sensitive activities and access to natural resources (Thomas et al. 2007; Osbahr et al. 2011); their access to extension services and weather information (Maddison 2007; Bryan et al. 2009; Deressa et al. 2009; Gbetibouo 2009; Mubaya et al. 2012); their access to irrigation (Gbetibouo 2009; Hitayezu et al. 2017); as well as various socio-demographic characteristics (including the gender, age and education of the household head) (Simelton et al. 2013; Hitayezu et al. 2017).

Cognitive biases, including affect (emotive factors) and availability (experiential factors) heuristics, have also been noted for their role in shaping perceptions (Tversky and Kahneman 1973; Slovic et al. 2004; Keller et al. 2006). In their South African study, Hitayezu et al. (2017) distinguish between experience- and description-based risk perceptions. Affect and availability heuristics are determinants of experience-based risk perceptions whereby peoples' perceptions, and subsequent decision-making, are influenced by an emotional response to recent climate events and extremes, rather than by expert opinion and information (i.e. description-based risk perceptions) (Keller et al. 2006; Leiserowitz 2006; Hitayezu et al. 2017). These cognitive biases may result in unsuitable adaptation responses, with some households over-estimating the risks while others, under-invest in their adaptive responses, being already risk-averse and resigned to their fate (Cooper et al. 2008; Slegers 2008; Rao et al. 2011). Several studies from South Africa highlight the influence of recent climatic stimuli and extreme events on farmers' perceptions and adaptation responses (e.g. Thomas et al. 2007; Muller and Shackleton 2014).

Understanding the factors that shape local perceptions of climate change, and that explain any discrepancies with the meteorological data, may help identify households' primary concerns related to their local climate, climate change, and its impacts on their livelihoods (Gandure et al. 2013; Simelton et al. 2013; Devkota et al. 2016). Divergences between perceptions and the meteorological data, may also reflect important, non-climatic issues and concerns

(Manandhar et al. 2012; Moyo et al. 2012). Understanding these nuances may provide insights into how households might adapt and help in the design and targeting of appropriate climate change communications and actions for the development of more climate-resilient communities (Keller et al. 2006; Reid and Vogel 2006; Twomlow et al. 2008; Otto-Banaszak et al. 2011; Wiid and Ziervogel 2012; Crona et al. 2013). Within this context, this study aims to contribute towards the growing body of perception-based studies, exploring the experiences and perceptions of climate change of two rural communities, in different agro-ecological zones, in South Africa's Limpopo Province. Focusing on climate-related shocks and long-term precipitation and temperature trends, the objectives of the study are to, i.) assess whether the local-level perceptions of climate change and variability reflect the meteorological data; ii.) explore whether these perceptions are uniform, both within, and across the two communities; and iii.) to consider possible explanations for any divergences, both between the perceptions and the meteorological data, and between the perceptions themselves.

Study Area

The study was conducted in two rural villages in Limpopo Province, one of South Africa's poorest provinces (SSA 2014). Bennde Mutale (327 households) and Vondo (340 households) lie approximately 90 km apart, within the Vhembe District Municipality. This area, previously located in a demarcated homeland area, remains characterized by low levels of service provision and development, with high unemployment rates and dependency ratios (SSA 2014). Limited access to, and availability of, productive land and assets, variable (and often extreme) weather conditions, food insecurity, and increasing living costs undermine households' efforts to secure a sustainable livelihood (Neves and Du Toit 2013; Venter and Witkowski 2013). Climate change is expected to exacerbate these challenges, with the area's small-scale farming systems already sensitive given low irrigation rates, poor access to inputs and limited extension support (Ofoegbu et al. 2016).

Bennde Mutale (31°1'48"E; 22°24'14"S; elevation: 308m) is characterized by an arid climate (IFPRI 2015). Dominant vegetation types include Musina Mopane Bushveld and Makuleke Sandy Bushveld (Mucina and Rutherford 2011). The village is bordered by neighboring communities and communal rangelands, the Kruger National Park, and the Madimbo military corridor. Vondo (30°21'60"E; 22°56'5"S; elevation: 1022m) is characterized by a semi-arid climate (IFPRI 2015). The dominant vegetation type is Soutpansberg Mountain Bushveld

(Mucina and Rutherford 2011). Vondo is surrounded by other communities, and pine and tea plantations. The sites were selected based on differences in mean climate, particularly mean annual precipitation, with Vondo receiving around 3 times more rainfall than Bennde Mutale. The two sites are henceforth distinguished as the “wet site”, Vondo, and the “dry site”, Bennde Mutale.

The key socio-demographic and socio-economic characteristics of the households in the two sites are described in Online Resource 1.

Methods

Data collection

Community- and household- level data

Qualitative and quantitative data were collected using complementary approaches, including a participatory rural appraisal (PRA), key informant interviews (KII) and a household survey (HHS).

The PRA was conducted through a series of voluntary workshops in each village. The same participants were invited to each workshop, to build on previous discussions. The PRA was designed to capture community perspectives on local livelihoods, on the overall vulnerability context, and to explore peoples’ perceptions and experiences of climate-related seasonality, shocks, and trends. Historical profiles, seasonal calendars, time trend exercises, and impact chain exercises were conducted (Dazé et al. 2009; Turnbull and Turvil 2012). For the historical profiles, participants detailed memorable events (e.g. floods and droughts) experienced since their villages were established (the wet site in 1901; the dry site in 1969). The seasonal calendar and time trend exercises explored perceived variations in, and connections between, pre-selected variables, including those related to climate and the main livelihood activities (Online Resource 2). The seasonal calendars were compiled for the year preceding the fieldwork. For the time trends, participants identified changes over the different decades from when their village was established. Impact chain exercises explored the impacts of floods and droughts (Paumgarten et al. 2018). The workshops were conducted in the local language, with the assistance of a trained group of enumerators/translators.

Semi-structured interviews were administered to 170 randomly-selected households, 85 per village, a quarter of households in each site. Using a community-based mapping exercise, conducted during the PRA, each village was subdivided into four sections, and an approximately equal number of households was interviewed from each section. A household was classified as a unit of people residing together, sharing meals. The interviews were conducted with a well-informed, resident adult, preferably the household head. Given the risk of inaccurate recall, the HHS focused on the decade preceding the fieldwork (2004-2013), while the PRA explored longer-term trends and community narratives. At the household-level, respondents were questioned on perceived changes in rainfall and temperature over the selected period, including whether i.) the amount of summer rainfall had increased, decreased or remained unchanged, ii.) the onset and cessation of the rainy season were unchanged, more erratic, or had shifted either earlier or later, and iii.) the wet season (summer) and dry season (winter) temperatures had increased, decreased or remained unchanged (Online Resource 3). Data were also collected on various socio-demographic indicators, on households' livelihood strategies, on their agricultural and animal husbandry practices, and their exposure to multiple stressors, including droughts and floods.

To triangulate the PRA and HHS data, KII were conducted with local farmers and livestock owners, village elders, traditional healers, local leadership, and agricultural extension officers.

Meteorological data

Since no weather station data were available, monthly precipitation data were extracted from CHIRPS v2.0 (Funk et al. 2015), which covers the latitude band 50°S–50°N at all longitudes, from 1981 to the near-present, at a 0.05° spatial resolution (available from http://chg.geog.ucsb.edu/data/index.html). This dataset incorporates monthly precipitation climatology CHPClim v1, infrared satellite observations from CPC and NCDC[9], TRMM[10] product, atmospheric model rainfall fields from CFSv2, and in situ precipitation observations obtained from a variety of sources including national and regional meteorological services. The relevance and applicability of this dataset, at this small spatial scale over South Africa, were evaluated by Van den Hoof et al. (2018). The temperature data were taken from the "Climate Data Guide: Global (land) precipitation and temperature" developed by Willmott

[9] National Climate Data Center (NCDC)
[10] Tropical Rainfall Measuring Mission (TRMM)

and Matsuura (1995). The data are available monthly over the period 1900-present at a resolution of 0.5°x0.5°. These data are based on land stations from GHCNv2 and a few other sources. The monthly rainfall data for the CHIRPS grid cells, and the monthly temperature data from the Climate Data Guide grid cells, which cover both sites, were retrieved. The two sites are located, for both variables, in different grid cells. Unless otherwise indicated, the acronyms above are defined in Funk et al. (2015).

Data analysis

We explored differences between the community and household-level perceptions of climate change and variability, and the actual meteorological observations. For extreme events and longer-term precipitation and temperature trends, the qualitative PRA data were evaluated against the recorded precipitation and temperature data for the 1981-2013 period. For this period, years with potential floods and droughts were arbitrarily defined as years with seasonal precipitation falling outside two standard deviations from the mean; i.e. these seasons were categorized “very wet” or “very dry”. Seasons with precipitation rates deviating by less than two, but more than one, standard deviation from the mean were categorized as “wet” or “dry”. Data on major historical floods and droughts experienced over the last century were taken from the literature. To allow for comparison with household-level perceptions, summer total precipitation and mean temperature (October to March) and winter mean temperature (April to September) (Mucina and Rutherford 2011), were computed from the monthly meteorological datasets. The trends for these variables were evaluated over two periods: 1981-2013 (the period for which the climate data is available) and 2004-2013 (the period covered in the HHS). Significant trends were determined using the Kendall tau test ($p=0.1$). The slope was computed based on the linear regression drawn through the yearly mean values of each variable over the given period. To evaluate the potential shift in the onset and cessation of the rainy season, the trend and variability in precipitation between September and November (SON), the expected onset period, and between February and April (FMA), the expected cessation period, were evaluated over a monthly and a 3-monthly period (Mucina and Rutherford 2011). To assess the potential change in variability in the onset and cessation of the rainy season, the standard deviation, and its normalized value by the mean over a 5-year moving window along the 1981-2013 period, was computed for the monthly and 3-monthly precipitation amount. Here again, trends and variability were evaluated for significance. Standard deviations were computed from the de-trended precipitation datasets.

For the household-level perception data (i.e. from the HHS), a Pearson's chi-squared test was used to identify significant ($p<0.05$) site-related differences in the respondents' perceptions of change in the selected climate variables, specifically in the amount of rainfall, the onset and cessation of the rainy season, and the summer and winter temperatures (Online Resource 3). Then, using R version 3.5.0 (R Core Team 2018), a multiple logistic regression (using least squares) was applied to find any relationship between the respondents' perceptions of change in these climate variables and a set of independent predictor variables related to the households' socio-demographic characteristics, main livelihood strategies, experience of floods and drought, and so forth. The regression was applied to the total dataset, and then to each site separately (Online Resource 4). For each model, Variance Inflation Factors (VIF) were computed to identify correlations between the predictor variables, with five variables subsequently removed due to moderate to high VIF values (VIF>4) (Online Resource 3). A MANOVA was used (with Pillai's trace as the post hoc test statistic) to determine which predictors were informative (Online Resource 5). As only ten of the 26 predictor variables contributed to the model, a reduced model was tested, however when the two models were compared (using an ANOVA), they were found to be generally equivalent. Given the similarities between the full and reduced models, the original set of 26 predictor variables was used for subsequent analyses. Additionally, basic descriptive statistics (including Pearson's chi-squared test and two sample t-test) were used to explore and compare the general socio-demographic and socio-economic characteristics of the households in each site. Consistencies and divergences between the perceived and observed trends were explored, using the PRA and KII data.

Results

Mean, trend and variability in precipitation and temperature based on meteorological datasets

The mean annual precipitation, for the wet and dry sites, over the 1981-2013 period, was 1108±371mm and 401±140mm, respectively (Figure 1). Both sites received summer rainfall although the dry site had a shorter rainy season. January was the wettest month. June and July were the driest months in the dry and wet sites, respectively. The wet site was cooler, with a mean annual temperature of 19.0°C, compared to 24.7°C in the dry site. The hottest months were December and January in the dry and wet sites, respectively. Both villages experienced their coolest weather in July. Monthly precipitation and temperature values for 2012-2013

(Figure 2) indicated the dry site's shorter rainy season and a significant precipitation excess in January 2013.

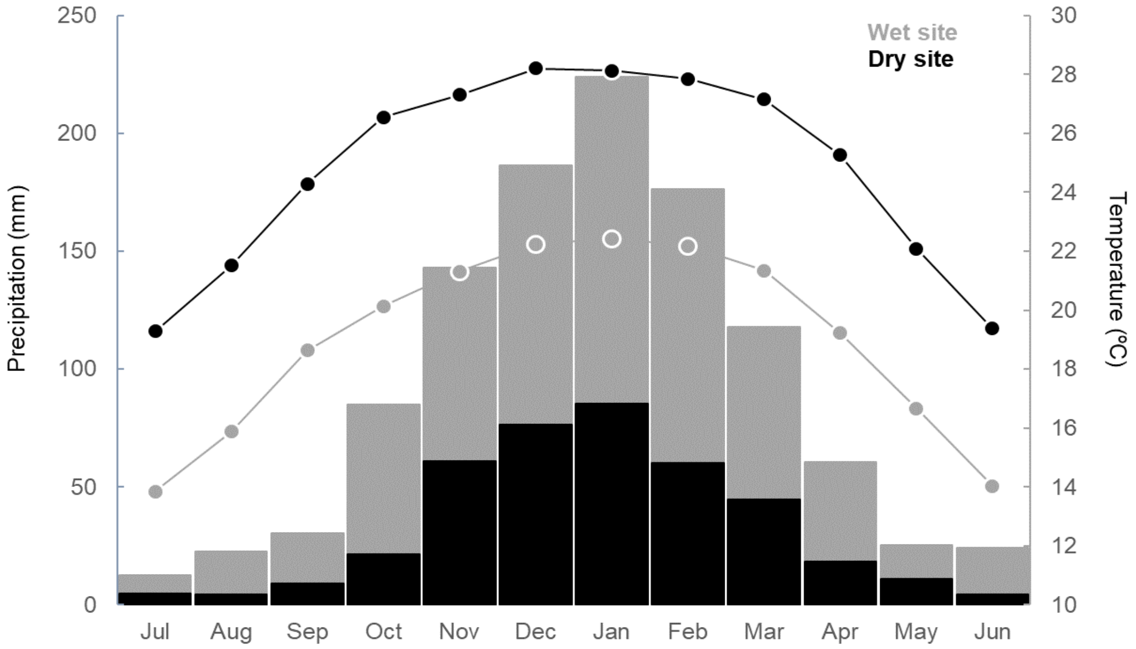

Fig. 1 Mean monthly precipitation (bars, mm) and temperature (lines, °C) for the wet and dry sites, from 1981-2013

Based on the climate dataset, although precipitation increased in both sites between 1981 and 2013, this was only significant ($p<0.1$) for the dry site for the 2004-2013 period (Figure 3). Neither site experienced a significant shift in the onset or cessation of the rainy season over the 1981-2013 period. However, for the 2004-2013 period, the wet site experienced a significant increase in precipitation over the whole SON period (not for the individual months), suggesting a wetter (possibly earlier) spring. As the values of the normalized standard deviation of the total precipitation during the SON (onset) and FMA (cessation) periods were smaller than 1, neither the onset nor cessation could be considered as notably erratic. Both the summer and winter temperatures decreased however the trends were only significant over the 1981-2013 period for both sites during the winter, and only for the wet site during the summer (Figure 3).

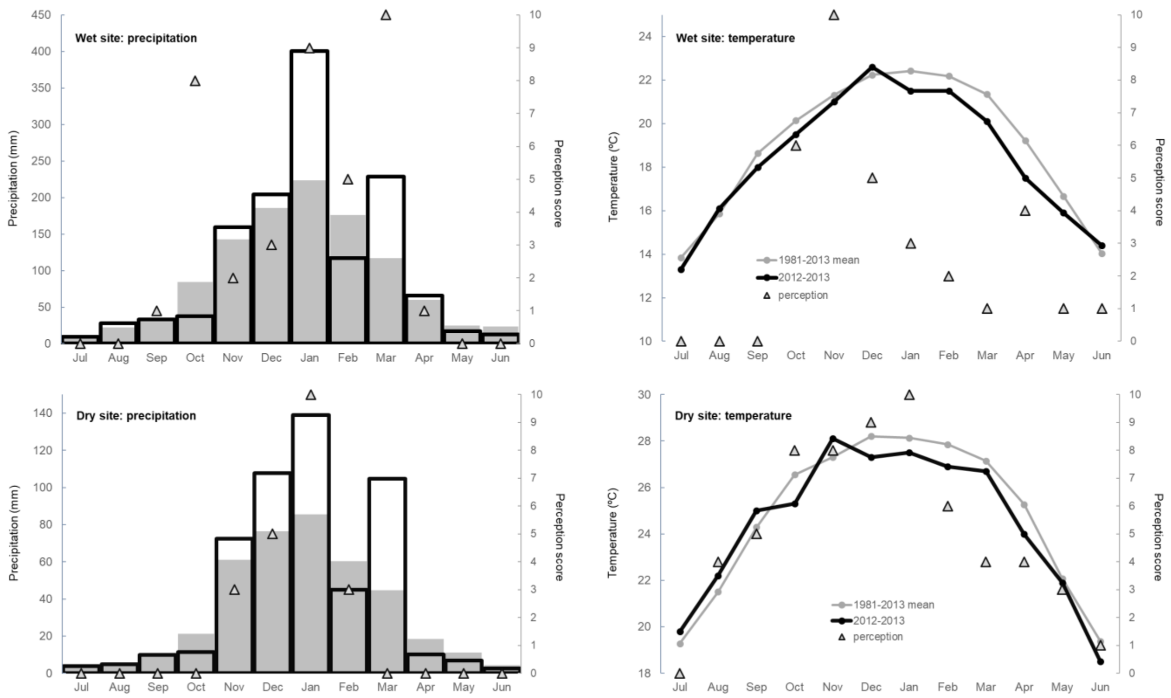

Fig. 2 Mean monthly precipitation (mm) and temperature (°C) for 2012-2013 (black-outlined bars and black lines) compared with the 1981-2013 means (grey bars and lines) (see Figure 1) for both the wet and dry sites. Community perceptions (from the seasonal calendar exercises) are indicated (Δ) with a perception score between 0 and 10, with 10 indicating high rainfall/temperature and 0 indicating no rainfall/low temperature, for the month in question (and relative to the other months) (Paumgarten et al. 2018)

Based on the 1981-2013 meteorological datasets, the summer of 1999/2000 was defined as very wet in both sites. Additionally, very wet summers were observed in the dry site in 1984/85 and 2010/11, and in the wet site in 2003/4 (Figure 3, Table 1). A wet summer was observed in both sites in 1995/6. Dry summers were observed in both sites in 1982/3, 1991/2 and 2004/5, and additionally in the dry site in 2001/2. No very dry summers were observed. For floods and droughts prior to 1980 and since each village was established, we drew from the literature (Dyer and Tyson 1977; Rouault and Richard 2003; FAO 2004; Washington and Preston 2006; Sheffield et al. 2009; Manatsa et al. 2011; SAWS 2016) (Table 1).

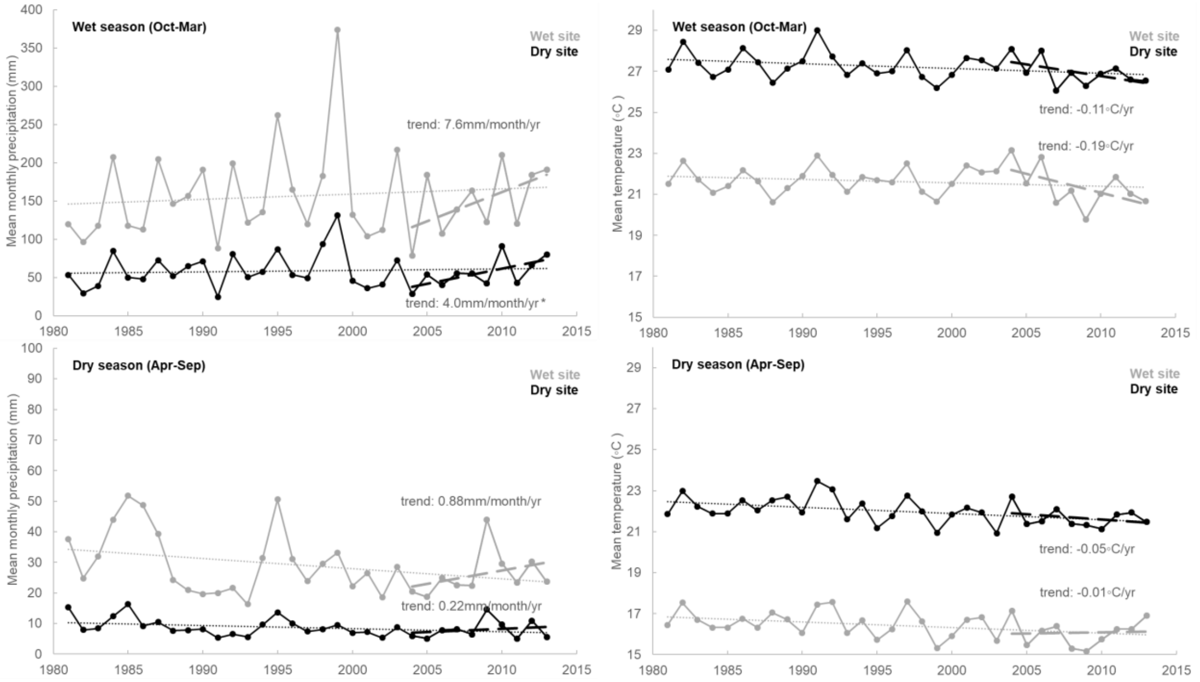

Fig. 3 Time series of mean monthly precipitation and temperature during the wet (summer) and dry (winter) seasons for the wet and dry sites, indicating the trends over the 1981-2013 (solid line) and 2004-2013 (dashed line) periods

Trends and variability perceived at community level and comparison with meteorological data

The dry site respondents perceived a declining trend in rainfall (since 1969), particularly in the wake of the 1980s and 1990s droughts (time trend exercises). There was less consensus in the wet site. Respondents, particularly in the dry site, perceived an increasingly unpredictable rainy season. Respondents in both sites suggested there were no long-term temperature trends, but rather decadal variability influenced by rainfall, with wetter decades considered cooler and drought decades, hotter. Generally, for both precipitation and temperature, the perceptions tended to diverge from the meteorological trends (Figure 3).

As a point of reference, and to better understand what factors shape perceptions of change in rainfall and temperature, PRA respondents were also asked to describe rainfall and temperature in the year directly preceding the fieldwork. These perceptions tended to correspond well with the meteorological data (Figure 2). For example, respondents in both sites correctly perceived the length of their respective rainy seasons. In both sites the rainy season was perceived to start once the monthly precipitation reached ~40mm/month, which was the precipitation rate of the month most frequently perceived as the onset month. The same limit was valid for the end of the season. Respondents in both sites accurately perceived the high rainfall (and flood event) of January 2013. In the wet site, respondents correctly perceived higher than average rainfall in October 2012, however perceptions of higher rainfall in March 2013 were possibly distorted by the drier-than-average February. According to the meteorological data, maximum seasonal temperatures were reached, in both sites, in December-January. This was correctly perceived in the dry site, with the wet site respondents perceiving a slightly earlier peak. July was correctly perceived as the coldest month in the dry site. Respondents in the wet site reported a longer winter (Figure 2).

Trends and variability perceived at the household-level and comparison with the meteorological data

For the 2004-2013 period, most respondents at the household-level (88%) perceived a change in the amount of precipitation (Table 2). Overall, 59% and 71% of respondents perceived a change to the onset and cessation of the rainy season, respectively. Most respondents (80%) perceived a change in summer temperatures while 68% perceived a change in the winter temperatures.

The nature of the change perceived was explored for the selected climate variables, with significant site-related differences noted (Table 2). Respondents in the wet site tended to perceive an increase in rainfall, despite no significant trend for the 2004-2013 period. Over half of the dry-site respondents perceived decreasing rainfall, contrary to the significant increase indicated in the meteorological data. The wet-site respondents tended to perceive no change to either the onset or cessation of rainy season, while their dry-site counterparts tended to perceive increasing unpredictability in both. According to the climate dataset, the timing of the rainy season had not become more erratic. This dataset solely showed a weak increase in precipitation in the wet site during spring, possibly implying an earlier spring. There were also significant site-related differences in respondents’ perceptions of change in the summer and winter temperatures. More respondents in the dry site perceived a decrease in the summer and winter temperatures, although the climate dataset showed no significant decrease in either for the 2004-2013 period. There was however a significant decrease in winter temperatures in both sites over the 1981-2013 period. Only 8.2% of wet-site respondents felt the winter temperatures had decreased.

Table 1 Recorded and perceived extreme events, particularly floods and droughts, grouped by each decade from 1900 until present (2013), with the wet site established in 1901 and the dry site in 1969. Local perceptions were gathered during the PRA (historical profiles and time trend exercises). (Time periods are designated differently: e.g. 2004-05 indicates a drought period of several months from 2004 to 2005, while 2005/6 indicates the experience of flooding towards the end of 2005, into early 2006)

Recorded events	**Local perceptions**	
	Wet site	**Dry site**
No data available in the 1910s	1901: village established 1908: flood	*No data as village only established in 1969*
1911-16: drought	1914: locust outbreak	
1926-27: drought	1924: locust outbreak	
1930-33: drought	1932-40: drought	
1941-42: drought 1946-47: drought	1945-48: drought 1948: flood	
1958: tropical cyclone	1953/4: flood 1958: severe hailstorm	
1963-65: drought 1966: tropical cyclone	1962: drought	1969: village established 1969: flood
1972: two tropical cyclones 1976: tropical cyclone 1977: tropical cyclone	1977: flood	1972/3: flood
1982-83: drought 1984: tropical cyclone	1983: drought	1982-83: drought
1991-92: drought 1995/6: flood 1997/8: flood	1992/3: worm outbreak	1992-93: drought
1999/2000: tropical cyclone 2001-02: drought[a] 2003/4: flood[b] 2004-05: drought 2008-09: drought	2000: flood 2005/6: flood 2008-09: drought	2000: flood 2005/6: flood[c]
2010/11: flood[b] 2013: flood	2013: heavy rains	2013: flood

[a] only recorded for the dry site
[b] only recorded for the wet site
[c] associated with tornado

Potential factors shaping perceptions at the household-level

Given the significant site-related differences in respondents' perceptions of change across the selected climate variables (Table 2), and that several of the predictor variables tend to be linked to site (Online Resources 1 and 6), we considered the two sites separately when exploring the relationship between perceptions of change and the set of predictor variables (Table 3 summarizing the variables with significant associations; Online Resource 4).

In the wet site, most of the predictor variables which showed an association with the respondents' perceptions of change, relate to the households' engagement in land-based livelihoods, their reliance on natural resources, and their previous experiences of floods and drought (Table 3). Respondents from households that cultivate tree crops and that have experienced drought were more likely to perceive a change in the amount of annual rainfall. Those from households with irrigation were more likely to perceive a change in both the onset and cessation of the rainy season. Changes in the cessation of the rainy season were also more likely to be perceived by respondents from households with fields and access to weather information, but less likely to be perceived by those from households selling agricultural produce. Changes in temperature were more likely to be perceived by respondents living in houses made of natural material, with grass roofing, and less likely to be perceived by those having experienced drought. Respondents from households impacted by floods or climate-related challenges to animal husbandry were more likely to perceive a change in the winter temperatures, as were those from households engaged in the sale of NTFPs and/or agricultural produce.

There was no association, in either site, between the respondents' perceptions and the age of the household, the gender and education of the household head, and the households' existing kinship networks. Households' engagement in off-farm livelihood strategies (including migrant labor), and their access to savings, also showed no significant association with the respondents' perceptions, except in the wet site where respondents in households receiving a government grant were more likely to perceive a change in winter temperatures.

Table 2 Site-related differences in household respondents' perceptions of changes in the amount of summer rainfall, the timing of the rainy season, and the summer and winter temperatures, with significant differences indicated ($p<0.05$), with the dominant perception in each site in bold, italics, and underlined, and with any significant meteorological trends (met. data) indicated (✓)

	Total (%) *(170HH)*	**Wet site (%)** *(85HH)*	**Dry site (%)** *(85HH)*	**df**	**X^2**	**p-value**	**Wet site** Met. data	**Dry site** Met. data
The amount of summer rainfall has:								
decreased	26.5	0.0	<u>***52.9***</u>	2	68.7	<0.05		
increased	<u>***61.8***</u>	<u>***90.6***</u>	32.9					✓
not changed	11.8	9.4	14.2					
The onset of the rainy season is:								
earlier	3.5	1.3	5.9	3	116.7	<0.05	✓	
later	4.1	8.2	0.0					
more erratic	<u>***51.8***</u>	12.9	<u>***90.6***</u>					
the same	40.6	<u>***77.6***</u>	3.5					
The cessation of the rainy season is:								
earlier	0.0	0.0	0.0	2	95.9	<0.05		
later	9.4	16.5	2.4					
more erratic	<u>***61.2***</u>	24.7	<u>***97.6***</u>					
the same	29.4	<u>***58.8***</u>	0.0					
The summer (rainy season) temperatures have:								
decreased	15.8	5.9	25.9	2	42.9	<0.05		
increased	<u>***64.2***</u>	<u>***55.3***</u>	<u>***72.9***</u>					
not changed	20.0	38.8	1.2					
The winter (rainy season) temperatures have:								
decreased	26.5	8.2	<u>***44.7***</u>	2	41.2	<0.05		
increased	<u>***41.2***</u>	<u>***40.0***</u>	42.4					
not changed	32.4	51.8	12.9					

Table 3 Summarized results, for the wet and dry sites, from the multiple logistic regression models used to explore whether there is a relationship between household respondents' perceptions of change in five selected climate variables, including the amount and timing of rainfall and summer and winter temperatures, and the selected set of household-level predictor variables. (For a description of the indicators, see Online Resource 3. For the full set of analyses, see Online Resource 4. Estimate (SE) values in bold indicate p<0.05)

	Climate Variables (dependent variables)									
	Amount of annual rainfall (RAIN_AMOUNT)		Start of the rainy season (RAIN_ONSET)		End of the rainy season (RAIN_CESSATION)		Summer (rainy season) temperatures (TEMP_SUMMER)		Winter (dry season) temperatures (TEMP_WINTER)	
Predictor variables	Estimate (SE)	t-value	Estimate (SE)	t-value	Estimate (SE)	t-value	Estimate (SE)	t-value	Estimate (SE)	t-value
Wet Site										
GOVT GRANT	-0.183 (0.22)	-0.82	0.273 (0.52)	0.53	0.255 (0.29)	0.89	0.747 (0.42)	1.78	**0.807 (0.38)**	2.11
NTFP SALE	0.247 (0.33)	0.76	0.651 (0.76)	0.86	-0.457 (0.42)	-1.09	0.534 (0.61)	0.87	**1.207 (0.56)**	2.16
AGRIC_FIELD	0.206 (0.12)	1.68	0.050 (0.29)	0.18	**0.337 (0.16)**	2.14	0.128 (0.23)	0.55	0.120 (0.21)	0.57
AGRIC_TREE CROPS	**0.800 (0.21)**	3.74	0.352 (0.50)	0.70	-0.418 (0.27)	-1.52	-0.201 (0.40)	-0.50	-0.311 (0.37)	-0.85
AGRIC_SALE	0.209 (0.15)	1.37	-0.049 (0.36)	-0.14	**-0.595 (0.20)**	-3.03	0.317 (0.29)	1.10	**0.772 (0.26)**	2.94
AGRIC_IRRIGATION	0.051 (0.20)	0.25	**0.987 (0.47)**	2.10	**1.214 (0.26)**	4.70	0.388 (0.38)	1.02	0.157 (0.35)	0.46
LIVST_CHAL _CLIMATE	0.440 (0.25)	1.77	0.095 (0.58)	0.16	0.121 (0.32)	0.38	0.513 (0.47)	1.10	**1.159 (0.43)**	2.72
WEATHER INFO	0.331 (0.28)	1.17	0.599 (0.66)	0.91	**1.264 (0.36)**	3.48	0.546 (0.53)	1.02	0.017 (0.49)	0.04
FLOOD EXPERIENCE	-0.325 (0.20)	-1.60	0.055 (0.47)	0.12	-0.481 (0.26)	-1.85	0.583 (0.38)	1.53	**0.720 (0.35)**	2.07
DROUGHT EXPERIENCE	**0.300 (0.14)**	2.07	-0.160 (0.34)	-0.48	-0.195 (0.19)	-1.05	**-0.748 (0.27)**	-2.75	**-0.622 (0.25)**	-2.50

ROOF_NATURAL	0.411 (0.23)	1.76	-0.641 (0.54)	-1.18	-0.553 (0.30)	-1.85	**1.055 (0.44)**	2.41	**1.085 (0.40)**	2.71
Adjusted R-squared	0.327		-0.053		0.475		0.112		0.252	
F-statistic$_{(24, 60)}$	2.702		0.825		4.169		1.439		2.180	
p-value	0.00		0.69		0.00		0.13		0.01	
Dry Site	Estimate (SE)	t-value	Estimate (SE)	t-value	Estimate (SE)	t-value	Estimate (SE)	t-value	Estimate (SE)	t-value
NTFP SALE	0.045 (0.19)	0.23	-0.191 (0.20)	-0.95	-0.024 (0.05)	-0.51	**-0.312 (0.13)**	-2.32	-0.034 (0.19)	-0.18
WEATHER INFO	-0.225 (0.19)	-1.21	-0.188 (0.19)	-0.98	-0.027 (0.05)	-0.58	0.001 (0.13)	0.01	**-0.529 (0.18)**	-2.90
Adjusted R-squared	-0.036		0.043		-0.193		0.045		0.067	
F-statistic$_{(25, 59)}$	0.882		1.153		0.457		1.157		1.242	
p-value	0.63		0.32		0.98		0.32		0.24	

In the dry site, none of the predictor variables explained the respondents' divergent perceptions related to the amount and timing of rainfall. In this site, only two variables showed a significant association with the respondents' perception of change (and only change in temperature). Respondents from households with access to weather information were less likely to perceive a change in winter temperatures, while those selling NTFPs were less likely to perceive a change in the summer temperatures.

Extreme events – floods and droughts perceived at community level and comparison with meteorological data

In both sites, the PRA respondents identified past floods, which generally corresponded well with recorded flood events, particularly recent events and regional floods associated with tropical cyclones (e.g. floods in 2000 and 2013) (Table 1, Figure 3). Drought events were also well remembered, with respondents in the wet site noting droughts going back a century prior to the fieldwork. Some recorded events were not noted: e.g. respondents in the dry site did not mention the 1984/85 and 2010/11 floods, while those in the wet site identified the 1990s as a particularly wet decade (time trend exercise), not mentioning the 1992-93 drought. Respondents in both sites suggested that the experience of floods and droughts was worse in the dry site. For example, while the dry site respondents noted severe floods in 2013, those in the wet site only noted "heavy rains", and while the dry site respondents perceived a 3-year drought in the 1980s, those in the wet site reported a one-year drought. Strong oral narratives were reported around these events, their immediate and long-term impacts, and how households coped (impact chain exercises). For example, the dry-site respondents attributed the site's settlement pattern (i.e. on higher ground away from the river) to floods experienced shortly after people first settled in the area. The severe droughts of the 1980s and 1990s were associated with changes in farming and livestock practices, with respondents noting a shift to cultivating smaller home-gardens, which are easier to irrigate by hand, and to more resilient livestock types (e.g. goats) (time trend exercises) (Online Resource 6). The dry site respondents associated droughts with greater hardship than floods, while those in the wet site perceived floods as more destructive.

Discussion

Trends and variability in local climate, in terms of the timing and amount of precipitation, as well as temperature, were widely perceived but differed from the meteorological data, with respondents inclined to perceive worsening conditions, such as a decrease in rainfall. As the gradual climate trends may be too small to discern from the local climate's natural variability, this wide perception of change needs to be better understood, particularly those perceptions that are diametrically opposite to the actual trends (e.g. respondents in our dry site perceived decreasing rainfall, rather than the actual increase) (Maddison 2007). Our results provide some insights into factors which may potentially explain this misalignment between local perceptions and the data.

The experience and impacts of extreme events and weather conditions influence perceptions of climate change. Although floods were more recently experienced in both sites, perceptions in the dry site appear to be more strongly influenced by the severe droughts of the 1980s and 1990s, with a decreasing precipitation trend perceived, instead of the actual increase. The long-lasting influence of these droughts on people's perceptions and practices suggests it is not necessarily recent events that influence perceptions, but rather the extent of impact on livelihoods, i.e. the affect heuristic outweighs the availability heuristic (Tversky and Kahneman 1973; Slovic et al. 2004; Keller et al. 2006). This may explain why the dry-site respondents did not report the 1984/85 floods, with their impacts overshadowed by those associated with the preceding drought. Conversely, in the wet site, respondents failed to mention the 1992-93 drought, instead describing the 1990s as a particularly wet decade, with their perceptions possibly shaped by the 1999/2000 floods. Studies from southern Africa and elsewhere, have similarly noted the influence of extreme events, and the strong, collective oral narratives associated with these, on perceptions (Thomas et al. 2007; Slegers 2008; Bryan et al. 2009; Mertz et al. 2009; Osbahr et al. 2011; Moyo et al. 2012; Gandure et al. 2013; Simelton et al. 2013; Muller and Shackleton 2014). The tendency to attach significance to these negative experiences may result in adaptation responses targeted at the extremes rather than the trends (Maddison 2007; Gbetibouo 2009; Bryan et al. 2013; Hitayezu et al. 2017). Similarly, in behavioral economics, studies refer to "myopic loss aversion", whereby investors base their decisions on short-term losses, failing to consider the bigger picture, often to the detriment of potential long-term gains (Kahneman and Lovallo 1993; Thaler et al. 1997).

The exposure of local livelihoods to climatic risks influences perceptions and may explain both the clear site-related divergence in the perceptions as well as divergent perceptions within each site (Slegers 2008; Osbahr et al. 2011; Simelton et al. 2013). For example, respondents in the wet site, particularly in households engaged in arable agriculture (and the cultivation of tree crops), were more likely to perceive the actual increase in precipitation than those in the dry site, because heavy rains were associated with the destruction of orchards, houses and roads. Both farmers and livestock owners in the wet site were more likely to report climate constraints to local food production than their dry site counterparts (see Online Resource 6), with respondents who reported climatic constraints to animal husbandry being more likely to perceive a change in winter temperatures. Other studies have also noted a link between perceptions and bio-physical vulnerability in higher rainfall areas, where heavy downpours have environmental and agricultural impacts, although the actual climate trends are often better perceived in these areas (Twomlow et al. 2008; Bryan et al. 2009; Osbahr et al. 2011; Rao et al. 2011; Mubaya et al. 2012; Gandure et al. 2013; Muller and Shackleton 2014; Hitayezu et al. 2017).

The sensitivity of local livelihoods to climatic risks may also explain perceptions, for example, the perceptions of temperature changes by respondents with grass-roofed houses, in the wet site. In the dry site, households' engagement in more climate-resilient, land-based livelihood strategies (e.g. livestock-rearing, NTFP collection/sale, and hand-irrigated, winter cultivation) may make them less sensitive to changes in precipitation, including the increase in rainfall. This may explain why, in the dry site, none of the selected household-level, predictor variables were associated with perceptions of change in either the amount or timing of rainfall. Cooper et al. (2008) argue that people in more risk-prone, arid environments have focused on mitigating negative impacts, rather than on strategies that take advantage of opportunities. The tendency of the dry-site respondents to perceive decreasing rainfall, rather than the actual increase, may be shaped more by the affect heuristic related to past droughts and by external factors/stressors such as overgrazing and poor water supply infrastructure, however to make an unequivocal statement, further research is required (Maddison 2007; Thomas et al. 2007; Mertz et al. 2009; Moyo et al. 2012; Simelton et al. 2013; Muller and Shackleton 2014). Although these cognitive biases and external factors may explain the dry-site respondents' perceptions of decreased rainfall, it is less clear what factors influence their perceptions of an increasingly erratic rainy season, suggesting the need for further research. While this may just indicate a tendency to perceive worsening conditions, other studies suggest that factors such as dry spells during key stages of a crop's production cycle have an influence (Bryan et al. 2009; Moyo et al. 2012; Simelton et al. 2013).

Our results show that respondents' perceptions were not related to the household's engagement in off-farm activities nor to the household's socio-demographic characteristics, despite other South African studies showing an association with characteristics such as gender and education of the household head (Gbetibouo 2009; Hitayezu et al. 2017). Access to inputs (specifically irrigation equipment and weather information) has an influence, particularly in the wet site where arable agriculture dominates. Although a large proportion of respondents in the wet site perceived no change to the predictability of the rainy season, those who did perceive a change, tended to be from households with access to irrigation. Further research would be needed to conclude whether these households invested in irrigation because of the changes perceived by its members. Given that the meteorological data indicates no significant shift to the timing of the rainy season, the influence of other factors (e.g. intra-seasonal dry spells) needs to be better understood. Although our dataset showed that respondents with access to weather information were more likely to perceive climate change and variability, discrepancies between these perceptions and the meteorological data suggest that this access hasn't necessarily improved the respondents' understanding of the specific changes occurring. As such there may be the need for more targeted and appropriate climate change communications, as well as improved access to data (including risk management models, etc.) (Bryan et al. 2009; Deressa et al. 2009; Gbetibouo 2009; Mubaya et al. 2012).

Some of the associations between the respondents' perceptions and the selected predictor variables were difficult to explain, suggesting possible limitations to the model. For example, it is unclear why, in the wet site, there is a link between households' access to government grants and the likelihood of respondents perceiving a change in winter temperatures. Households' engagement in the sale of NTFPs has an influence on perceptions of temperature change in both sites, however the nature of this association differs between the sites. The reasons for this would require further investigation. Although the community-level (PRA) data indicates an association between the experience of extreme events and perceptions of climate change, this is less clear when looking at the household-level data. For example, in the dry site there is no association between respondents' perceptions and their households' experience of floods and drought. There is an association in the wet site. The different timeframes used for the PRA and HHS may have an influence. Related to this is the possibility that farmers in higher rainfall areas are more susceptible to smaller changes in rainfall than their dry-site counterparts, with their perceptions therefore influenced by smaller, more frequent dry and wet spells, while households in more arid areas are influenced by significant, less frequent extremes (Hitayezu et al. 2017).

Conclusions

Trends and variability in local climate, in terms of the timing and amount of precipitation, as well as temperature, were widely perceived. Although recollections of recent intra-annual precipitation and temperature variations, and previous extreme events, were well aligned with the meteorological data, over a longer timeframe, perceptions tended to diverge from the meteorological datasets. The perceptions diverge strongly by location however, they are also not uniform within each site. At the site-level, perceptions are influenced by households' engagement in land-based livelihoods, and the exposure and sensitivity of these livelihoods, their access to inputs, specifically irrigation and weather information, and cognitive biases related to the experience of extreme events. Households' socio-demographic characteristics and engagement in off-farm activities have little influence on these divergent perceptions. Given the intra- and inter-site differences in perceptions, care should be taken in using perception-based studies for one location or group, to guide broader adaptation planning. Although lessons can be learnt from these nuanced perceptions, ultimately communities, households and individuals experience and prioritize climate risk differently, resulting in cognitive biases which make it difficult to draw clear conclusions. This suggests the need for caution in using subjective observations, such as perceptions, of local climate change for adaptation planning. To better support households' ability to make strategic, long-term decisions there is the need to better understand the non-climatic concerns and challenges which may confound peoples' perceptions and the need for more targeted and appropriate climate change communications and support.

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Compliance with Ethical Standards

Conflict of Interest: The authors declare that they have no conflict of interest
The necessary ethical clearance was obtained from the Research Office of the University of the Witwatersrand (H120803). All ethical standards were adhered to. Permission to conduct the research was obtained from the relevant local authorities and formal, free, prior, and informed consent was obtained from all the participants. Anonymity was assured.

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Online Resources

Online Resource 1 Description of the key socio-demographic and socio-economic characteristics differentiating the households in the wet and dry sites

There were no significant site-related differences in the age or size of the households (Table S1). There was no difference in the proportion of female-headed households, however the wet site had more educated household heads. Households in both sites engaged in off-farm livelihood strategies with government social grants being a common source of income. Significantly more wet-site households had savings. Households' land-based strategies differ significantly with animal husbandry being more prevalent in the dry site. Other site-related differences include households' dependence on natural water sources, their use of natural (informal) construction materials, and their access to weather information. In the dry site weather information is limited by poor phone, television, and radio reception workshops).

Table S1 Socio-demographic and socio-economic attributes differentiating households (HH) in the wet and dry sites, with significant differences indicated ($p<0.05$) (X^2-values are written in normal text; Z-values are italicized)

	Wet site *(85HH)*	**Dry site** *(85HH)*	X^2/*Z*	**p-value**
Age of HH *(years)*	20.8±1.4	19.5±1.1	*0.62*	0.537
HH size *(no. of members)*	4.7±0.2	5.3±0.2	*-1.84*	0.066
Education of HH head *(years)*	7.1±0.5	5.9±0.5	*1.66*	<0.05
HH with female-head (%)	43.5	42.4	0.02	0.877
HH with government grant (%)	90.6	84.7	1.36	0.244
HH with remitting migrant (%)	29.4	28.2	0.03	0.866
HH with employment (%)	45.9	49.4	0.21	0.645
HH with self-employment (%)	9.4	9.4	0.00	1.000
HH with formal/informal savings (%)	92.9	82.4	4.40	<0.05
HH with arable agriculture (%)	95.3	63.5	26.23	<0.05
HH with animal husbandry (%)	25.9	61.2	21.54	<0.05
HH uses NTFPs (%)	96.5	100.0	3.05	0.081
HH collects water from natural sources (%)	67.1	1.2	82.1	<0.05
HH collects water from communal taps (%)	41.3	98.1	63.8	<0.05
HH buildings have thatch roofs (%)	7.1	72.9	76.9	<0.05
HH with access to weather information (%)	92.9	47.1	42.6	<0.05

Online Resource 2 Pre-selected variables used for the seasonal calendar and time trend exercises (participatory rural appraisal)

Seasonal calendar exercise	Time trend exercise
Rainfall	Rainfall
Temperature	Temperature
Planting (fields)	Number of fields
Planting (home-gardens)	Number of home-gardens
Harvesting (fields)	Number of cattle
Harvesting (home-gardens)	Number of goats
Crop pests	Grazing availability
Crop sales	Water availability
Livestock diseases	Fuelwood availability
Grazing availability	Fuelwood use
Livestock sales	Wild food availability
Hungry season (food shortages)	Wild food use
Human diseases	Cost of living
Expenditure	Population size
Wild food use	Population health
Wild food sales	Available infrastructure
Fuelwood use	Employment opportunities
Fuelwood sales	Education levels

Online Resource 3 Description of the dependent and independent variables used in a multiple logistic regression to explore factors influencing households' perceptions of climate change in the wet and dry sites

Variable code	Variable description
Dependent variables	
RAIN_AMOUNT	Amount of annual (summer) rainfall has, i.) not changed, ii.) decreased, or iii.) increased
RAIN_ONSET	Onset of the rainy season is, i.) the same, ii.) earlier, iii.) later, or iv.) more erratic
RAIN_CESSATION	Cessation of the rainy season is, i.) the same, ii.) earlier, iii.) later, or iv.) more erratic
TEMP_SUMMER	Summer (rainy season) temperatures have, i.) not changed, ii.) decreased, or iii.) increased
TEMP_WINTER	Winter (dry season) temperatures have, i.) not changed, ii.) decreased, or iii.) increased
Independent (predictor) variables	
HH characteristics:	
HH AGE	HH was established, i.) <10, ii.) 11-20, iii.) 21-30, or iv.) >30 years ago
HH HEAD_GENDER	HH head is either female or male
HH HEAD_EDUCATION	HH head has, i.) no formal education, ii.) only a primary school education (1-7 years), or iii.) a secondary school education (8-12 years)
MIGRANTS	HH has at least one member who has migrated
KINSHIP	HH has kinship networks in the village
Off-farm livelihood strategies, income, and savings:	
OFF-FARM STRATEGIES	HH has a source of off-farm income (e.g. migrant remittances and/or formal, informal or self-employment)
GOVT GRANT	HH receives a government social grant (e.g. an old age pension, child care or disability grant)
SAVINGS	HH has access to formal (e.g. bank account) or informal (e.g. community savings club) savings

Land-based livelihood strategies:

NTFP USE	HH uses non-timber forest products (NTFPs)
NTFP SALE	HH sells NTFPs
AGRIC_TOTAL[a]	HH engages in arable agriculture
AGRIC_FIELD	HH cultivates a field
AGRIC_HOME-GARDEN[a]	HH cultivates a home-garden
AGRIC_TREE CROPS	HH cultivates exotic tree crops, or maintains indigenous fruit trees, on their stand
AGRIC_SALE	HH sells agricultural produce
AGRIC_SEASONAL[a]	HH cultivates, i.) throughout the year, ii.) only during the summer (rainy season) or, iii.) only during the winter
AGRIC_IRRIGATION	HH irrigates, either by hand (e.g. from buckets) or via piped irrigation
LIVESTOCK	HH owns livestock
LIVESTOCK_SALE	HH sells livestock

Challenges to arable agriculture and animal husbandry:

AGRIC_CHAL_CLIMATE	Climatic constraints are a challenge to arable agriculture
AGRIC_CHAL_OTHER[a]	Other constraints are a challenge to arable agriculture (e.g. weak input/output markets, etc. (Online Resource 6))
LIVST_CHAL_CLIMATE	Climatic constraints are a challenge to animal husbandry
LIVST_CHAL_OTHER[a]	Other constraints are a challenge to animal husbandry (e.g. weak input/output markets, etc. (Online Resource 6))
WEATHER INFO	HH has access to weather information (e.g. via a television, radio, or cellphone)

Experience of extreme events:

FLOOD EXPERIENCE	HH has experienced floods
DROUGHT EXPERIENCE	HH has experienced drought

Primary water sources and water storage:

WATER_NATURAL	HH collects water from natural water sources (e.g. rivers and springs)
WATER_TAPS	HH collects water from communal taps
WATER_STORAGE	HH stores water
Construction materials:	
ROOF_NATURAL	HH buildings are constructed with natural roofing materials (e.g. thatching grass)
WALL_NATURAL	HH buildings are constructed with natural wall materials (e.g. locally produced, mud bricks)

[a]Indicates variables removed due to collinearity (VIF>4)

Online Resource 4a-e Multiple logistic regression results for variables predicting households' likelihood of perceiving changes in the selected climate variables (i.e. the dependent variable, as described in Online Resource 3), with models for the total sample, the wet site and the dry site (p<0.05 in bold and underlined, with these cases summarized in Table 3) (NA indicates variables not defined because of singularities)

4a: Amount of annual rainfall (RAIN_AMOUNT)

	Total *(170HH)*				**Wet site** *(85HH)*				**Dry site** *(85HH)*			
	Estimate	SE	t-value	Pr(>|t|)	Estimate	SE	t-value	Pr(>|t|)	Estimate	SE	t-value	Pr(>|t|)
Predictor variables												
(Intercept)	2.258	0.85	2.67	**<u>0.01</u>**	1.483	0.63	2.34	**<u>0.02</u>**	1.768	1.30	1.36	0.18
HH AGE	0.092	0.06	1.49	0.14	0.091	0.07	1.22	0.23	0.124	0.13	0.95	0.34
HH HEAD_GENDER	-0.034	0.11	-0.30	0.76	-0.211	0.13	-1.63	0.11	0.043	0.20	0.21	0.83
HH HEAD_EDUCATION	0.018	0.07	0.25	0.80	0.066	0.10	0.68	0.50	-0.052	0.11	-0.47	0.64
MIGRANTS	-0.024	0.12	-0.20	0.85	0.272	0.15	1.87	0.07	-0.038	0.22	-0.17	0.86
KINSHIP	-0.684	0.65	-1.06	0.29	NA	NA	NA	NA	-0.588	0.76	-0.77	0.44
OFF-FARM STRATEGIES	0.190	0.12	1.59	0.11	-0.263	0.15	-1.73	0.09	0.290	0.19	1.55	0.13
GOVT GRANT	-0.173	0.16	-1.07	0.29	-0.183	0.22	-0.82	0.42	-0.136	0.25	-0.55	0.59
SAVINGS	-0.060	0.16	-0.38	0.71	-0.283	0.24	-1.19	0.24	0.083	0.23	0.37	0.72
NTFP USE	-0.395	0.38	-1.05	0.29	-0.362	0.31	-1.16	0.25	NA	NA	NA	NA
NTFP SALE	0.057	0.14	0.42	0.68	0.247	0.33	0.76	0.45	0.045	0.19	0.23	0.82
AGRIC_FIELD	0.024	0.12	0.20	0.84	0.206	0.12	1.68	0.10	-0.023	0.29	-0.08	0.94
AGRIC_TREE CROPS	0.210	0.16	1.34	0.18	0.800	0.21	3.74	**<u>0.00</u>**	-0.071	0.34	-0.21	0.83
AGRIC_SALE	0.289	0.15	1.94	**<u>0.05</u>**	0.209	0.15	1.37	0.18	0.435	0.46	0.95	0.35
AGRIC_IRRIGATION	-0.033	0.13	-0.24	0.81	0.051	0.20	0.25	0.80	0.095	0.23	0.42	0.67
LIVESTOCK	-0.144	0.16	-0.91	0.37	-0.566	0.28	-2.00	0.05	-0.125	0.22	-0.58	0.57
LIVESTOCK_SALE	0.159	0.17	0.91	0.36	0.146	0.28	0.52	0.60	0.175	0.24	0.74	0.46

AGRIC_CHAL_CLIMATE	0.162	0.14	1.18	0.24	-0.017	0.18	-0.10	0.92	0.146	0.23	0.63	0.53
LIVST_CHAL_CLIMATE	-0.145	0.17	-0.83	0.41	0.440	0.25	1.77	0.08	-0.167	0.28	-0.59	0.56
WEATHER INFO	-0.082	0.14	-0.60	0.55	0.331	0.28	1.17	0.25	-0.225	0.19	-1.21	0.23
FLOOD EXPERIENCE	-0.271	0.17	-1.60	0.11	-0.325	0.20	-1.60	0.12	-0.464	0.39	-1.21	0.23
DROUGHT EXPERIENCE	0.177	0.13	1.37	0.17	0.300	0.15	2.07	**0.04**	0.039	0.26	0.15	0.88
WATER_NATURAL	0.201	0.15	1.30	0.20	NA	NA	NA	NA	0.176	0.21	0.83	0.41
WATER_TAPS	-0.254	0.14	-1.79	0.08	-0.023	0.13	-0.17	0.86	-0.626	0.55	-1.13	0.26
WATER_STORAGE	0.180	0.28	0.65	0.52	-0.061	0.30	-0.21	0.84	0.694	0.61	1.14	0.26
ROOF_NATURAL	-0.109	0.15	-0.75	0.45	0.411	0.23	1.76	0.08	0.071	0.37	0.19	0.85
WALL_NATURAL	0.080	0.13	0.60	0.55	0.059	0.13	0.45	0.65	-0.087	0.27	-0.32	0.75
Adjusted R-squared	0.231				0.327				-0.036			
F-statistic	$2.956_{(26,143)}$				$2.702_{(24,60)}$				$0.882_{(25,59)}$			
p-value	0.00				0.00				0.63			

4b: Start of the rainy season (RAIN_ONSET)

	Total *(170HH)*				**Wet site** *(85HH)*				**Dry site** *(85HH)*			
	Estimate	SE	t-value	Pr(>|t|)	Estimate	SE	t-value	Pr(>|t|)	Estimate	SE	t-value	Pr(>|t|)
Predictor variables												
(Intercept)	2.137	1.47	1.46	0.15	-1.602	1.48	-1.09	0.28	3.622	1.35	2.69	**0.01**
HH AGE	0.040	0.11	0.37	0.71	0.177	0.17	1.02	0.31	0.064	0.13	0.48	0.63
HH HEAD_GENDER	-0.107	0.20	-0.55	0.59	0.103	0.30	0.34	0.74	0.041	0.21	0.20	0.84
HH HEAD_EDUCATION	0.193	0.12	1.58	0.12	0.207	0.23	0.90	0.37	0.201	0.11	1.76	0.08
MIGRANTS	-0.152	0.22	-0.71	0.48	0.047	0.34	0.14	0.89	-0.441	0.23	-1.91	0.06
OFF-FARM STRATEGIES	-0.040	0.21	-0.19	0.85	-0.067	0.35	-0.19	0.85	-0.142	0.19	-0.73	0.47
GOVT GRANT	0.316	0.28	1.13	0.26	0.273	0.52	0.53	0.60	0.422	0.26	1.64	0.11
SAVINGS	-0.403	0.28	-1.46	0.15	-0.776	0.56	-1.39	0.17	-0.306	0.24	-1.30	0.20

KINSHIP	-1.318	1.12	-1.18	0.24	NA	NA	NA	NA	-0.253	0.79	-0.32	0.75
NTFP USE	0.707	0.65	1.09	0.28	0.514	0.73	0.71	0.48	NA	NA	NA	NA
NTFP SALE	0.501	0.24	2.12	**0.04**	0.651	0.76	0.86	0.40	-0.191	0.20	-0.95	0.35
AGRIC_FIELD	-0.095	0.21	-0.46	0.65	0.050	0.29	0.18	0.86	-0.431	0.30	-1.45	0.15
AGRIC_TREE CROPS	-0.070	0.27	-0.26	0.80	0.352	0.50	0.70	0.48	0.53	0.35	1.53	0.13
AGRIC_SALE	-0.269	0.26	-1.04	0.30	-0.049	0.36	-0.14	0.89	0.196	0.47	0.41	0.68
AGRIC_IRRIGATION	0.554	0.23	2.40	**0.02**	0.987	0.47	2.10	**0.04**	-0.306	0.23	-1.32	0.19
LIVESTOCK	0.131	0.28	0.48	0.64	-0.145	0.66	-0.22	0.83	0.057	0.22	0.26	0.80
LIVESTOCK_SALE	0.045	0.30	0.15	0.88	-0.087	0.65	-0.13	0.89	0.105	0.25	0.43	0.67
AGRIC_CHAL_CLIMATE	-0.042	0.24	-0.18	0.86	-0.027	0.42	-0.06	0.95	0.153	0.24	0.64	0.53
LIVST_CHAL_CLIMATE	-0.112	0.30	-0.37	0.71	0.095	0.58	0.16	0.87	-0.508	0.29	-1.74	0.09
WEATHER INFO	-0.173	0.24	-0.72	0.47	0.599	0.66	0.91	0.37	-0.188	0.19	-0.98	0.33
FLOOD EXPERIENCE	0.173	0.30	0.59	0.56	0.055	0.47	0.12	0.91	-0.033	0.40	-0.08	0.93
DROUGHT EXPERIENCE	-0.245	0.23	-1.09	0.28	-0.160	0.34	-0.48	0.64	-0.062	0.27	-0.23	0.82
WATER_NATURAL	-0.810	0.27	-3.02	**0.00**	NA	NA	NA	NA	-0.322	0.22	-1.46	0.15
WATER_TAPS	0.520	0.25	2.11	**0.04**	0.247	0.31	0.80	0.43	-0.251	0.57	-0.44	0.66
WATER_STORAGE	0.184	0.48	0.38	0.70	0.559	0.69	0.81	0.42	-0.15	0.63	-0.24	0.81
ROOF_NATURAL	0.455	0.25	1.81	0.07	-0.641	0.54	-1.18	0.24	-0.054	0.39	-0.14	0.89
WALL_NATURAL	-0.509	0.23	-2.20	**0.03**	-0.245	0.30	-0.81	0.42	0.058	0.28	0.21	0.84
Adjusted R-squared	0.459				-0.053				0.043			
F-statistic	$6.488_{(26, 143)}$				$0.825_{(24, 60)}$				$1.153_{(25,59)}$			
p-value	0.00				0.69				0.32			

4c: End of the rainy season (RAIN_CESSATION)

	Total *(170HH)*				**Wet site** *(85HH)*				**Dry site** *(85HH)*			
	Estimate	SE	t-value	Pr(>|t|)	Estimate	SE	t-value	Pr(>|t|)	Estimate	SE	t-value	Pr(>|t|)
Predictor variables												
(Intercept)	2.357	0.79	2.98	**<u>0.00</u>**	0.397	0.81	0.49	0.63	2.116	0.32	6.58	**<u>0.00</u>**
HH AGE	-0.069	0.06	-1.20	0.23	0.082	0.10	0.86	0.39	-0.020	0.03	-0.62	0.54
HH HEAD_GENDER	-0.121	0.11	-1.15	0.25	-0.125	0.17	-0.75	0.46	0.029	0.05	0.60	0.55
HH HEAD_EDUCATION	0.025	0.07	0.37	0.71	0.035	0.13	0.28	0.78	0.008	0.03	0.30	0.77
MIGRANTS	0.096	0.12	0.83	0.41	0.276	0.19	1.48	0.14	-0.039	0.06	-0.71	0.48
OFF-FARM STRATEGIES	-0.074	0.11	-0.66	0.51	-0.284	0.19	-1.46	0.15	-0.014	0.05	-0.30	0.76
GOVT GRANT	0.153	0.15	1.01	0.31	0.255	0.29	0.89	0.38	0.076	0.06	1.24	0.22
SAVINGS	-0.049	0.15	-0.33	0.74	0.147	0.31	0.48	0.63	-0.048	0.06	-0.86	0.39
KINSHIP	-0.573	0.60	-0.95	0.35	NA	NA	NA	NA	-0.061	0.19	-0.33	0.75
NTFP USE	0.331	0.35	0.94	0.35	0.376	0.40	0.94	0.35	NA	NA	NA	NA
NTFP SALE	0.285	0.13	2.24	**<u>0.03</u>**	-0.457	0.42	-1.09	0.28	-0.024	0.05	-0.51	0.61
AGRIC_FIELD	0.271	0.11	2.43	**<u>0.02</u>**	0.337	0.16	2.14	**<u>0.04</u>**	0.019	0.07	0.27	0.79
AGRIC_TREE CROPS	-0.441	0.15	-3.01	**<u>0.00</u>**	-0.418	0.28	-1.52	0.13	0.017	0.08	0.20	0.84
AGRIC_SALE	-0.557	0.14	-3.99	**<u>0.00</u>**	-0.595	0.20	-3.03	**<u>0.00</u>**	0.048	0.11	0.43	0.67
AGRIC_IRRIGATION	0.662	0.12	5.33	**<u>0.00</u>**	1.214	0.26	4.70	**<u>0.00</u>**	0.018	0.06	0.33	0.75
LIVESTOCK	-0.001	0.15	-0.01	0.99	-0.104	0.36	-0.29	0.78	-0.017	0.05	-0.31	0.76
LIVESTOCK_SALE	-0.065	0.16	-0.40	0.69	-0.133	0.36	-0.37	0.71	-0.044	0.06	-0.76	0.45
AGRIC_CHAL_CLIMATE	-0.199	0.13	-1.55	0.12	-0.381	0.23	-1.65	0.11	-0.013	0.06	-0.23	0.82
LIVST_CHAL_CLIMATE	0.204	0.16	1.25	0.21	0.121	0.32	0.38	0.71	-0.004	0.07	-0.05	0.96
WEATHER INFO	0.111	0.13	0.86	0.39	1.264	0.36	3.48	**<u>0.00</u>**	-0.027	0.05	-0.58	0.56
FLOOD EXPERIENCE	-0.258	0.16	-1.63	0.11	-0.481	0.26	-1.85	0.07	-0.002	0.10	-0.02	0.99
DROUGHT EXPERIENCE	-0.100	0.12	-0.83	0.41	-0.195	0.19	-1.05	0.30	-0.049	0.06	-0.77	0.45

WATER_NATURAL	-0.293	0.15	-2.02	0.05	NA	NA	NA	NA	0.012	0.05	0.23	0.82
WATER_TAPS	0.093	0.13	0.70	0.48	0.008	0.17	0.05	0.96	-0.045	0.14	-0.33	0.74
WATER_STORAGE	-0.294	0.26	-1.14	0.26	-0.603	0.38	-1.59	0.12	0.012	0.15	0.08	0.93
ROOF_NATURAL	0.091	0.14	0.67	0.50	-0.553	0.30	-1.85	0.07	0.044	0.09	0.48	0.63
WALL_NATURAL	-0.073	0.13	-0.58	0.56	-0.063	0.17	-0.38	0.71	-0.020	0.07	-0.29	0.77
Adjusted R-squared	0.596				0.475				-0.193			
F-statistic	$10.581_{(26, 143)}$				$4.169_{(24,60)}$				$0.457_{(25, 59)}$			
p-value	0.00				0.00				0.98			

4d: Summer (rainy season) temperatures (TEMP_SUMMER)

	Total *(170HH)*				**Wet site** *(85HH)*				**Dry site** *(85HH)*			
	Estimate	SE	t-value	Pr(>|t|)	Estimate	SE	t-value	Pr(>|t|)	Estimate	SE	t-value	Pr(>|t|)
(Intercept)	1.761	1.02	1.72	0.09	-0.989	1.19	-0.83	0.41	2.13	0.90	2.36	**0.02**
HH AGE	-0.038	0.08	-0.52	0.61	-0.095	0.14	-0.68	0.50	0.1	0.09	1.11	0.27
HH HEAD_GENDER	-0.112	0.14	-0.82	0.41	-0.092	0.24	-0.38	0.71	0.101	0.14	0.73	0.47
HH HEAD_EDUCATION	0.084	0.09	0.99	0.32	0.199	0.19	1.07	0.29	0.058	0.08	0.76	0.45
MIGRANTS	0.000	0.15	0.00	1.00	0.027	0.27	0.10	0.92	-0.002	0.15	-0.01	0.99
OFF-FARM STRATEGIES	0.038	0.14	0.26	0.79	0.088	0.29	0.31	0.76	-0.018	0.13	-0.14	0.89
GOVT GRANT	0.315	0.20	1.61	0.11	0.747	0.42	1.78	0.08	-0.042	0.17	-0.25	0.81
SAVINGS	-0.081	0.19	-0.42	0.67	-0.108	0.45	-0.24	0.81	0.022	0.16	0.14	0.89
KINSHIP	-1.135	0.78	-1.45	0.15	NA	NA	NA	NA	-0.428	0.53	-0.81	0.42
NTFP USE	0.533	0.45	1.17	0.24	0.516	0.59	0.88	0.38	NA	NA	NA	NA
NTFP SALE	-0.085	0.17	-0.52	0.61	0.534	0.61	0.87	0.39	-0.312	0.13	-2.32	**0.02**
AGRIC_FIELD	0.115	0.15	0.79	0.43	0.128	0.23	0.55	0.58	-0.008	0.20	-0.04	0.97
AGRIC_TREE CROPS	-0.440	0.19	-2.32	**0.02**	-0.201	0.40	-0.50	0.62	-0.096	0.23	-0.41	0.68
AGRIC_SALE	0.210	0.18	1.16	0.25	0.317	0.29	1.10	0.28	0.352	0.32	1.11	0.27

AGRIC_IRRIGATION	0.282	0.16	1.76	0.08	0.388	0.38	1.02	0.31	0.1	0.16	0.64	0.53
LIVESTOCK	-0.117	0.19	-0.61	0.54	0.096	0.53	0.18	0.86	-0.168	0.15	-1.12	0.27
LIVESTOCK_SALE	0.152	0.21	0.72	0.47	-0.067	0.53	-0.13	0.90	0.053	0.16	0.32	0.75
AGRIC_CHAL_CLIMATE	0.039	0.17	0.24	0.81	-0.062	0.34	-0.18	0.86	-0.133	0.16	-0.83	0.41
LIVST_CHAL_CLIMATE	0.229	0.21	1.08	0.28	0.513	0.47	1.10	0.28	-0.125	0.20	-0.64	0.53
WEATHER INFO	0.069	0.17	0.41	0.68	0.546	0.53	1.02	0.31	0.001	0.13	0.01	1.00
FLOOD EXPERIENCE	0.238	0.21	1.16	0.25	0.583	0.38	1.53	0.13	-0.217	0.27	-0.82	0.42
DROUGHT EXPERIENCE	-0.457	0.16	-2.91	**0.00**	-0.748	0.27	-2.75	**0.01**	-0.21	0.18	-1.17	0.25
WATER_NATURAL	-0.042	0.19	-0.23	0.82	NA	NA	NA	NA	0.264	0.15	1.79	0.08
WATER_TAPS	-0.187	0.17	-1.09	0.28	-0.284	0.25	-1.14	0.26	0.101	0.38	0.26	0.79
WATER_STORAGE	0.141	0.34	0.42	0.68	0.391	0.56	0.71	0.48	-0.069	0.42	-0.16	0.87
ROOF_NATURAL	0.743	0.18	4.23	**0.00**	1.055	0.44	2.41	**0.02**	-0.05	0.26	-0.20	0.85
WALL_NATURAL	-0.267	0.16	-1.65	0.10	-0.316	0.25	-1.29	0.20	0.352	0.19	1.87	0.07
Adjusted R-squared	0.156				0.112				0.045			
F-statistic	$2.201_{(26, 143)}$				$1.439_{(24, 60)}$				$1.157_{(25, 59)}$			
p-value	0.00				0.13				0.32			

4e: Winter (dry season) temperatures (TEMP_WINTER)

	Total *(170HH)*				**Wet site** *(85HH)*				**Dry site** *(85HH)*			
	Estimate	SE	t-value	Pr(>|t|)	Estimate	SE	t-value	Pr(>|t|)	Estimate	SE	t-value	Pr(>|t|)
(Intercept)	2.026	1.12	1.81	0.07	-1.800	1.09	-1.66	0.10	2.519	1.28	1.97	0.05
HH AGE	-0.042	0.08	-0.52	0.60	-0.057	0.13	-0.45	0.65	-0.013	0.13	-0.10	0.92
HH HEAD_GENDER	-0.071	0.15	-0.47	0.64	0.258	0.22	1.16	0.25	-0.177	0.20	-0.91	0.37
HH HEAD_EDUCATION	0.064	0.09	0.69	0.49	0.247	0.17	1.46	0.15	0.076	0.11	0.70	0.49
MIGRANTS	0.079	0.16	0.48	0.63	-0.123	0.25	-0.49	0.63	0.254	0.22	1.16	0.25

OFF-FARM STRATEGIES	0.029	0.16	0.18	0.86	0.364	0.26	1.40	0.17	-0.084	0.18	-0.46	0.65
GOVT GRANT	0.035	0.21	0.17	0.87	0.807	0.38	2.11	**0.04**	-0.38	0.24	-1.56	0.13
SAVINGS	-0.094	0.21	-0.45	0.66	0.086	0.41	0.21	0.84	-0.163	0.22	-0.73	0.47
KINSHIP	-1.027	0.86	-1.20	0.23	NA	NA	NA	NA	-0.295	0.75	-0.40	0.69
NTFP USE	-0.038	0.50	-0.08	0.94	-0.108	0.54	-0.20	0.84	NA	NA	NA	NA
NTFP SALE	0.117	0.18	0.65	0.52	1.207	0.56	2.16	**0.04**	-0.034	0.19	-0.18	0.86
AGRIC_FIELD	0.171	0.16	1.08	0.28	0.12	0.21	0.57	0.57	0.217	0.28	0.77	0.44
AGRIC_TREE CROPS	-0.500	0.21	-2.41	**0.02**	-0.311	0.37	-0.85	0.40	-0.282	0.33	-0.85	0.40
AGRIC_SALE	0.501	0.20	2.54	**0.01**	0.772	0.26	2.94	**0.01**	0.105	0.45	0.23	0.82
AGRIC_IRRIGATION	-0.024	0.18	-0.14	0.89	0.157	0.35	0.46	0.65	-0.101	0.22	-0.46	0.65
LIVESTOCK	-0.035	0.21	-0.17	0.87	-0.279	0.49	-0.57	0.57	0.08	0.21	0.38	0.71
LIVESTOCK_SALE	-0.056	0.23	-0.24	0.81	-0.117	0.48	-0.24	0.81	-0.111	0.23	-0.48	0.64
AGRIC_CHAL_CLIMATE	0.161	0.18	0.89	0.38	-0.039	0.31	-0.13	0.90	-0.063	0.23	-0.27	0.79
LIVST_CHAL_CLIMATE	0.360	0.23	1.55	0.12	1.159	0.43	2.72	**0.01**	-0.078	0.28	-0.28	0.78
WEATHER INFO	-0.444	0.18	-2.42	**0.02**	0.017	0.49	0.04	0.97	-0.529	0.18	-2.90	**0.01**
FLOOD EXPERIENCE	0.342	0.23	1.52	0.13	0.72	0.35	2.07	0.04	-0.307	0.38	-0.81	0.42
DROUGHT EXPERIENCE	-0.387	0.17	-2.26	**0.03**	-0.622	0.25	-2.50	**0.02**	-0.005	0.26	-0.02	0.99
WATER_NATURAL	0.013	0.21	0.06	0.95	NA	NA	NA	NA	0.209	0.21	1.00	0.32
WATER_TAPS	-0.263	0.19	-1.39	0.17	-0.293	0.23	-1.28	0.20	0.31	0.55	0.57	0.57
WATER_STORAGE	0.289	0.37	0.79	0.43	0.911	0.51	1.80	0.08	-0.43	0.60	-0.72	0.48
ROOF_NATURAL	0.442	0.19	2.30	**0.02**	1.085	0.40	2.71	**0.01**	0.248	0.37	0.68	0.50
WALL_NATURAL	0.045	0.18	0.25	0.80	-0.017	0.22	-0.07	0.94	0.013	0.27	0.05	0.96
Adjusted R-squared	0.102				0.252				0.067			
F-statistic	$1.737_{(26, 143)}$				$2.180_{(24, 60)}$				$1.242_{(25, 59)}$			
p-value	0.02				0.01				0.24			

Online Resource 5 MANOVA results (NA indicates variables not defined because of singularities, which were removed from the respective site level tests)

Type II MANOVA Tests: Pillai test statistic									
	Total *(170HH)*			**Wet Site** *(85HH)*			**Dry Site** *(85HH)*		
	test stat	approx F	Pr(>F)	test stat	approx F	Pr(>F)	test stat	approx F	Pr(>F)
HH AGE	0.034	0.98	0.43	0.069	0.83	0.53	0.072	0.86	0.52
HH HEAD_GENDER (female)	0.012	0.34	0.89	0.110	1.38	0.25	0.027	0.30	0.91
HH HEAD_EDUCATION	0.023	0.66	0.65	0.052	0.61	0.69	0.067	0.79	0.56
MIGRANTS	0.018	0.52	0.76	0.109	1.38	0.25	0.092	1.11	0.37
KINSHIP	0.030	0.85	0.52	NA	NA	NA	0.033	0.38	0.86
OFF-FARM STRATEGIES	0.021	0.61	0.69	0.136	1.76	0.14	0.049	0.57	0.72
GOVT GRANT	0.036	1.03	0.40	0.110	1.38	0.24	0.122	1.52	0.20
SAVINGS	0.017	0.47	0.80	0.071	0.86	0.51	0.038	0.43	0.82
NTFP USE	0.028	0.80	0.55	0.055	0.65	0.66	NA	NA	NA
NTFP SALE	0.060	1.78	0.12	0.100	1.25	0.30	0.099	1.21	0.31
AGRIC_FIELD	0.065	1.94	0.09	0.120	1.53	0.20	0.062	0.73	0.60
AGRIC_TREE CROPS	0.118**	3.74	0.00	0.249**	3.72	0.01	0.067	0.79	0.56
AGRIC_SALE	0.160***	5.30	0.00	0.228*	3.31	0.01	0.049	0.57	0.72
AGRIC_IRRIGATION	0.170***	5.69	0.00	0.300**	4.81	0.00	0.051	0.59	0.71
LIVESTOCK	0.010	0.29	0.92	0.072	0.86	0.51	0.035	0.40	0.85
LIVESTOCK SALE	0.016	0.46	0.81	0.009	0.10	0.99	0.039	0.45	0.81
AGRIC_CHAL_CLIMATE	0.032	0.92	0.47	0.045	0.53	0.76	0.026	0.29	0.92
LIVST_CHAL_CLIMATE	0.041	1.20	0.31	0.133	1.73	0.14	0.074	0.88	0.50
WEATHER INFO	0.065	1.93	0.09	0.206*	2.90	0.02	0.162	2.13	0.08

FLOOD EXPERIENCE	0.068	2.03	0.08	0.186*	2.55	0.04	0.065	0.76	0.58
DROUGHT EXPERIENCE	0.081*	2.44	0.04	0.217*	3.10	0.02	0.026	0.29	0.91
WATER_NATURAL	0.077*	2.30	0.05	NA	NA	NA	0.145	1.86	0.12
WATER_TAPS	0.069	2.06	0.07	0.041	0.48	0.79	0.029	0.33	0.89
WATER_STORAGE	0.022	0.61	0.69	0.106	1.33	0.26	0.028	0.32	0.90
ROOF_NATURAL	0.130**	4.15	0.00	0.195*	2.70	0.03	0.071	0.84	0.53
WALL_NATURAL	0.062	1.84	0.11	0.050	0.59	0.71	0.016	0.18	0.97

Sign. codes: *p<0.05, **p<0.01, ***p<0.001

DF 1

num DF 5

den DF 139 (total), 56 (wet), 55 (dry)

Online Resource 6 Description of households' arable agricultural practices and the key constraints to local food production

Agricultural practices differ between the sites, with significant differences noted in the cropping seasons and management practices, specifically those related to irrigation, the application of fertilizers, and the storage of seed and crops (Table S2). A quarter of the dry-site farmers only cultivate during the winter when cooler temperatures allow for the cultivation of vegetables in small home-gardens. A significantly greater proportion of dry-site farmers irrigate although this is mostly done by hand (>10% have piped irrigation). Significantly more wet-site farmers apply fertilizers and store crops, with the latter suggesting they can produce a surplus (Table S2). A significantly greater proportion of dry site farmers store seed in response to limited access to agricultural inputs (Table S3). Maize is the main crop in both sites, however other crops are also cultivated, with the dry-site farmers cultivating less water-intensive crops (e.g. okra and sorghum) than farmers in the wet site (e.g. sugarcane and green peppers) (KII). The cultivation of exotic fruit trees (e.g. mango and avocado) is more common in the wet site, with some farmers owning extensive orchards.

Table S2 Significant site-related differences in arable agriculture practices, with significant differences ($p<0.05$) indicated

	Wet site (%) *(81HH)*	**Dry site (%)** *(54HH)*	**df**	X^2	**p-value**
Main cropping season:					
Throughout the year	8.6	51.9	1	31.5	<0.05
Summers only	91.4	24.1	1	64.0	<0.05
Winters only	0.0	24.1	1	21.6	<0.05
Management practices:					
Irrigation	12.4	83.3	1	67.6	<0.05
Fertilization	84.0	46.3	1	21.4	<0.05
Seed storage	26	57.4	1	13.6	<0.05
Crop storage	84.0	55.6	1	13.1	<0.05

Farmers and livestock owners in both sites identified challenges to food production. Climate-related constraints were more commonly reported in the wet site, although respondents in the dry site described insufficient rainfall as a key deterrent to engaging in arable agriculture (KII) (Table S3). The high price of agricultural inputs, and the distance to input markets, was a key constraint in both sites.

Table S3 Challenges to arable agriculture and animal husbandry in the wet and dry sites, ranked by the proportion of farmers (135HH) and livestock owners (74HH) reporting each challenge

	Arable Agriculture				Animal Husbandry			
Rank	**Wet site**	**% HH**	**Dry site**	**% HH**	**Wet site**	**% HH**	**Dry site**	**% HH**
1st	Poor input markets	86.0	Poor input markets	94.0	Poor input markets	100.0	Pests & diseases[a]	92.0
2nd	Climate constraints	**78.0**	Pests & diseases[a]	80.0	Climate constraints	**59.0**	Theft	69.0
3rd	Poor output markets	41.0	Climate constraints	**44.0**	Poor output markets; pests & diseases[a]	55.0	Poor input markets	65.0
4th	Pests & diseases[a]	40.0	Limited land availability	41.0	Limited water availability	14.0	Climate constraints	**31.0**
5th	Limited land availability	10.0	Poor output markets	17.0	Limited land availability	9.0	Poor output markets & limited land availability	19.0

[a] includes raiding by livestock and/or wildlife

CHAPTER 5

Prepare for the unanticipated: Portfolios of coping strategies of rural households facing diverse shocks

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Prepare for the unanticipated: Portfolios of coping strategies of rural households facing diverse shocks

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Abstract

High adaptive capacity enables households to cope with, and adapt to, climate change stresses. Climate change adaptation, now considered essential, is unlikely to completely negate households' need to cope, particularly given their broader vulnerability context. Efforts to improve households' adaptive capacity, need to consider this ongoing need to cope with multiple, often concurrent, and non-climate related shocks. An improved understanding of households' coping strategies, including the factors that influence their application, may support the design of locally relevant adaptation strategies. We, therefore, explored the influence of shock type, and household- and location-specific characteristics, on the use of various coping strategies. We report on semi-structured interviews, administered to 170 randomly selected households, and a participatory rural appraisal. The households fall within two rural villages in Venda, South Africa, selected, in part, because of notable differences in precipitation. Almost 90% of households reported the experience of at least one unanticipated shock over a prescribed 5-year period, with natural hazards reported by 42%. Although households reported a diversity of coping strategies, our results suggest that their choice of strategy is influenced by the type of shock experienced as well as various household-level characteristics, including access to human and financial capital. Households' access to natural and social capital allowed for the protection of *ex-ante* coping options. Overall, the findings suggest that households' response to shocks is not entirely reactive. Instead, when possible, households actively manage their coping strategy portfolio, both in response to the shock experienced and in anticipation of future shocks.

Highlights

- Coping responses are influenced by the shock experienced suggesting conscious coping choices
- The key role of savings for coping with natural hazards is concerning if these occur more frequently
- NTFPs were not often used to cope with natural hazards, suggesting limitations to this coping option
- Access to natural and social capital allows for the protection of households' assets and savings
- Households' access to human and financial capital affects their coping choices

Keywords

Coping; multiple shocks; natural hazards; non-timber forest products; participatory rural appraisal; rural households

1. Introduction

Rural households in sub-Saharan Africa inhabit a state of often persistent and complex uncertainty, which undermines their efforts to secure a sustainable livelihood (DFID, 1999; Hänke and Barkmann, 2017). Increasing climate variability and change is expected to exacerbate this uncertainty in livelihood procurement, reinforcing existing location-based inequalities (Castells-Quintana et al., 2018). Marginalized groups, including poorer, female-headed, and natural resource dependent households, are expected to be hardest hit (Shackleton and Shackleton, 2004; Börner et al., 2015; Djoudi et al., 2016; Flato et al., 2017). Within the context of climate change, there has been increasing focus on the need for adaptation, defined as the process of proactive adjustment, in either natural or human systems, in response to actual or expected climatic stimuli or their impacts, which moderates harm or capitalizes on beneficial opportunities (IPCC, 2014). Adaptation, however, is likely to involve a long-term process, particularly in marginal areas of developing countries, with households still required to cope with interim shocks, both climate-related and other. The Intergovernmental Panel on Climate Change (IPCC, 2014: p. 135), refers to the adaptation deficit, described as "the gap between the current state of a system and a state that minimizes adverse impacts from existing climate conditions and variability". Furthermore, although adaptation may ultimately reduce households' need to cope, it is unlikely to negate it completely, particularly given households' broader vulnerability context (DFID, 1999).

Rural households, in response to uncertainty, and given limited public safety-nets and poor access to formal, private insurance, have established various informal coping strategies. These consist of short-term responses to immediate threats, through which households, within the ambit of their available resources, aim to minimize the impact of the stress (Davies, 1993; Blaikie, 1994; Eriksen and Silva, 2009; Coulibaly et al., 2015; Mehar et al., 2016). Common strategies include the liquidation of assets (e.g. livestock); the reallocation of labor; changes in household spending and consumption; the use of formal and informal savings and loans and, the reliance on family and community-support networks (kinship), as well as external organizations (Corbett, 1988; Adger and Nelly, 1999; Dercon, 2002; Wong and Godoy, 2003; Dekker, 2004; Heemskerk et al., 2004; Cooper et al., 2008; Eriksen and Silva, 2009; Adimassu and Kessler, 2016; Hänke and Barkmann, 2017). More recently, attention has been drawn to the safety-net function of natural resources (including non-timber forest products (NTFPs)) and their role in smoothing consumption and income variations (McSweeney, 2005; Hunter et al., 2007; Paumgarten and Shackleton, 2011; Mugido and Shackleton, 2017; Mbiba et al.,2019).

Many studies distinguish between *ex-post* and *ex-ante* coping strategies, with the former described as reactive strategies and the latter, as more anticipatory, precautionary and active strategies, which could be considered as adapting rather than coping (Lazarus and Folkman, 1984; Davies, 1993; Adams et al., 1998; Cooper et al., 2008; McCarthy and Martello, 2010). Households' reliance on *ex-post* strategies is often framed within the context of limited control over their coping responses and limited alternatives, although some suggest that even these *ex-post* strategies require some degree of anticipation, for example, the liquidation of assets such as livestock, requires their initial, anticipatory accumulation (Cooper et al., 2008; Börner et al., 2015). Households may also purposefully turn to these *ex-post* options to manage their future insurance options, with Corbett (1988) arguing that households actively sequence and prioritize strategies. Despite the common bundle of responses, households' ultimate selection and application of coping strategies (whether *ex-post* or *ex-ante*), and their overall capacity to cope, has been argued to depend on multiple factors, including the nature and duration of the shock; individual household characteristics; as well as contextual factors such as access to public and financial services, natural resources and markets (Pattanayak and Sills, 2001; McSweeney, 2005; Osbahr et al., 2008; Wunder et al., 2014; Börner et al., 2015;

Tran, 2015; Gautier et al., 2016; Van Aelst and Holvoet, 2016). Although these informal coping strategies may prove effective in the face of small to medium idiosyncratic shocks, concerns exist over their ability to insure against large, covariate shocks, such as natural hazards, which affect several households simultaneously (Skoufias, 2003; Wong and Godoy, 2003; Heemskerk et al., 2004; McSweeney, 2005; Günther and Harttgen, 2009; Wunder et al., 2014). Increasingly frequent and intense covariate, climate-related shocks, may overburden households' existing coping portfolio, pushing households and communities beyond their capacity to cope and undermining their chances of responding to opportunities (Smit and Wandel, 2008; Börner et al., 2015; Coulibaly et al., 2015).

The IPCC (2014) focuses on the risk of climate-related impacts, with risk described as the potential for consequences, resulting from the interaction of vulnerability, exposure, and hazard. Vulnerability here, encompasses various elements, including the lack of capacity to cope and adapt (IPCC, 2014). As such, within the climate change context, there has been renewed interest in households' existing coping strategies, and the role they do, and can play, in enhancing households' adaptive capacity, described as the "ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences" (IPCC, 2014: 135) (Eriksen and Silva, 2009; Brockhaus et al., 2013, Börner at al., 2015; Hänke and Barkmann, 2017). Distinctions between coping and adapting are generally framed on the timescale of response, with coping considered a short-term adjustment while adaptation involves longer-term shifts (Davies, 1993; Vogel, 1998; Smit and Wandel, 2006; Osbahr et al., 2008). Others suggest that coping and adapting may overlap temporally, with coping strategies morphing into adaptation strategies, or with households using their coping strategies to adapt (Berkes and Jolly, 2001; Fabricius et al., 2007). The dichotomy between coping and adapting may therefore be misleading. Eriksen and Silva (2009) argue that supporting households' ability to both engage short-term coping strategies, and adapt to long-term risks, is critical to reducing vulnerability.

It is argued that an improved understanding of households' past responses to climate-related and other shocks, their existing coping options, the opportunities and constraints associated with these, as well as how households combine and protect their coping strategies, may provide useful insights into enhancing coping and facilitating adaptation, thereby reducing vulnerability (Eriksen and Silva, 2009; Cooper et al., 2008; Smit and Wandel, 2006; Fisher et al., 2010; Börner et al., 2015; Adimassu and Kessler, 2016; Mehar et al., 2016; Ofoegbu et al., 2016). Strengthening households' existing coping portfolio, is a possible means of facilitating early forms of adaptation (Cooper et al., 2008; Castells-Quintana et al., 2018).

We consider the nature and prevalence of multiple, unanticipated shocks, including natural hazards, experienced by rural households in Venda, South Africa. We explore the range and prevalence of coping strategies used in response to these shocks, and whether households apply these strategies randomly or selectively, in response to the shock. In addition to exploring whether shock type influences the strategy used, we consider whether a range of household characteristics and location have an influence. The null hypothesis is that households' coping strategies are applied randomly, irrespective of the shock, the households' location, and their socio-demographic and economic characteristics. Finally, we consider the respective coping strategies' limitations in buffering households against covariate, climate-related shocks. By exploring how households cope with shocks in general, and with climate-related events (specifically natural hazards) we aim to contribute towards the understanding of how climate change may impact on households' overall ability to cope, and to explore measures needed to support improved adaptive capacity.

The remainder of the paper is organized as follows: section two describes the study area, section three describes the data collection and analysis processes, section four describes and discusses the main findings, including i.) households' exposure to multiple shocks, ii.) households' use of, and preference for, specific coping strategies, iii.) the associations between the different shocks and strategies and, iv.) the determinants of the strategies used. Section five presents the main conclusions.

2. Study Area

The research was conducted in the villages of Bennde Mutale (31°1'48"E; 22°24'14"S) and Vondo (30°21'60"E; 22°56'5"S), in the Vhembe District Municipality of South Africa's Limpopo Province, one of the poorest provinces (Statistics South Africa, 2014; Paumgarten et al., 2018). Prior to South Africa's 1994 democratic transition, both villages fell within the Venda homeland. "Homelands" were territories set aside, under South Africa's apartheid policies, for the re-settlement of black South Africans (Thornton, 2002). These areas remain characterized by limited development, poor service provision, low education levels, high dependency ratios, and high unemployment rates, with state welfare grants and migrant remittances making an important contribution to households' income (Statistics South Africa, 2014; Ofoegbu et al., 2016). To secure their livelihoods, households engage in diverse, land-based and off-farm, livelihood strategies (Venter and Witkowski, 2013; Ofoegbu et al., 2016). Limited access to productive assets, a high incidence of HIV/Aids and food insecurity, and variable (and often extreme) weather conditions, including natural hazards such as droughts and floods, exacerbate household vulnerability (Neves and Du Toit, 2013; Venter and Witkowski, 2013; Shisana et al., 2014). Climate change is likely to intensify households' overall vulnerability context: projections for Vhembe district, include a 1-3°C increase in temperature and a 5-10% reduction in rainfall by the mid-21st century (DEAT, 2004; Turpie and Visser, 2013).

Bennde Mutale and Vondo consist of 327 and 340 households respectively and are representative of their neighboring communities (Table 1). Bennde Mutale is bordered by communal rangelands, conservation areas (e.g. the Kruger National Park) and a military corridor. Pine and tea plantations border Vondo. The dominant vegetation types include mixed Musina Mopane Bushveld and Makuleke Sandy Bushveld in Bennde Mutale and Soutpansberg Mountain Bushveld in Vondo (Mucina and Rutherford, 2011). Sites were chosen which display a minimum level of dependence on natural resources, including NTFPs, however Vondo falls within a more densely populated local municipality, with less access to unconverted land. Vondo however, has better access to the nearest, sizeable commercial center (i.e. Thohoyandou). Although both sites receive summer rainfall, the difference in mean annual precipitation was one of the primary criteria for the site selection, with Bennde Mutale and Vondo receiving, respectively, 402 ± 141mm and 1108 ± 371mm for the period 1981-2014 (Funk et al., 2015). Bennde Mutale is warmer, with a mean annual temperature of 24.7°C, versus 19.0°C for Vondo. Bennde Mutale is henceforth referred to as the “dry site”, and Vondo as the “wet site”. Natural hazards, including floods and droughts, are experienced in both sites.

Table 1 Summary profile of the two sites – socio-cultural attributes of sampled households (n=170) were compared - (*) indicates those variables with differences at $p<0.05$

	Dry Site		**Wet Site**
Av. number of people/household	5.3		4.7
Av. age of the household (years)	19.5		20.8
Av. age of the household members (years)	26.3		27.4
Av. education of the household members (years)	6.2		7.2
Female-headed households (%)	43.5		42.4
Electricity for lighting (%)	94.1		98.8
Firewood for cooking and heating (%)	100.0		95.1
Formal housing (%):			
~ brick walls	49.4		56.5
~ metal roofs	67.1	*	100.0
Water sources (%):			
~ communal taps	97.6	*	41.2
~ natural (rivers, springs, etc.)	28.2	*	98.8
Households owning livestock (%)	61.2	*	25.9
Households cultivating (%)	63.5	*	95.3
Households using NTFPs (%)	100.0		96.5
Households receiving migrant remittances (%)	28.2		29.4
Households receiving government grants (%)	84.7		90.6
Households with formally employed members (%)	29.4	*	16.5

3. Methods

3.1 Data collection

Quantitative and qualitative data were collected through a participatory rural appraisal (PRA), a semi-structured household survey, key informant interviews and personal observations. Following a livelihoods approach, data were collected on households' characteristics, their livelihood strategies, their access to different assets (i.e. natural, social, financial, human and physical capital, as described in the Sustainable Livelihoods Framework, (DFID, 1999)), their vulnerability context (including their exposure to various unanticipated shocks), and the coping strategies employed in response to these shocks. The PRA, conducted during voluntary community workshops, consisted of exercises, including the construction of seasonal calendars; historical profiles; time trends; and impact chains, which allowed for discussions on the community's overall vulnerability context (DFID, 1999; Dazé et al., 2009; Turnbull and Turvil, 2012). Respondents discussed the experience of common climate shocks, specifically floods and droughts, their impacts, as well as the measures households, and the community, have historically used to cope with them. The household survey was administered to 170 randomly selected households, 85 per village, and included questions on households' experience (over the preceding 5 years) of twelve common shocks identified during the PRA (Table 2). The focus was on unexpected shocks, for example, unexpected crop losses rather than predictable, seasonal crop shortfalls. Similarly, the costs associated with unpredictable social events (e.g. funerals) were considered, not those associated with more predictable, annual social events, including religious holidays. For each shock, households were asked to identify the coping strategies used, selecting from a list of twelve common strategies, also identified during the PRA.

3.2 Data analysis

We grouped the pre-selected shocks into four overarching groups, namely production, financial and human shocks as well as natural hazards (Table 2). The selected responses were grouped into 8 categories, and designated as either internal (e.g., adjustments to household savings or consumption) or external (e.g., assistance from outside the household) strategies.

The first analysis examined whether the type of shock experienced influences the coping strategies used. We represented the frequency of reported shocks and coping strategies in mosaic plots, highlighting associations between shocks and strategies (Fig. 1). For the second analysis, we used a multivariate analysis to explore whether the adoption of a coping strategy was influenced by explanatory variables related to site and/or household characteristics (Table A.1). These variables fell into 5 categories, namely: 1.) basic household descriptors related to location and the demography of the household, 2.) available savings and assets (capital stocks) (financial and physical capital), 3.) access to kinship and community-support networks (social capital), 4.) livelihood strategies and income sources, and 5.) labor availability (human capital). Some skewed explanatory variables were log-transformed before the analysis. We used a logit linear model to explain the use of a strategy. In R3.3.2, the “step” function was used to select variables for the model. The function started from a full model and successively dropped or added variables to minimize the AIC score. We reported the significant variables ($p<0.05$) of the final model and described whether they had a positive or negative effect on the strategy used.

4. Results and Discussion

4.1 Households’ exposure to multiple shocks

Production shocks were the most commonly reported (Table 2). Multiple factors caused crop and livestock losses (workshops). For example, in the wet site, respondents noted crop losses from pest outbreaks while, in the dry site, livestock is occasionally killed by wildlife escaping the neighboring conservation areas, and cross-border cattle rustling occurs, driven by neighboring Zimbabwe’s economic crisis (Thornycroft, 2017). Crop and livestock losses were also associated with extreme temperatures and unpredictable rainfall. Production shocks included the loss of, or damage to, household infrastructure and assets, including, for example, termite damage to food/seed storage facilities.

Table 2 Percentage of households (HH) using a coping strategy (in rows, either external or internal) among the households reporting a shock (in columns)

Shocks	**All shocks** (152 or 89% of all HH)	**Production shocks** (127 or 75% of all HH)	**Human shocks** (100 or 59% of all HH)	**Financial shocks** (67 or 39% of all HH)	**Natural hazards** (71 or 42% of all HH)
Description of shocks (prior to clustering)		Crop and livestock losses; crop and livestock pests/diseases; loss of agricultural/grazing land; damage to HH infrastructure/assets	Increase in the number of dependents; death of a HH member; serious/chronic illness or injury	Loss of remittances and wages; failure of self-owned business; expenditure on social events	Floods, droughts, strong winds, etc.
External Strategies					
Kinship	***80***	66	58	73	53
External Assistance (from government or NGOs)	***79***	64	59	22	63
Loans	***18***	15	3	18	6
Internal Strategies					
Savings	***80***	79	54	72	69
Labor Reallocation (local employment or outmigration)	***67***	42	57	48	21
Spending Reductions (reducing cash expenses or quantity/quality of meals)	***66***	55	44	31	21
Natural Products (NTFPs)	***41***	33	25	19	1
Asset Depletion (of manufactured assets or livestock)	***27***	23	13	19	8

Human shocks were the second most commonly reported. Although primarily associated with increased dependents, these shocks included the death of household members, and serious illnesses/injuries, resulting in reduced labor availability (of the patient or primary caretaker) and/or expensive medical treatment. For example, respondents in both sites reported an increase in HIV-Aids and diabetes, with one elder explaining that historically, it was unusual for young adults to die, with this no longer being the case. An increase in dependents is a complex shock, resulting in increased pressure on the household's existing resources, while simultaneously (potentially) increasing access to government social grants.

The experience of impacts associated with natural hazards, was reported by 42% of households. Both sites experienced floods in 2013, the year preceding the fieldwork, with the dry site worst affected, receiving more rainfall in one week, than its annual average (Du Preez and Seale, 2013; Pringle et al., 2013). These floods, caused by a tropical low-pressure system, were associated with multiple, simultaneous impacts, including production, human and financial shocks (workshops), which may therefore, have been more commonly reported than usual. For example, crops, livestock, irrigation pumps, agricultural and grazing land, and NTFPs were washed away, community infrastructure was damaged, and houses collapsed, damaging assets and food/seed stores. In the dry site, temporary job losses occurred when a nearby tourist camp was closed due to flood damage. Incidences of malaria and cholera increased. Other natural hazards and their associated impacts, were also reported, including hail and strong winds (including a tornado in the dry site). In the wet site, landslides destroyed several orchards.

Financial shocks were the least commonly reported, and included the loss of income from wages, remittances, government grants, and money earned through self-employment.

For example, in the dry site, the closure of a nearby mine resulted in job losses. Respondents noted the failure of locally-owned businesses, with one household having to close their tuck-shop when a bigger store opened in the village, while another claimed that their business, raising and selling chickens, failed because households preferred, and had access to, bushmeat. Financial shocks were also associated with expensive social events such as weddings, funerals, and initiation ceremonies.

Only 11% of households reported having not experienced any shocks during the 5-year period while 71% of households reported the experience of two or more shocks during the same period.

4.2 External and internal household coping strategies

4.2.1 External coping strategies

Kinship was the most commonly reported external, and overall, coping strategy, with households seeking assistance from family and community support networks (e.g. religious groups and informal savings clubs) (Table 2). Seeking external assistance from government and non-government organizations (NGOs) was also common and included post-disaster assistance related to the 2013 floods and support through existing agricultural extension, food aid, and healthcare programs. The remaining external strategy was seeking loans, with this being the least common strategy overall. Some households received loans from formal money-lending institutions or their employers, but most sought loans from local loan sharks or informal, community-based savings groups. Some local shops sold goods on credit.

4.2.2 Internal coping strategies

Drawing from household savings was the most common internal coping strategy, with households drawing from investments in formal institutions (e.g. banks) or informal community-based savings groups and burial societies. Labor reallocation and household spending reductions were reported by similar proportions of households. Labor reallocation included migration in search of work and casual, community-based work in exchange for money or goods. For example, some farmers affected by the floods, employed people to repair their fences and replant. Household spending reductions included reductions in the quantity and/or quality of meals consumed. According to respondents, wealthier households were able to cut spending on “luxury” items while poorer households were forced to cut “essentials”.

Forty-one percent of households relied on the safety-net function of natural products (e.g. NTFPs) from non-cultivated ecosystems. For example, in the dry site, one woman started selling mopane worms after her husband was retrenched while fencing poles were harvested to replace flood-damaged fences. In both sites, people relied on medicinal plants to treat human/livestock diseases. Although not the most common strategy, relying on NTFPs, was more common than the sale of assets (internal) and loan seeking (external). Livestock was the most commonly sold asset, sold within the community and externally. Respondents indicated that selling small stock, particularly goats, was easier. Assets such as televisions and radios were also sold. The limited reliance on asset depletion, suggests households are reluctant to decapitalize, have limited disposable assets, or that market barriers exist.

4.3 Associations between shocks and strategies

Households’ coping response is influenced by the type of shock experienced. Although all the coping strategies were reported for all the shocks, certain strategies were either positively or negatively associated with certain shocks. This would not be the case if households were choosing responses randomly. This suggests that households make conscious coping choices, preferring to use certain strategies in response to certain shocks (Table 2; Fig. 1). Other studies have also noted the influence of shock type on households’ coping response, suggesting the need for either a few effective strategies, or a diverse coping portfolio (Takasaki et al., 2004; Wunder et al., 2014; Börner et al., 2015; Mugido and Shackleton, 2017). Asset depletion was the only strategy neither positively nor negatively associated with any of the selected shocks.

Although widely used, kinship was only significantly, positively associated with financial shocks, with households possibly relying on their social capital to tide them over until other livelihood and coping options come into play. Loan-seeking, also an external strategy, was also positively associated with financial shocks. Labor reallocation was positively associated with human shocks, but negatively associated with production shocks and natural hazards. Given the risks associated with migration, households may resort to labor reallocation to cope with the long-term challenge of an increase in dependents (human shock) but prefer to retain their labor locally to recover from more short-term disturbances related to production shocks and natural hazards (Davies and Hossain, 2000; Osbahr et al., 2008; Gao and Mills, 2018). Ofoegbu et al. (2016) found migration to be an uncommon response to drought in Venda. Others, however, have identified migration as a prevalent response to climate-related shocks, raising concerns of increasing climate change refugees (Börner et al., 2015). Natural products appear to be more useful for coping with production shocks that temporarily affect food supplies and infrastructure, rather than natural hazards. Other studies indicate a greater contribution of NTFPs towards coping with natural hazards (Takasaki et al., 2004; Liswanti et al., 2011; Wunder et al., 2014; Tibesigwa et al. 2016).

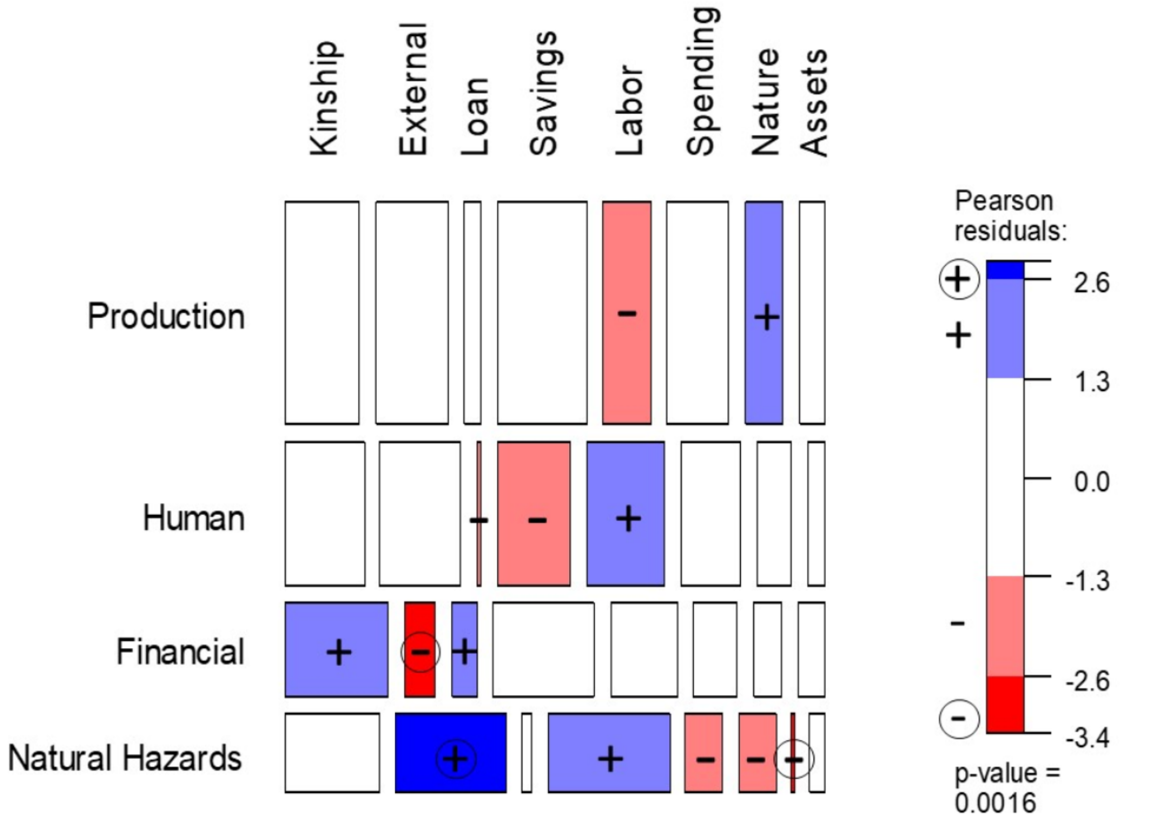

Fig 1: Mosaic plot of the frequency of reported shocks and coping strategies, indicating positive and negative associations between each shock and strategy. Each box is associated with a shock (left list) and a strategy (top list). The height of a box is proportional to the number of reports of the corresponding shock, while the width is proportional to the number of times a strategy was reported for this shock. Box colors show the outcome of an independence test using Pearson residuals to highlight associations between the shocks and strategies. Blue boxes or plus signs indicate positive residuals (i.e. this strategy was used more for this shock than expected, if the shock and strategy were independent variables) and red boxes or minus signs indicate negative residuals. Bright blue (or bright red) boxes (with circled plus or minus signs) indicate residuals with absolute values exceeding a critical value (95% percentile in the distribution of absolute Pearson residuals). For the sake of simplicity, boxes with absolute residuals below 50% of this critical value are white. The plot was drawn with the vcd package in R and the distribution of absolute Pearson residuals was calculated with the function coindep test of this package (Meyer et al., 2016).

Relying on external assistance was logically, positively associated with natural hazards (e.g. floods), and negatively associated with more idiosyncratic, financial shocks. Drawing from household savings was the only internal coping strategy that was positively associated with natural hazards. Poor households, with limited savings, are therefore more likely to resort to less optimal alternatives (Kazianga and Udry, 2006; Mugido and Shackleton, 2017). Furthermore, increasingly frequent, and intense natural hazards, may undermine households' ability to save, and their capacity to cope with other shocks and day-to-day expenses (Adimassu and Kessler, 2016). Castells-Quintana et al. (2018) argue that weather insurance may help ensure household savings do not get exhausted coping with natural hazards. Households used savings despite government's post-disaster assistance, with respondents suggesting limitations to government's support, including limited capacity and funds, corruption, and poor infrastructure, challenges also noted by Twomlow et al. (2008). Government support services may become increasingly strained in the face of climate change, increasing pressure on households' internal, coping options (Dercon, 2002; Gao and Mills, 2018). Given that household-level strategies may insufficient in buffering against natural hazards, strengthening external social safety-nets is essential for maintaining household welfare (Gao and Mills, 2018).

Households' informal, *ex-post* coping options may be insufficiently robust for the covariate nature of natural hazards, with households' therefore relying on external assistance and *ex-ante* options (i.e. drawing from household savings). Internal coping strategies, including the reliance on natural products, labor reallocation, and household spending reductions, were all negatively associated with natural hazards, suggesting limitations to their safety-net function. For example, respondents associated droughts and floods with reduced NTFP availability, increased competition for scarce resources, and the need to travel further to harvest and market, challenges noted by Boafo et al. (2016) and Ofoegbu et al. (2016).

Although households may store NTFPs, these stores may be insufficient in the face of prolonged droughts, while recent floods damaged households' storage facilities. Furthermore, in the immediate aftermath of natural hazards, households may be unable to reallocate labor to the collection and sale of NTFPs. Households possibly choose strategies that provide more immediate relief (e.g. drawing from savings), turning to NTFPs later (e.g. to rebuild houses), with this delayed use not captured in our survey. Labor reallocation, by means of outmigration, is only beneficial if the migrant finds work, undermining the usefulness of this strategy for coping with the immediate impacts of natural hazards (Gao and Mills, 2018). Given the costs of migrating, this strategy may be unavailable to more vulnerable households (Castells-Quintana et al., 2018). Respondents identified a few local job opportunities related to the recent floods, with households and government employing people to assist with repairs. The option to reallocate labor may be undermined by decreased health (and therefore human capital) associated with flood-related incidences of malaria and cholera and drought-related hunger and weakness. Households may also need to retain their labor to recover locally.

Although kinship, loans and asset depletion were neither positively nor negatively associated with natural hazards, these strategies also have limitations in the face of covariate shocks. Kinship networks and informal, community-based savings clubs may be strained if several members require support simultaneously (Ligon et al., 2002; Börner et al., 2015; Gao and Mills, 2018). Informal money lenders (operating in the absence of formal credit facilities) may be unable to provide sufficiently large loans to numerous afflicted households. Where loans are relied on, increasingly frequent and intense natural hazards may result in repeat borrowing, leading to greater indebtedness (Castells-Quintana et al., 2018). The option to sell assets may be limited when several households try to offload assets simultaneously (Kazianga and Udry, 2006; Börner et al., 2015). Households may be unable to sell their assets quickly enough, or for a reasonable price, if supply outweighs demand. This coping option is undermined by asset losses associated with these natural hazards (Ngigi et al., 2015; Mehar et al., 2016; Hänke and Barkmann, 2017). For example, respondents in both sites reported livestock losses resulting from droughts and floods, with one respondent noting that these losses are “a problem because we lose our insurance for other things”. Finally, asset depletion undermines households’ future production and coping options (Del Ninno et al., 2016). Other studies highlight the limitations of these local, informal insurance options for coping with covariate shocks, with poor households, with limited alternatives being hardest hit (Andrade Pérez et al., 2010; Börner et al., 2015).

4.4 Determinants of the coping strategies used

4.4.1 Kinship and external assistance – informal and formal social safety-nets

Kinship was not used exclusively by households with limited coping alternatives. Households with formal savings and livestock were more likely to rely on kinship to cope, suggesting that households with *ex-ante* coping options, avoid depleting their resources and future coping potential, relying instead on essentially free, *ex-post* strategies such as kinship (Table 3). Households with labor occupied in NTFP collection, possibly more vulnerable households with fewer options, were also more likely to rely on kinship. Households with self-employed members were, however, less likely to do so, possibly being more self-sufficient. The nature of households’ kinship networks influenced their coping choices. Households with family support networks avoided spending reductions but still applied for loans and depleted assets (possibly within their networks). Households with only non-family kinship networks were more dependent on their savings. These results suggest the need for nuanced considerations of the nature of kinship networks; i.e. although kinship is an *ex-post* strategy, it is influenced by the nature of households’ existing social capital and their capacity to reciprocate. Others also suggest that households with better social capital, cope better (Adimassu and Kessler, 2016; Ofoegbu et al., 2016). Overall, kinship was a common strategy, used irrespective of location and demography, and as part of a suite of strategies (Paumgarten and Shackleton, 2011; Boafo et al., 2016; Mugido and Shackleton, 2017; Mbiba et al. 2019).

With respect to external assistance, from government or NGOs, larger households, and those with a high proportion of children were less likely to rely on this option. Assuming these households are more vulnerable, this raises concerns of formal social safety-nets not reaching those most in need, with the World Bank (2010) suggesting these social safety-nets are critical for supporting households adapt to climate change. It is possible that these households may not require external assistance due to their access to child-care grants. Households with formal savings were also more likely to rely on external assistance, supporting the argument that external assistance may not be reaching those most in need. Households with a high equipment value (i.e. asset rich households) were however, less likely to rely on external assistance.

Table 3 Summary of the effect of location and household characteristics on the use of coping strategies. Only variables with a significant positive (+) or (-) negative effect are described (p<0.05)

	Kinship	External assistance	Loans	Savings	Labor reallocation	Spending reductions	Natural products	Asset depletion
Location…HH is located in the dry site						+		-
Demography…HH is:								
Older				+		-		+
Larger		-	-			+		+
Female-headed							-	-
Has a high proportion of children		-	-		-	+		
Capital stocks…HH has/owns:								
Formal savings	+	+	-				+	
Informal savings				-			-	
Livestock	+					-		
Equipment of high value (total)		-				-		
Kinship networks…HH has:								
Family kinship networks			+			-		+
Non-family kinship networks				+				
Off-farm livelihoods…HH has a high number of members who are:								
Formally employed				+				
Self-employed	-				+			
Remitting migrants			+		+	+		
Non-remitting migrants								+
Land-based livelihoods…HH sells:								
NTFPs				-		+	+	-
Crops								-
Livestock				+			+	+
Labor availability…HH spends more time collecting:								
NTFPs	+		+		-			
Water						+		-

4.4.2 Household savings and loans

Although drawing from household savings was the most common internal coping strategy, households endeavor to protect their financial capital by engaging alternatives. Households with *ex-ante* formal savings still relied on *ex-post* coping strategies, including kinship, external assistance, and natural products. Alternatively, households' savings are insufficient, and a bundle of strategies is required. Households who have had the time (i.e. older households) and income (i.e. through formally employed members and livestock sales) to accumulate savings, were more likely to draw from savings. Households' ability to save is undermined by limited sources and amounts of income (Mugido and Shackleton, 2017). Households with only non-family kinship networks were also more likely to rely on their savings. Households selling NTFPs were less likely to rely on savings, possibly reflecting the safety-net function of NTFPs, or that households selling NTFPs have limited savings. As with kinship, there is the need for a more nuanced understanding of the insurance function of household savings, including savings type. For example, households with informal savings were less likely to draw from these for unanticipated shocks. Informal, community-based savings clubs often have conditions to use, making them better suited to more anticipated periods of hardship (Paumgarten and Shackleton, 2011).

Generally, *ex-post* loan-seeking was limited to households with remitting migrants, a possible indicator of better access to, and awareness of, loan facilities. Ofoegbu et al. (2016) found poor access to credit to be a major challenge for households in Venda. This lack of access to financial products, including credit facilities, hinders households' ability to both cope and adapt (Börner et al., 2015; Castells-Quintana et al., 2018). Households with family kinship networks also relied on loans, possibly receiving these from within their networks. Larger households and those with a high proportion of children were less likely to seek loans. Assuming these are more vulnerable households, they may lack the resources to access and repay loans. However, households with labor engaged in NTFP collection, also possibly vulnerable households, relied on loans, which may reflect limited alternatives. Households with formal savings avoided loan-seeking.

4.4.3 Reallocation of labor

Households' access to, and ability to reallocate, labor has an important effect on their coping choices. Overall, *ex-post* labor reallocation was the third most commonly reported coping strategy, however households with human capital constraints were unlikely to consider this option. This included households with a high proportion of children and those with labor committed to NTFP collection. Households who have successfully traded labor in the past, including those with remitting migrants and self-employed members, continue to rely on their human capital. Migration involves "start-up" costs, which may be reduced when there is an existing migrant able to support new arrivals. Therefore, although labor reallocation is an *ex-post* option, it is affected by households' existing human and social capital. Similarly, Hänke and Barkmann (2017) identified labor reallocation as a common strategy, practiced more by households already engaged in waged labor, although they found households resorted waged farm labor rather than outmigration.

4.4.4 Household spending reductions

Reductions in household spending and consumption were less common in households with high physical, natural, and social capital. Although two thirds of households reported this *ex-post* strategy, older households, those with a high equipment value (physical capital), with livestock (natural capital), and with family kinship networks (social capital), were less likely to reduce spending, suggesting access to alternative coping options (Tran 2015). Similarly, Mehar et al. (2016) found that livestock-owning households were less likely to reduce food intake. Households with remitting migrants reduced spending, suggesting limits to migrants' capacity to provide support, including delayed support, requiring households to make temporary cuts. Larger households, those with a high proportion of children, and those with labor occupied in collecting water, were also more likely to reduce spending and consumption. Although households may choose to reduce consumption to preserve their assets and future options, poorer households are likely to be worse affected, having to cut essential items while their wealthy counterparts cut luxuries (Eriksen and Silva, 2009; Börner et al., 2015; Mehar et al., 2016; Hänke and Barkmann, 2017; Castells-Quintana et al., 2018). These consumption decreases have been associated with increased NTFP extraction, which may explain why households in the dry site, with better access to, and engaged in the sale of, NTFPs, were more likely to reduce spending (McGarry and Shackleton, 2009; Mugido and Shackleton, 2017; Paumgarten et al., 2018).

4.4.5 Natural products

The safety-net function of NTFPs was limited for female-headed households, suggesting gender-specific limitations to this coping option. This differs to other South African studies which found households relied on the safety-net function of NTFPs irrespective of the gender of the household head (Paumgarten and Shackleton, 2011; Mugido and Shackleton, 2017). Although NTFPs are argued to be of greater benefit to poor, rural women and female-headed households, others suggest women may have limited access to, and control over, these resources (Pattanayak and Sills, 2001; Posel, 2001; Takasaki et al., 2004; Mehar et al., 2016). The notable difference in the proportion of households reporting the daily-net (98%) versus safety-net (41%) function of NTFPs, emphasizes the possible limitations to this safety-net function. Börner et al. (2015) also noted a lower than expected reliance on natural resources. Mugido and Shackleton (2017) identified NTFPs as a common coping strategy, especially in low-potential agro-ecological zones, although only 35.6% of their sample reported this safety-net function. We found that households already selling NTFPs, and those with livestock, were more likely to rely on NTFPs to cope, suggesting an existing knowledge of these resources, their harvesting areas, and their markets (Boafo et al., 2016; Ofoegbu et al., 2016; Mugido and Shackleton, 2017). Households with formal (rather than informal) savings, were also more likely to rely on NTFPs to cope suggesting that households purposely rely on NTFPs, to protect their alternative, and future, coping options.

Households engaged in the sale of NTFPs were less likely to deplete assets and savings, but more likely to reduce spending, with NTFPs most likely providing substitutes. These households may be poorer, with limited coping options. Other studies have also highlighted that by relying on NTFPs (and environmental services) for minor crises, households maintain their cash and assets, and thereby their future welfare (Skoufias, 2003; Boafo et al., 2016). Paumgarten and Shackleton (2011) found households relied on the safety-net function of NTFPs irrespective of household wealth, while Hänke and Barkmann (2017) found almost all households, irrespective of their primary economic activity, relied on the gap-filling function of wild foods in response to crop failure. McSweeney (2005) argues that access to these natural resources should maintained, particularly if alternatives are limited.

4.4.6 Asset depletion

Asset depletion by households engaged in livestock sales, by older and larger households, and by those with a high number of non-remitting migrants, suggests existing market experience, asset accumulation, greater need, and limited alternatives may all influence households' decision to decapitalize. Households with family kinship networks were also more likely to deplete assets, possibly selling assets within their networks. Female-headed households and those with labor constraints (i.e. labor engaged in water collection) were less likely to deplete assets, suggesting gender- and labor-related barriers to asset accumulation and sales (Tran 2015). Börner et al. (2015) also noted that female-headed households in their African subsample were less likely to sell assets. Surprisingly, households in the dry site, where livestock ownership is more prevalent, were also less likely to deplete assets. Limited and variable market demand, veterinary controls on the movement of animals, and the multiple functions of livestock, may discourage sales (Ofoegbu et al. 2016). Hänke and Barkmann (2017) found that even with extreme food scarcity, households kept their cattle because of their socio-cultural value. Other studies have considered asset accumulation as an *ex-ante* risk management strategy and an *ex-post* coping strategy, with mixed views on this strategy's robustness (Dercon, 2002; Kazianga and Udry, 2006; Deressa et al., 2009). Households selling NTFPs and crops, were also less likely to deplete assets

5. Conclusion

Rural households in Venda, South Africa, are exposed to a mix of unanticipated production, human, and financial shocks, as well as natural hazards. Although a range of informal household coping strategies was identified, our findings suggest that households' response to these shocks is largely not random but influenced by the type of shock experienced. This suggests that households' make conscious coping choices, based on either the effectiveness of a strategy in buffering against the shock, or on households' active intent to manage their coping portfolio in anticipation of future shocks.

With respect to natural hazards, informal, *ex-post*, household coping strategies appear limited, with households relying on external assistance from government or NGOs, and *ex-ante* household savings. The reliance on external assistance is expected but our findings suggest that more vulnerable households are less likely to rely on this option. This requires further investigation as to whether there are barriers to accessing these formal, external social safety-nets. Given the possibility of increasingly intense and frequent natural hazards, associated with climate change, this assistance, and the institutions that provide it, will need to be increasingly robust, appropriately targeted, and accessible to the most vulnerable. The key role of household savings in helping households cope with natural hazards, is also concerning if these events occur with increasing frequency and intensity. Without alternative options, households' ability to accumulate savings will be hindered, undermining their efforts to secure a sustainable livelihood, reducing their overall coping capacity, and limiting their ability to make the necessary investments to adapt to climate change. Increasing households' access to alternative financial services, including credit, and weather insurance, needs further exploration.

In addition to exploring whether shock type influences households' coping choices, we explored whether a range of household characteristics and location have an influence. Generally, households' access to human and financial capital influenced the coping strategies used. Our findings also suggest that female-headed households have fewer coping options, being less likely to deplete assets or rely on NTFPs. Female-headed households may face barriers in accumulating and/or disposing of assets, and in accessing NTFPs, which need to be explored, particularly as climate change is expected to exacerbate gender inequalities. This includes understanding why female-headed households were less likely to rely on NTFPs, often considered an important safety-net for those with limited alternatives. Larger households and those with a high proportion of children, also appear to have more limited coping options, relying on negative strategies such as spending and consumption reductions, which may negatively affect their human capital. The influence of location on households' willingness to deplete assets to cope, provides insights into the insurance role of livestock, and suggests that although households may accumulate livestock as an *ex-ante* insurance strategy, this is not their primary reason for doing so, with livestock fulfilling multiple functions. It also suggests barriers to selling livestock. It would be useful to better understand at what point households are prepared to discount the benefits of retaining their livestock, versus selling it to cope, as well as what support services could be put in place to enhance the insurance value of livestock.

Natural products were not often used to cope with natural hazards, suggesting limitations to their safety-net function for covariate, climate-related shocks. However, access to natural capital, as well as social capital, allows for the protection of households' assets and savings, and the avoidance of spending and consumption reductions, thereby contributing towards households' overall resilience. Households' reliance on natural and social capital, is therefore not necessarily an indicator of vulnerability, but may be a considered means of managing their future insurance options. Given the key role of household savings in coping with natural hazards, by relying on natural products to buffer against other shocks, households may be better able to retain their savings for natural hazards.

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Conflicts of interest: none

Compliance with Ethical Standards

The Research Office of the University of the Witwatersrand granted the ethical clearance to conduct the research (H120803). All ethical standards were adhered to. The relevant local authorities granted permission to conduct the research and formal, free, prior, and informed consent was obtained from all participants. Anonymity was assured.

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Annexes

Annex 1 Explanatory variables used in the logit linear model to explain the use of a selected coping strategy. Those variables dropped by the model are indicated by N/A.

Category	Description	Code used in Table 3
1: Basic Household Descriptors		
Location	Dry site (Bennde Mutale) vs. wet site (Vondo)	*Location (dry site)*
Age	Age of the household (years since established)	*Older*
Composition of household members	Number of household members (excluding migrants)	*Larger*
	Female- vs. male-headed households	*Female-headed*
	Percentage of female vs. male household members	*N/A*
	Percentage of children vs. adult household members	*High proportion of children*
Migrant household members	Number of migrants	*N/A*
2: Savings and Household Assets		
Savings	Household has formal savings	*Formal savings*
	Household has informal savings (e.g. burial society, stokvel, weather insurance, other)	*Informal savings*
Equipment	The value of equipment owned by the household (calculated in ZAR)	*Equipment of high value*
3: Kinship		
Kinship	Household has family in the village they can rely on	*Family kinship networks*
	Household does not have family but can rely on other groups (i.e. churches, burial societies, stokvels (informal savings groups) and cooperatives)	*Non-family kinship networks*
4: Livelihood Strategies & Income Sources		
Off-farm strategies	Number of formally employed household members	*Formally employed*
	Number of informally employed household members	*N/A*
	Number of self-employed household members	*Self-employed*

	Value of government grants received (ZAR) including old age pensions, child care grants and disability grants	*N/A*
	Whether the migrant sends remittances	*Remitting vs. non-remitting migrants*
Land-based strategies:		
~ NTFPs	Household stores NTFPs	*N/A*
	Household sells NTFPs	*(Sells) NTFPs*
~ Arable agriculture	Household cultivates (field and/or homegarden)	*N/A*
	Household sells crops	*(Sells) crops*
~ Animal husbandry	Household owns livestock	*Livestock*
	Household sells livestock	*(Sells) livestock*
5: Labor availability		
	Time spent collecting NTFPs	*(More time collecting) NTFPs*
	Time spent collecting water	*(More time collecting) water*

CHAPTER 6

Wild Foods: Safety Net or Poverty Trap? A South African Case Study

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Wild Foods: Safety Net or Poverty Trap? A South African Case Study

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Abstract

Wild foods contribute towards the food security of an estimated one billion people. In light of expectations of the contribution of wild foods to sustainable and climate-resilient livelihoods and widespread evidence of their consumption, their contribution to households' diets requires a more nuanced understanding, specifically with respect to their safety net function during food shortages. Data were collected from two villages in Venda, South Africa, selected due to differences in mean annual precipitation. Semi-structured interviews were administered to 170 households and a Participatory Rural Appraisal was conducted to assess the influence of multiple variables, including household characteristics and site, on wild food use. Household archetypes were defined based on the frequency of consumption in response to increasing food scarcity. Our findings suggest limitations to the safety net function of wild foods including seasonal fluctuations in availability and decreased availability during extreme events, with dependent households decreasing their consumption frequency in response to food scarcity. Given this potential poverty trap, further research is required, particularly in terms of when the safety net function of wild foods may be weak or detrimental to the livelihoods of the vulnerable.

Keywords Climate · Food security · Seasonal availability fluctuations · Vulnerability · Wild foods · Participatory rural appraisal · South Africa

Introduction

Wild foods contribute towards the diets of an estimated one billion people (Pimentel *et al.* 1997; Burlingame 2000). While seldom the primary share of the household food basket, they complement other food sources, provide dietary and nutritional diversity, and offer a 'safety net' for households experiencing seasonal or shock-related food shortages (Addis *et al.* 2005; Shackleton and Shackleton 2004; Powell *et al.* 2015). Studies have noted the consumption of a diversity of species, arguing this adds a robustness to the daily- and safety net function of wild foods and provides important micronutrients (Sunderland 2011; Powell *et al.* 2015). Wild foods are argued to be particularly important to vulnerable households, including child-, elderly, or female-headed households and those impacted by HIV/Aids (Kaschula 2008; McGarry and Shackleton 2009). In addition to direct consumption benefits, households may also benefit from the sale of wild foods (Nasi *et al.* 2011).

Wild foods are argued to be more resilient than many crop varieties to changes in both season and climate, and therefore potentially important within the context of societal adaptation to climate change (Pramova *et al.* 2012; Chivandi *et al.* 2015). This is particularly the case in marginal areas of developing countries where agro-ecological constraints, regular crop failures, and recurrent droughts undermine food and nutritional security (Delang 2006). Together with other non-timber forest products (NTFPs), wild foods form part of a "hidden harvest", fulfilling both a regular daily and a safety net role and contributing to livelihood diversification and resilience through their consumption and sale (Shackleton and Shackleton 2004; Arnold *et al.* 2011). Biodiversity loss threatens the sustainability of rural livelihoods, particularly in cases where alternative daily and 'safety net' food resources are limited (McSweeney

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2005). Consequently, ecosystem protection may provide a cost-effective buffer to the impacts of climate variability and change.

Wild foods have received insufficient attention in food security, development, and natural resource management discourses and policies despite both their existing and potential role in resilient and sustainable food systems (Sunderland 2011). Although their use is widespread, questions remain on their exact function particularly with respect to their role in supporting rural livelihoods on a daily basis compared to periods of increased vulnerability (Shackleton and Shackleton 2004; Bharucha and Pretty 2010). Further research is required as to when wild foods constitute a 'daily-net', a 'safety net,' or a poverty trap, as well as whether they are more suitable as a short-term gap-filler or a long-term diversification strategy for adaptation. Wong and Godoy (2003) raise concerns over the ability of informal rural safety nets, including NTFPs and wild foods, to adequately insure households against covariate shocks, although other studies have highlighted the important role of such safety nets in buffering households against covariate, climate-related shocks (Takasaki *et al.* 2004; McSweeney 2005). Levang *et al.* (2005) caution, however, that relying on natural resources as a safety net may constitute a poverty trap in cases where the resource is limited, demand is high, and alternatives are lacking. For vulnerable, natural resource dependent households likely to face increasing risks due to climate change, it may be necessary to consider alternative insurance strategies (Hickey *et al.* 2016). Understanding what factors influence the daily and safety net roles of wild foods is necessary to ensure more locally appropriate interventions that support both sustainable livelihoods and biodiversity (Bharucha and Pretty 2010; Paumgarten and Shackleton 2011).

Although South Africa has been described as food secure at the national level, food insecurity and micronutrient malnutrition persist at the household level, driven by various, often interrelated economic, environmental, and socio-political factors (De Cock *et al.* 2013; Drimie and McLachlan 2013). Food insecurity is a threat to a large proportion of the rural population who face increasing vulnerability to climate change (Drimie and McLachlan 2013), with vulnerability defined as the "state of susceptibility to harm from exposure to stresses associated with environmental and social change and from the absence of capacity to adapt" (Adger 2006: 268). Studies have drawn attention to the widespread consumption of wild foods, including their contribution (through both consumption and sale) to more vulnerable households (Shackleton and Shackleton 2004; Kaschula 2008). Within this context, to better understand the potential contributions, and limitations, of wild foods to household food security, particularly given increased expectations of their role in food security, poverty alleviation, and climate change adaptation policies and with the aim of improving the existing understanding of both the regular and safety net use of wild foods, we investigated their role in rural livelihoods in Limpopo Province, South Africa. We considered the extent of wild food consumption and sale (in terms of the proportion of households reporting these activities), the frequency with which households consume wild foods, both regularly and during times of food shortages and hunger, as well as households' perceptions of the importance of the safety net function of wild foods.

Study Site

Our research was conducted in two rural communities in South Africa's north-eastern Limpopo Province (Fig. S1), one of the country's poorest regions (Statistics South Africa 2014). The villages of Bennde Mutale and Vondo were part of the Venda homeland, one of ten demarcated areas to which black South Africans were forcibly relocated until the 1994 democratic transition. These areas remain characterized by high poverty levels, limited employment opportunities, and low levels of service provision and development (Table 1). Many households continue to live close to the poverty line, engaging in diverse livelihood strategies, including the use and sale of NTFPs (Venter and Witkowski 2013; Ofoegbu *et al.* 2016). Migrant remittances and state welfare grants (including old age pensions, child care, and disability grants) are important sources of income. Food insecurity, a high incidence of HIV/Aids, increasing living costs, a shortage of productive land, and variable (and often extreme) weather, exacerbate vulnerability levels (Neves and Du Toit 2013; Murugani *et al.* 2014).

Both villages fall within the Vhembe District Municipality, approximately 90 km apart (Table 1). Vondo ("wet site") receives 2.8 times the precipitation of Bennde Mutale ("dry site"), with differences in mean annual precipitation being a key primary criterion for the site selection (wet site: 1108 mm ± 371 mm; dry site: 401 mm ± 140 mm). Bennde Mutale is bordered by communal rangelands, conservation areas (e.g., Kruger National Park), and a military corridor while Vondo is bordered by pine and tea plantations.

Methods

Data Collection

The relevant local authorities were approached for permission to conduct the research. Quantitative and qualitative data were collected through a trans-disciplinary, case-study approach, which included household interviews, participatory rural appraisal exercises (PRA), key informant interviews, and personal observations. Semi-structured interviews, based on those developed by the Poverty Environment Network (Wunder *et al.* 2014), were administered to 170 households (85 per village), with a household considered to be a unit of

Table 1 Summary profile of the two sites – municipal and village level attributes

	Dry Site	Wet Site
Municipal level attribute		
Local Municipality	Mutale	Thulamela
Population density (people/km^2)	24	110
Av. number people/household	3.8	3.9
Female-headed households (%)	54.8	54.4
Education (aged 20+): None (%)	18.8	17.4
Unemployment rate (%)	48.8	43.8
Av. household income: None (%)	13.2	11.9
Dependency Ratio (per 100: 15–64)	79.9	70.1
Piped water inside dwelling (%)	5.8	15.2
Electricity (for lighting) (%)	83.3	87.2
Pit toilet (%)	92.6	73.7
Biophysical village level attribute		
Latitude; longitude	31° 1′48″E; 22°24′14"S	30°21′60″E; 22°56′5"S
Elevation (m)	308	1022
Approx. MAP (mm)	401	1108
Rainy season	Summer (Nov-Feb)	Summer (Oct-Mar)
Approx. MAT (°C)	24.7	19.0
Vegetation type (Mucina and Rutherford 2011)	Musina Mopane Bushveld; Makuleke Sandy Bushveld	Soutpansberg Mountain Bushveld
Socio-cultural village level attribute		
Village size (no. households)	327	340
Av. number people/household	5.3	4.7
Female-headed households (%)	43.5	42.4
Av. age of household (years since household was established)	19.5	20.8
Av. age of household members (years)	26.3	27.4
Av. education of household members (years)	6.2	7.2
Electricity for lighting (%)	94.1	98.8
Formal housing (%): brick wall; metal roofs (*)	49.4; 67.1	56.5; 100.0
Water sources (%): communal taps (*); natural (*)	97.6; 28.2	41.2; 98.8
Tribe	Venda, Tsonga, Other	Venda
Households owning livestock (%) (*)	61.2	25.9
Households cultivating (%) (*)	63.5	95.3
Households using NTFPs (%)	100.0	96.5
Households receiving migrant remittances (%)	28.2	29.4
Households receiving government grants (%)	84.7	90.6
Households having formally employed members (%) (*)	29.4	16.5
Nearest commercial centers	Masisi (19 km) Musina (118 km) Thohoyandou (95 km)	Phiphidi (5 km) Sibasa (13 km) Thohoyandou (15 km)

Source: Statistics South Africa (2014) for municipal level, our field data for village level. Socio-cultural village level attributes for data collected during the household interviews ($n = 170$) were compared - (*) indicates those variables with differences at $p < 0.05$

people residing in the same dwelling and sharing meals. The sample constituted 26% and 25% of the households in the dry and wet sites, respectively. Each village is subdivided, by the village leadership, into designated zones. The interviews were divided between these zones, with the households selected through a simple, random sampling approach. Whenever possible, the household head was interviewed. In cases where the head was not available, another resident adult was interviewed. Given the length of the survey, it was split into two parts, with each household interviewed twice over the course of the fieldwork. The same respondent was interviewed each time. The PRA was conducted through a series of voluntary, community workshops. After the initial workshop in each village, the same participants were invited to the subsequent workshops to allow us to build on previous discussions. The group size varied somewhat depending on people's availability but generally consisted of about 20 people, both male and female, of varying ages. Given the non-contentious nature of the discussion topics, we did not feel the need to sub-divide the groups by gender.

The fieldwork was conducted during the winter months, outside of the main agricultural season, to minimise the impact on participants' other responsibilities. For the same reason, only half-day workshops were organized. By hosting the workshops during the cooler, drier months, we ensured that travelling to, and participating in, the workshops was more comfortable for the participants. In addition to this, both villages are more difficult to access during the rainy season and malaria is a risk in the dry site. Key informant interviews were conducted with village elders and chiefs, traditional healers, farmers and livestock owners, the manager of a nearby tourist camp (dry site), and the closest available agricultural extension officers.

The PRA exercises included seasonal calendars; time trend exercises; historical profiles; and impact chain exercises, used to identify (inter alia) fluctuations in vulnerability and the availability, use, and sale of NTFPs, including wild foods (Dazé *et al.* 2009; Turnbull and Turvil 2012). The research was conducted with the assistance of trained enumerators/translators. All ethical standards of the host institution were adhered to. Formal, free, prior and informed consent was obtained, and anonymity assured.

"Wild foods" can include a diverse range of products and species. We focused on the most commonly sourced: wild edible fruits ("fruits"), wild edible herbs ("herbs"), and bushmeat (Powell *et al.* 2013). We use "wild edible herbs" as a broad, all-encompassing term to describe leafy vegetables (including both leaves and flowers), while "bushmeat" refers to edible mammals, birds, fish, insects, reptiles, and amphibians. The use of wild foods was reported through various means. During the workshops, participants listed the diversity of species consumed and discussed both historical and seasonal variations in availability and use. During the household interviews, respondents were questioned on their use of wild foods, both as a daily and a safety net resource. Households described their frequency of consumption (meals per week) of wild foods during three food availability periods, namely: when food is generally plentiful (e.g., after the harvest); when food is scarce (e.g., during seasonal crop shortfalls); and during "hungry periods" (e.g., during drought and unanticipated crop failure). Households were also questioned on their perceptions of the importance of wild foods in helping them survive "hungry periods". It was not within the scope of this study to explore the proportional contribution of wild foods relative to other household food sources (in terms of both quantity and nutritional value), although information of this nature would improve our overall understanding of the daily and safety net functions of wild foods.

Data Analysis

First, we assessed whether household characteristics and site influence variables related to wild food use with multivariate linear models. We used a logistic regression for binary variables (i.e., all yes/no responses in the interviews (Table 2), such as whether a household consumes or sells wild foods or has experienced food shortages). We reported odds ratios, which show how household characteristics and site influenced the odds that a household used wild foods. We used a Gaussian (normal) regression for continuous variables (e.g., the average number of meals per week in different food availability periods (Table 3)). Independent variables included village (site), household size and age (i.e., years since the household was established), average age and education of the household members, gender of the household head, formal and informal employment, involvement in agriculture and livestock, receipt of grants and remittances, and grant value. Some continuous variables were log-transformed to improve the normality of their distribution. Using the 'step' function in R3.3.2, we applied a backward stepwise procedure to select those independent variables that led to the regression model with the best AIC (Akaike Information Criterion).

Second, we defined archetypes of wild food users by clustering households based on three quantitative, semi-continuous variables representing the number of meals per week including wild foods in the three food availability periods (plenty, scarce, and hungry). We applied a hierarchical cluster analysis (Ward agglomeration method and Euclidian distance measure) with the hclust function of the stats package in R (R Core Team 2017). After applying the NbClust package (Charrad *et al.* 2014) to identify the best number of clusters, we tried clustering with two to four clusters. We decided to build three clusters, which provided the most meaningful interpretation of the clustering results. To describe the three clusters, we fitted binary logistic regressions that related the membership in a cluster to variables related to household location and demographics, livelihood activities and incomes, and coping strategies. We used binary logistic regressions instead of multinomial logistic regressions because we were interested in the variables explaining each cluster compared to all other clusters. For each cluster, we used a backward stepwise procedure to select independent variables and reported the variables that had a significant effect on the odds of a household being in this cluster ($p < 0.05$) (Table 4).

Results

Use and Sale of Wild Foods

Wild foods are used and sold in both villages, contributing to household diets and livelihoods. The consumption of wild

Table 2 Uses and perceptions of wild foods: average over the 170 households (HH) and effects of HH characteristics and location on uses and perceptions, estimated with a logit linear model

Use or perception	% of HH with this use or perception	Interpretation of odd ratios (how the odds of using or perceiving are influenced by HH characteristics and location)
Consumption: HH consuming…		
wild foods	96.5	None
wild fruits	83.5	The odds of consuming wild fruits increase by 3.0 if households have livestock ($p = 0.03$) and by 2.3 if they have twice as many members ($p = 0.02$)
wild herbs	87.6	The odds of consuming wild herbs increase by 7.6 if households have livestock ($p < 0.01$), by 3.1 if they have twice as many members ($p = 0.01$) and by 3.8 if they live in the wet site ($p = 0.01$)
bushmeat	87.1	The odds of consuming bushmeat increase by 11.4 if households live in the dry site ($p < 0.01$)
Sale: HH selling…		
wild foods	33.5	The odds of selling wild foods increase by 72 if households live in the dry site ($p < 0.01$)
wild fruits	1.2	None
wild herbs	0.6	None
bushmeat	32.4	The odds of selling bushmeat increase by 170 if households live in the dry site ($p < 0.01$)
Perceived food challenges: HH reporting…		
experiences of food shortages	98.8	None
increased challenges to finding food	64.1	The odds of perceiving increased challenges to finding food increase by 1.2 if households have half as many formally employed members ($p < 0.01$)
Perceived importance of wild foods during hungry periods: HH perceiving wild food as…		
very important	18.2	The odds of perceiving wild foods as very important increase by 6.0 if households live in the dry site ($p < 0.01$)
important	27.6	The odds of perceiving wild foods as important increase by 2.6 if households live in the wet site ($p = 0.02$) and by 3.0 if they have livestock ($p < 0.01$)
somewhat important	42.3	The odds of perceiving wild foods as somewhat important increase by 2.1 if households receive remittances ($p = 0.03$)
not important	11.8	The odds of perceiving wild foods as not important increase by 6.9 if households do not have livestock ($p < 0.01$)

foods is widespread irrespective of site and household characteristics, reported by 96.5% of households (Table 2). Most commonly consumed are herbs (87.6%), followed by bushmeat (87.1%), and fruits (83.5%). The odds of consuming herbs and fruits are higher in larger households and those with livestock. The odds of consuming herbs are higher in the wet site while the odds of consuming bushmeat are higher the dry site. Workshop participants identified a diversity of species, particularly fruits and bushmeat, in the dry site (Table S1). Wild foods are sold by 33.5% of households. Bushmeat is the most commonly sold wild food, particularly in the dry site.

The use of, and preference for, wild foods seems to be declining. Although wild food consumption was high (based on the proportion of households), respondents in both villages indicated decreasing use (time trend exercises). This was attributed to changing lifestyles, preferences, and the loss of traditional ecological knowledge (TEK), particularly among the younger generations, as well as declining availability. Older respondents associated this declining consumption with poor health and increases in “new diseases” (e.g., high blood pressure and diabetes). Nevertheless, children were observed consuming wild foods.

Table 3 Number of meals including wild foods per week during three periods of food availability: Descriptive statistics and household characteristics affecting those numbers according to a Gaussian linear model

Variable	Average value	Standard deviation	Median value	Household characteristics affecting the number of meals (log-transformed)	Interpretation (after correcting for log-transformations)
Number of meals with wild foods per week when food is plentiful	3.8	4.6	2	Agriculture (coefficient = 0.306, p = 0.03)	Number of wild food meals is 36% higher if households engage in agriculture
Number of meals with wild foods per week when food is scarce	4.0	3.7	3	Household age (coefficient = 0.0094, p = 0.01)	Number of wild food meals is 9.9% higher if households are 10-years older
Number of meals with wild foods per week during hungry periods	4.7	2.8	4	Household age (coefficient = 0.019, p < 0.01), grant value (log2-transformed, coefficient = −0.053, p = 0.02)	Number of wild food meals is 21% higher if households are 10-years older and 5.2% lower if the grant value received is twice as much

Availability of Wild Foods

Respondents indicated a declining trend in the availability of wild foods, which they attributed to land expropriation, land conversion, overharvesting, and a (perceived) decline in rainfall (time trend exercises). Over time, both communities have lost access to harvesting areas with land ex- propriated for agriculture, conservation, and military purposes (historical profiles). According to respondents, this, combined with an increasing population and the associated conversion of land for settlement and agriculture, has placed pressure on the remaining resource base, creating competition among users (time trend exercises). Land conversion has been greater in the more productive wet site, with population densities in the surrounding area being higher. In the dry site, the surrounding communal rangelands and the adjacent protected areas provide a more extensive habitat for a diversity of wild foods. Households in the dry site noted the maintenance of wild indigenous fruit trees on their homestead plots. Those in the wet site have shifted to exotic species, such as mango, litchi, and macadamia.

Respondents reported that wild foods are affected by competing activities. For example, overgrazing has impacted the availability of herbs; agricultural pesticides have reduced the availability of edible insects; uncontrolled fires (started by honey hunters and livestock owners (for grazing)) have destroyed fruit trees, and in response to fuel wood scarcity, people have started to cut fruit trees. In the dry site, overharvesting of fuel wood and mopane worms in response to a large external market was noted as a concern (workshops). Seasons and extreme climate events were also identified as determinants of wild food availability. Respondents in both sites noted seasonal variations in the availability, use, and sale of wild foods, being higher in the summer rainy season, providing a pre-harvest source of food and income, but low during the annual "hunger season" towards the end of winter (Figs. S2a and S2b). This pattern is clearer in the dry site although exceptions exist including the emergence of mopane worms at the end of summer and the availability of baobab fruit during winter. Both droughts and floods have affected wild food availability (Figs. S3a and S3b). For example, recent floods and heavy storms knocked fruit off trees and washed away riverine fruit trees. Respondents noted fewer mopane worms after drier summers, and associate periods of low wild food availability with food shortages, hunger, and poor health (seasonal calendars and impact chain exercises).

Perceptions of Food Shortages

Consistent food availability is a widespread challenge, with ~99% of households reporting the experience of food shortages at some point during the course of a year (Table 2). In addition, 64% of households perceive increasing difficulties in finding sufficient food, with the odds of perceiving these difficulties being higher in households with fewer formally employed members. Child-headed households (i.e., those with a head 18-years old or younger) were also described as susceptible to food shortages, often relying on government food parcels (workshops). Increasing food and living costs, unemployment, declining agricultural production, and declining wild food availability were identified as challenges to meeting household food needs.

Collective food shortages were associated with seasons and climate events. The "hunger season" described above was characterized by seasonal crop, livestock, and wild food shortfalls (Figs. S2a and S2b). Respondents in both wet and dry communities also noted hungry periods associated with extreme events, although these were considered less extreme in the wet site. Both floods and drought restrict food supplies, with crop, livestock, and wild food losses reported (Figs. S3a and S3b). Previous floods damaged food stores and

Table 4 Household characteristics with a significant effect on the odds of being in a cluster

Variable with a significant effect on the odds of being in a cluster	Coefficient sign	*p*-value	Odd ratio (detailed interpretation on how the odds of being in a cluster are influenced by the variable)
Odds of being in the cluster "Dependence"			
Average age of HH members	+	0.001	Odds increase by 2.8 times if average age doubles
Coping by reducing meals	–	0.012	Odds decrease by 2.6 times if HH copes with shocks by reducing meals
Coping by HH spending reductions	–	0.001	Odds decrease by 3.8 times if HH copes with shocks by reducing spending
Coping by finding work	–	<0.001	Odds decrease by 5.3 times if HH copes with shocks by finding work
Coping with NGO assistance	–	0.002	Odds decrease by 3.9 times if HH copes with shocks by seeking NGO assistance
Odds of being in the cluster "Safety"			
Location in the dry site	+	<0.001	Odds increase by 4.6 times if HH is in the dry site
Livestock	+	0.043	Odds increase by 1.9 times if HH has livestock
Agriculture	–	0.016	Odds decrease by 2.9 times if HH practices agriculture
Coping with spending reductions	+	0.002	Odds increase by 2.8 times if HH copes with shocks by reducing spending
Coping by finding work	+	<0.001	Odds increase by 4.3 times if HH copes with shocks by finding work
Coping with NGO assistance	+	0.016	Odds increase by 2.3 times if HH copes with shocks by seeking NGO assistance
Odds of being in the cluster "Disinterest"			
Location in the dry site	–	<0.001	Odds decrease by 37 times if HH is in the dry site
Household age	–	0.001	Odds decrease by 2.2 times if household age doubles
Child grants	+	0.047	Odds increase by 1.3 times if the HH receives one additional child grant
Agriculture in summer	+	<0.001	Odds increase by 16 times if the HH engages in seasonal (summer) agriculture
Formal employment	–	0.037	Odds decrease by 8.4 times if HH members are formally employment
Livestock	–	0.019	Odds decrease by 3.2 times if HH has livestock
Coping with NTFPs	–	0.007	Odds decrease by 5.6 times if HH copes with shocks with NTFPs

temporarily restricted access to shops while droughts resulted in increased crop raiding and livestock losses to wildlife. Some respondents attributed the increase of home-gardens to drought-related losses of wild herbs (workshops). Both events were associated with increased spending on food. Drought was identified as the bigger threat, with household food production able to recover more quickly from floods. Drying and storing food (including wild foods) were reported as a means of coping although producing/collecting surpluses for storage were identified as a challenge.

Importance of Wild Foods for Coping

Overall, the greatest proportion of households consider wild foods to be only "somewhat important" for coping with hungry periods (42.3%), with the odds of this being higher for households receiving migrant remittances (Table 2). The odds of households perceiving wild foods as "very important" for coping with hungry periods were higher in the dry site. Households with livestock and those in the wet site perceived wild foods as "important" while those without livestock perceived wild foods as "not important".

Wild foods help households cope with flood- and drought-related food shortages, sustaining children in particular (workshops). Although wild foods are themselves impacted by these extreme events, they still contribute to household food security. For example, respondents in both villages noted certain important, more drought resistant fruit species, including *Adansonia digitata*, *Berchemia zeyheri*, *Trichilia dregeana*, and *Xanthocercis zambesiaca* (dry site), *Vangueria infausta* and *Strychnos spinosa* (both sites), and *Parinari curatellifolia* (wet site). Respondents in the dry site told of eating birds found sheltering in the shade of their homes during droughts.

Frequency of Use of Wild Foods during Different Times

Overall, the frequency of consumption of wild foods increased during times of food shortage. On average, only 3.8 meals/week incorporated wild foods when food was plentiful (Table 3). This frequency increases with increasing food scarcity. The odds of households increasing their frequency of wild food consumption per week, in response to increased food scarcity (including hungry periods), are higher for older households. Households receiving a lower value of state grants also increase their frequency of consumption during hungry periods.

Three types of households clearly differed in their frequency of wild food consumption, both as a daily and 'safety net' strategy (Fig. 1). A quarter of households (25.3%), the second largest cluster, consume a high number of meals (at least one meal/day) containing wild foods during "times of plenty". Their frequency of consumption decreases when food is scarce (but remains notably higher than the other clusters), and continues to decrease during hungry periods. Because of their reliance on wild foods, we categorized this cluster as "Dependence". Most households (58.8%) belong to a cluster characterized by a low frequency of consumption during "times of plenty" with consumption increasing with increasing food scarcity, indicating a safety net function (categorized as 'Safety"). Households in the smallest cluster (15.9%), consumed wild foods approximately every second day during times when food was plentiful, more than the "Safety" cluster, but decreased their use during food shortages. Because of their low overall use of wild foods relative to the other clusters we categorized this cluster as "Disinterest".

The odds of a household being in the "Dependence" cluster increase amongst households with older members (reflected by the high average age) (Table 4). The odds decrease if the household reported coping with shocks by reducing household spending, reducing the quantity/quality of meals, or by seeking work and assistance from NGOs. The odds of a households being in the "Safety" cluster are higher for households located in the dry site and those engaged in livestock rearing rather than arable agriculture. The odds are also higher for households who reported coping with shocks by reducing household spending, or by seeking work and assistance from NGOs. The odds of a household being in the "Disinterest" cluster are higher for younger households, those receiving child grants, those in the wet site, and those engaging in summer agriculture rather than livestock rearing and formal employment. The odds of a household falling within this cluster decrease if the households rely on NTFPs to cope with shocks.

Discussion

The Role of Wild Foods in Rural Livelihoods

The consumption of a diversity of wild foods remains a common feature of rural livelihoods in Venda, South Africa, reported by almost all the households. This high proportion, irrespective of site and household characteristics, implies either widespread need or that products are collected opportunistically when available or in response to dietary preferences and cultural traditions (Trefry *et al.* 2014; Sylvester *et al.* 2016) and emphasizes the ongoing role of wild foods in supplementing diets and livelihoods, suggesting that greater cognizance be taken of wild foods in biodiversity and food assessments and policies (Hickey *et al.* 2016). In their review

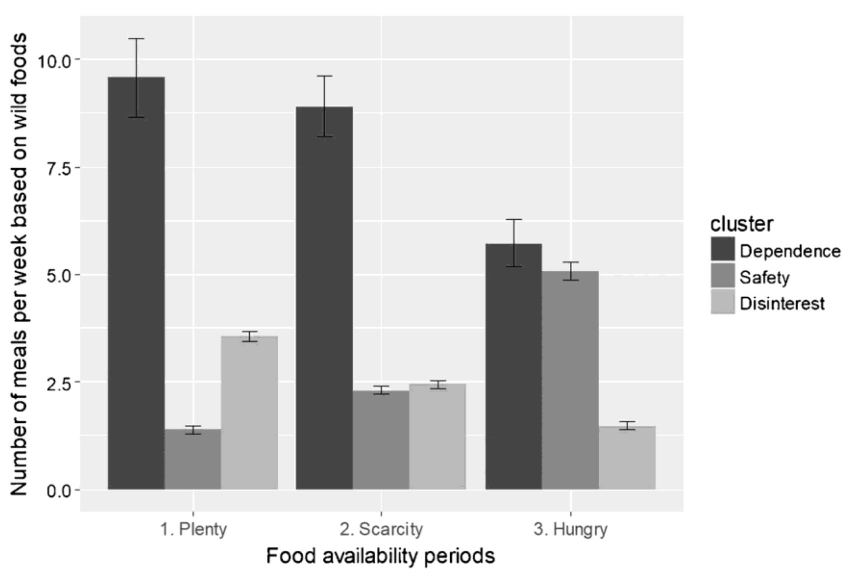

Fig. 1 Wild food consumption (based on number of meals per week) by different household food dependency clusters during periods of decreasing food availability

of NTFP use by households in 14 South African villages, Shackleton and Shackleton (2004) noted similarly prevalent wild food consumption, while in their global comparison, Hickey *et al.* (2016) found wild food collection to be most common in Africa. Several studies have drawn attention to the diversity of species consumed (Addis *et al.* 2005; Bharucha and Pretty 2010; Bvenura and Afolayan 2015).

Fewer households were engaged in the sale of wild foods, with the consumption-to-sale ratio being similar to that reported in Hickey *et al.* (2016). Nevertheless, the proportion selling is considerably higher than that noted in other South African studies, particularly as these considered a wider selection of NTFPs than wild foods (Dovie 2001; Paumgarten and Shackleton 2009). Although driven in part by an external market, sales also reflect that households are willing to pay for locally available (and essentially "free") resources. This suggests barriers to collection, including time and labor constraints, skill and equipment requirements, and risk and/or illegality concerns that some households are either more capable of overcoming (e.g., through access to labor) or more willing to tackle in response to opportunity or need (Baiyegunhi and Oppong 2016; Sylvester *et al.* 2016).

Although widespread, wild food use is not generic. Variations exist in the use and sale of different sub-categories of wild foods (i.e., herbs, fruit, and bushmeat). Household size, existing livelihood strategies (livestock ownership), and location influence the proportion of households consuming wild foods, with location also influencing their sale. Larger households with labor for harvesting may rely more on wild foods to supplement their diets (Baiyegunhi and Oppong 2016). The consumption of herbs and fruit by households with livestock suggests opportunistic harvesting while herding, and that the maintenance of communal grazing lands ensures better access to these resources (McGarry and Shackleton 2009). Wild herbs were consumed by a greater proportion of households at the wet site despite arable agriculture being more common. These herbs may be actively maintained on agricultural land (Bharucha and Pretty 2010) and benefit from the higher rainfall and lower levels of livestock grazing in this site. Bushmeat consumption was more prevalent in the dry site, despite the high proportion of households engaged in animal husbandry. Although access may be the primary driver, it also suggests a preference for bushmeat and/or that households consume bushmeat to save costs and to preserve livestock, which is valued as an insurance option. In addition, it reflects the presence of mopane worms. An increasing number of studies from Limpopo Province have drawn attention to the contribution of edible insects to households' nutritional and financial needs (Egan *et al.* 2014; Dzerefos and Witkowski 2015; Baiyegunhi and Oppong 2016).

Wild foods fulfil both a daily and a safety net function. On average, they were consumed once every two days suggesting that they continue to make a regular and important contribution to households' diets; however, data on the quantities consumed and nutritional value (relative to other foods) would strengthen this argument (Powell *et al.* 2015; Ncube *et al.* 2016). Although the overall consumption frequency of wild foods is high, nuances exist which suggest they play a more important role in some households than others. For example, even during times of high food availability, households in the "Dependence" cluster reported the daily consumption of wild foods, suggesting that they associate high food availability with wild foods, and may be constrained by the costs associated with farming and therefore have limited alternative food sources. By relying on wild foods, they may be able to direct limited household funds to other household necessities. Relative to the "Dependence" cluster, the "Safety" cluster's household consumption of wild foods under good conditions (i.e., when food is plentiful) is low, suggesting wild foods are not preferred during periods of high food availability from other sources but rather serve as a safety net in times of scar- city. For households in the "Disinterest" cluster, consumption of wild foods is driven more by availability (i.e., opportunistic harvesting) than need.

The frequency of wild food consumption increases with increasing food scarcity. A number of studies draw attention to this safety net role in response to both idiosyncratic and covariate shocks (Takasaki *et al.* 2004; McSweeney 2005; Baiyegunhi and Oppong 2016). Older and poorer households were more likely to rely on wild foods during hungry times, suggesting the influence of previous experience of this coping option and limited alternatives. Although households in the dry site assigned a higher value to the safety net function of wild foods, households in the wet, less marginal site still considered them "important" for coping with hungry periods. Households with livestock also perceived wild foods as important, reflecting the association between livestock herding and wild food collection. Households with migrant remittances considered wild foods as only "somewhat important" during times of scarcity, possibly reflecting labor constraints but also the contribution of remittances to household food security. Studies indicate high (and regular) levels of NTFP use as a safety net, particularly by poor households in low agro-ecological zones where drought, crop pests, and food shortages are frequent, and incidences of HIV/Aids are high (Shackleton and Shackleton 2004; Arnold *et al.* 2011).

Wild Foods as a Safety Net – A Nuanced Perspective

Interesting nuances emerge when looking at the typology of households and the frequency with which they consume wild foods under circumstances of increasing food scarcity. For the "Dependence" cluster (25.3% of households), the safety net function of wild food appears limited. Although they consume wild foods regularly during good times, their frequency of consumption declines with food scarcity and hunger, which given their apparent reliance on wild foods as a primary part of their diet, in addition to indications of limited coping options, is cause for alarm. "Dependence" households are characterized by older members who may struggle to collect wild foods if weakened by increasing hunger and in situations of increasing competition for limited resources (i.e., when the "Safety" cluster increases their wild food consumption). Several studies have highlighted the essential role of NTFPs and wild foods in supporting more vulnerable households (Pattanayak and Sills 2001; Drimie and McLachlan 2013; Sylvester *et al.* 2016). However, this reliance may constitute a poverty trap in cases where access to crucial resources becomes constrained either permanently (e.g., through land conversion) or temporarily (e.g., during certain seasons and extreme climate events) (Levang *et al.* 2005). Our findings indicate this is the case with the "Dependence" cluster.

Although 96.5% of households consume wild foods, suggesting the safety net function is available to most, only 58.8% (the "Safety" cluster) increased their frequency of consumption in response to increased food scarcity. Although this may indicate limitations to the safety net function of wild foods, these households' use of wild foods as a safety net, despite low daily use, also suggests possible advantages (Paumgarten and Shackleton 2011). During times of increased need, this cluster may be more willing to discount the challenges associated with wild food collection. It is unclear however, why their frequency of consumption during food shortages does not increase further. Possible explanations include that they had sufficient food or, more worryingly, they could not access more. In the first case, it is possible that these households were able to meet most of their dietary requirements (more easily) through other means, with wild foods providing an occasional buffer. However, given the high proportion of households who reported increasing challenges in finding sufficient food, unsustainable use is a risk, particularly in the case of covariate shocks to the food system (e.g., droughts, rising food prices, etc.), and particularly for those households who rely on the frequent consumption of wild foods (i.e., the "Dependence" cluster).

The "Disinterest" cluster's reduced frequency of consumption of wild foods in response to food scarcity most likely reflects their general disinterest in and lack of reliance on NTFPs as a safety net. These households suggest a younger generation of people with limited ties to the natural resource base, less ecological knowledge, and changing preferences, all accentuated by the more extensive land conversion in the wet site (see also Bvenura and Afolayan 2015; Hickey *et al.* 2016).

Limitations to the Safety Net Function of Wild Foods

The safety net function of wild foods has four limitations, namely seasonality, the impact of extreme climate events, declining availability, and labor intensity. It is important to recognize that this list is not exhaustive, nor does it necessarily apply to the overall safety net function of NTFPs. For example, other studies have highlighted limitations associated with weak or absent markets and the loss of traditional ecological knowledge and skills (McSweeney 2005; Weyer *et al.* 2017).

Researchers have noted the role of wild foods in smoothing seasonal food gaps, with the diversity of species ensuring some availability throughout the year (Fukushima *et al.* 2010; Bvenura and Afolayan 2015). Chivandi *et al.* (2015) describe the role of wild foods in sustaining up to 80% of households in Malawi, Mozambique, and Zambia through an annual three-month hunger period. Our findings indicate a similar "hunger season", particularly in the dry site, occurring post-harvest in the face of challenges to producing (and storing) sufficient quantities of food to ensure stable consumption. Low levels of wild food consumption during the same period indicate limited availability (Ncube *et al.* 2016). Interestingly, high levels of wild food availability and use during the pre-harvest period suggests that wild foods reduce the length of the "hunger season" but do not eliminate it completely. The pre-harvest period coincides with a period of high expenditure (e.g., school fees), with wild foods possibly allowing for essential cost-savings (Shackleton and Shackleton 2004; Paumgarten and Shackleton 2011). Other studies suggest variable wild food consumption and sale are driven more by seasonal availability than periods of increased need (De Cock *et al.* 2013; Powell *et al.* 2015).

Our results indicate occurrences of food scarcity and hunger associated with climate extremes such as droughts and floods and that wild foods have an (existing and often underestimated) role in supporting households during periods of climate-induced vulnerability, contributing to climate change adaptation, being more resilient than cultivated crops (Arnold *et al.* 2011; Bvenura and Afolayan 2015). They further suggest, however, that there is the need for more tempered expectations. Both floods and droughts decrease the availability of wild foods, compounding crop and livestock losses. The capacity of wild foods to supplement rural diets may be insufficient in the face of more frequent and extended climate shocks, imply- ing limitations to their effectiveness for ecosystem-based adaptation (EBA) (Pramova *et al.* 2012). Although maintaining a diversity of species across the landscape is advocated as a means of ensuring sustainable and resilient diets (Powell *et al.* 2013), Elmqvist *et al.* (2003) argue that when considering ecosystem resilience, response diversity may be more important than functional diversity, as species react differently to disturbances. Thus, there is the need for an improved understanding of the impact of climate extremes and climate change on the diversity of wild foods as well as their actual and expected role relative to other coping and adaptation options (Takasaki *et al.* 2004; McSweeney 2005; Pramova *et al.* 2012).

Wild food availability is perceived to declining, possibly undermining their current and future safety net function and potential role in EBA and compounding seasonal and extreme-event fluctuations. As a consequence a reliance on wild foods may constitute a poverty trap, specifically for households who rely on their regular consumption (i.e., "Dependence" households) (Levang *et al.* 2005). During times of collective food insecurity (e.g., droughts), the "Dependence" cluster's "normal" harvesting levels of wild foods may be unsustainable, especially if competition for resources increases (with "Safety" households, livestock, and wildlife all increasing their consumption). Although storage may help, households may be unable to collect and store sufficient quantities to maintain their usual consumption levels (Pramova *et al.* 2012; Ncube *et al.* 2016). Increasing food insecurity may drive these households to illegal harvesting (e.g., poaching in protected areas), increasing their overall vulnerability. Given the large proportion of households in the "Safety" cluster, as well as indications of increasing difficulties in meeting food needs, declining availability of wild foods is worrying if alternatives are limited. The challenges of land loss, land conversion, competing resource users, and overharvesting all undermine the capacity of wild foods to support household food needs, exacerbating vulnerability (Ickowitz *et al.* 2014; Hickey *et al.* 2016). Well-defined property rights, effective local management, or off-farm coping and adaptation options may be needed to avoid unsustainable use and conflict among users, which may further undermine the livelihoods of the "Dependence" cluster (Pramova *et al.* 2012). It should however be noted that evidence suggests that increased out-migration from South Africa's rural areas, dietary transitions to a more westernized diet, and households' reliance on government social grants, are decreasing harvesting pressure on NTFPs (Ncube *et al.* 2016).

As a livelihood strategy, the collection of NTFPs (including wild foods) is argued to be attractive to the rural poor because of limited barriers to entry, although it is argued that those with control over labor often have greater access (Angelsen and Wunder 2003). Negative impacts on labor, including hunger and ill health associated with food shortages (e.g., seasonal crop shortfalls and droughts), may therefore constrain wild food collection. For "Dependence" households, characterized by existing labor constraints (i.e., composed of older members), maintaining necessary harvesting levels may become increasingly difficult during hungry periods. Although these households may rely on wild foods because their limited labor restricts their engagement in agricultural production and wage labor, increasing resource scarcity and competition over resources may limit the returns on effort, especially if they result in the need to travel further on collecting trips (Baiyegunhi and Oppong 2016). Further, limited labor may leave these households unable to collect, prepare, and store sufficient quantities of wild foods to sustain them during periods of resource scarcity. For this cluster with limited alternative coping strategies, difficult times are likely to increase in the face of climate change and declining resource availability.

Opportunities to the Use of Wild Foods as a Safety Net

Although our findings suggest limitations to the safety net function of wild foods, there are opportunities worth recognizing. The high proportion of households that do rely on wild foods as a safety net gives credence to their value (or suggests limited alternatives). Although wild foods undergo seasonal fluctuations, the diversity of species consumed ensures some supply throughout the year and it is suggested that in general, wild foods help reduce the length and intensity of the post-harvest "hunger" period associated with seasonal crop shortfalls. Similarly, this diversity is likely to ensure some availability during climate extremes, even though overall availability may be reduced. In addition to greater resilience to climate change, many wild foods can be dried and stored, and either used or sold. Their contribution to sustaining children during hungry times was noted. Relying on wild foods allows for cost-savings and prevents the need to use other resources (e.g., sell livestock), which may ensure longer-term resilience of the household.

Conclusions

Wild foods, including herbs, fruit, and bushmeat, are still used extensively by rural households in Venda, South Africa. Although wild foods are generally consumed frequently, for most households this frequency increases during periods of food scarcity. Given the regular contribution of wild foods, declining availability (whether as a result of permanent land conversion or during seasonal and climate-driven variations) poses a threat to households' ability to sustain their livelihoods both in the present and in the face of increasing climate variability and change. This is particularly so for those households who rely on wild foods on a daily basis, suggesting the need for sustainable management that accounts for increasing global environmental change.

Although wild foods fulfill a safety net function, our findings suggest the need for more cautious expectations of their role in helping households cope with covariate shocks and adapt to climate change. Declining and variable availability, driven in part by seasonality and climate extremes, means these foods may not be available in sufficient quantities when required. Furthermore, should increasing food insecurity drive increased (and possibly unsustainable) harvesting of wild foods, those households dependent on wild foods on a daily basis may find it increasingly difficult to meet their requirements. Although our findings support calls to acknowledge the role of wild foods in sustaining rural livelihoods by providing food (and nutritional) security, either regularly or on an ad hoc basis in response to increased need, we argue that wild foods should be considered as part of a suite of strategies. In certain circumstances, providing alternative, off-farm options may be required. In sum, the role of wild foods both as a daily resource and a safety net in times of scarcity needs further exploration, particularly in terms of when their safety net function may be weak or detrimental to the livelihoods of the most vulnerable.

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Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest. The necessary ethical clearance to conduct the research was obtained from the Research Office of the University of the Witwatersrand (H120803). All ethical standards were adhered to. The relevant local authorities were approached for permission to conduct the research and formal, free, prior and informed consent was obtained from all participants. Anonymity was assured.

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Supplementary material

NOTE:

This paper includes Electronic Supplementary Material (ESM) that has been inserted into this document. This material (ESM 1-6) can be accessed via the online version of the paper (https://doi.org/10.1007/s10745-018-9984-z).

ESM 1:

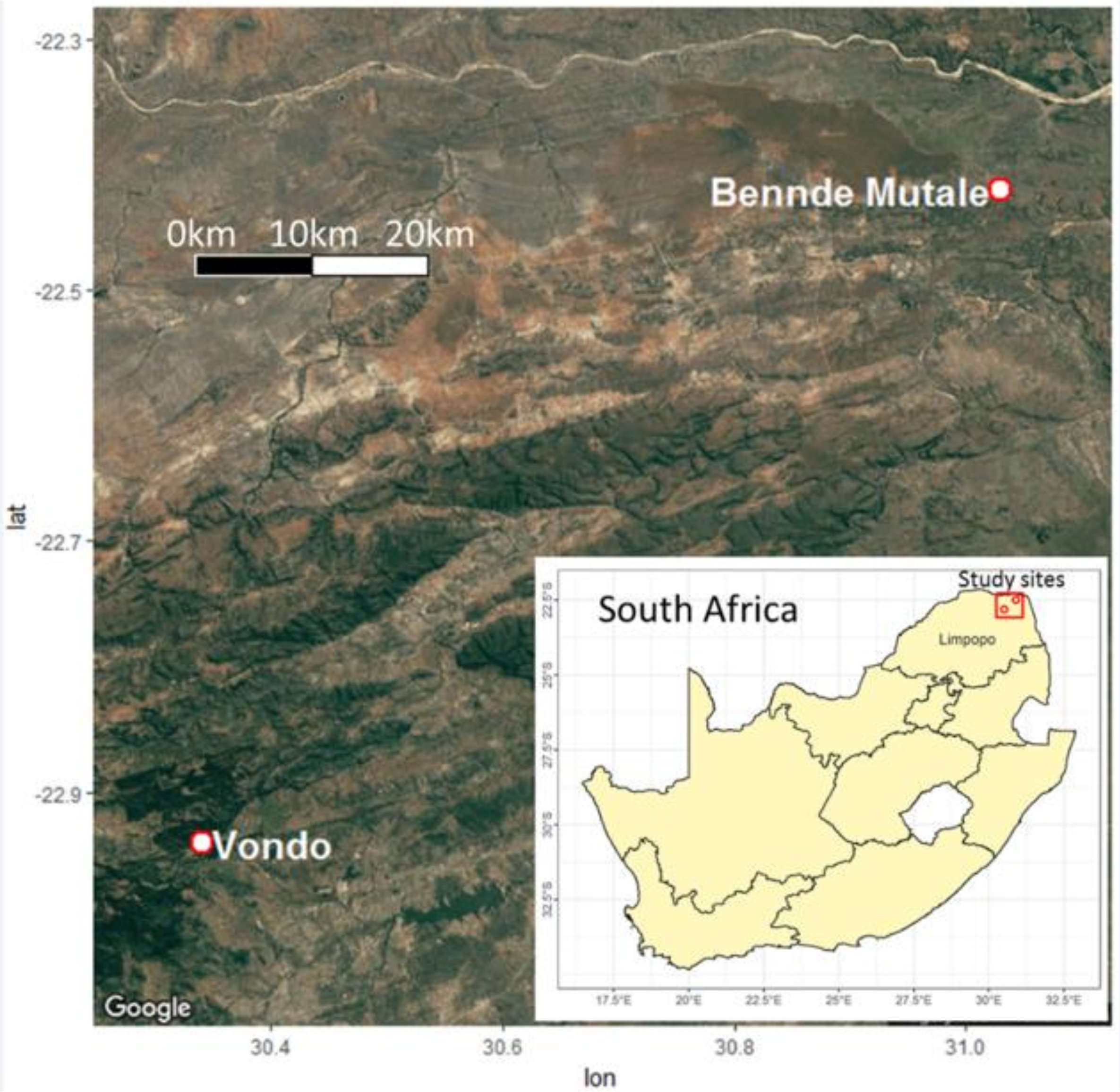


Fig. S1 Location of the study sites – Bennde Mutale (dry site) and Vondo (wet site); (images from Google Earth)

ESM 2:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall	**********	***									***	*****
Temperature	**********	******	****	****	***	*		****	*****	********	********	*********
Plant fields		**********									******	**********
Plant gardens					********	**********	*****					
Harvest fields			**********			**********						
Harvest gardens						*****	**********	**				
Crop pests				**********		**********						**********
Sell crops			**********				******					
Livestock disease									******	**********		
Grazing	***	******	**********	*******	****	**						
Sell livestock			***			**********						**********
Hunger season								**********	**********	********	********	
Human disease			*****			********	**********					
High expenditure	**********										**********	**********
Use wild foods	**********	**********	**********	**********		**********	**********					****
Sell wild foods				****	********	******						
Use firewood		*	*	****	*	**********	****	*	*	*	*	********
Sell firewood		*	*	**********	*	**********	*	*	*	*	*	**********

Limited agricultural produce; no wild foods used/sold

Fig. S2a Seasonal calendar for the dry site (2012-2013), highlighting periods when agricultural produce is available post-harvest (green), when seasonal hunger is experienced (red) and when wild foods are used and sold (yellow). Stars indicate extent/degree/severity (e.g. 10 stars = high rainfall; no stars = no rainfall)

ESM 3:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall	*********	*****	**********	*					*	********	**	***
Temperature	***	**	*	****	*	*	*	*	********	******	**********	*****
Plant fields										**********	********	****
Plant gardens			**********		********	****	**	******				
Harvest fields				**	*****	**********						
Harvest gardens					********	**********	*****	****	*			
Crop pests												
Sell crops	*******	*******										
Livestock disease												
Grazing	********	*******	***	**	*						****	**********
Sell livestock	*******											
Hunger season								**********	*******		*********	
Human disease						********	*******	**********	*****			
High expenditure	*********	**	*******		*	*****	*	*	*	****	***	**********
Use wild foods	*******	*****			***	**				******	*******	**********
Sell wild foods	******	*****			***	**				******	*******	**********
Use firewood	***	***	******	*	******	**********	*******	**	*			
Sell firewood	***	***	*****	*	******	**********	********	**	*			

Limited agricultural produce; no wild foods

No agricultural produce; wild foods

Fig. S2b Seasonal calendar for the wet site (2012-2013), highlighting periods when agricultural produce is available post-harvest (green), when seasonal hunger is experienced (red) and when wild foods are used and sold (yellow). Stars indicate extent/degree/severity (e.g. 10 stars = high rainfall; no stars = no rainfall)

ESM 4:

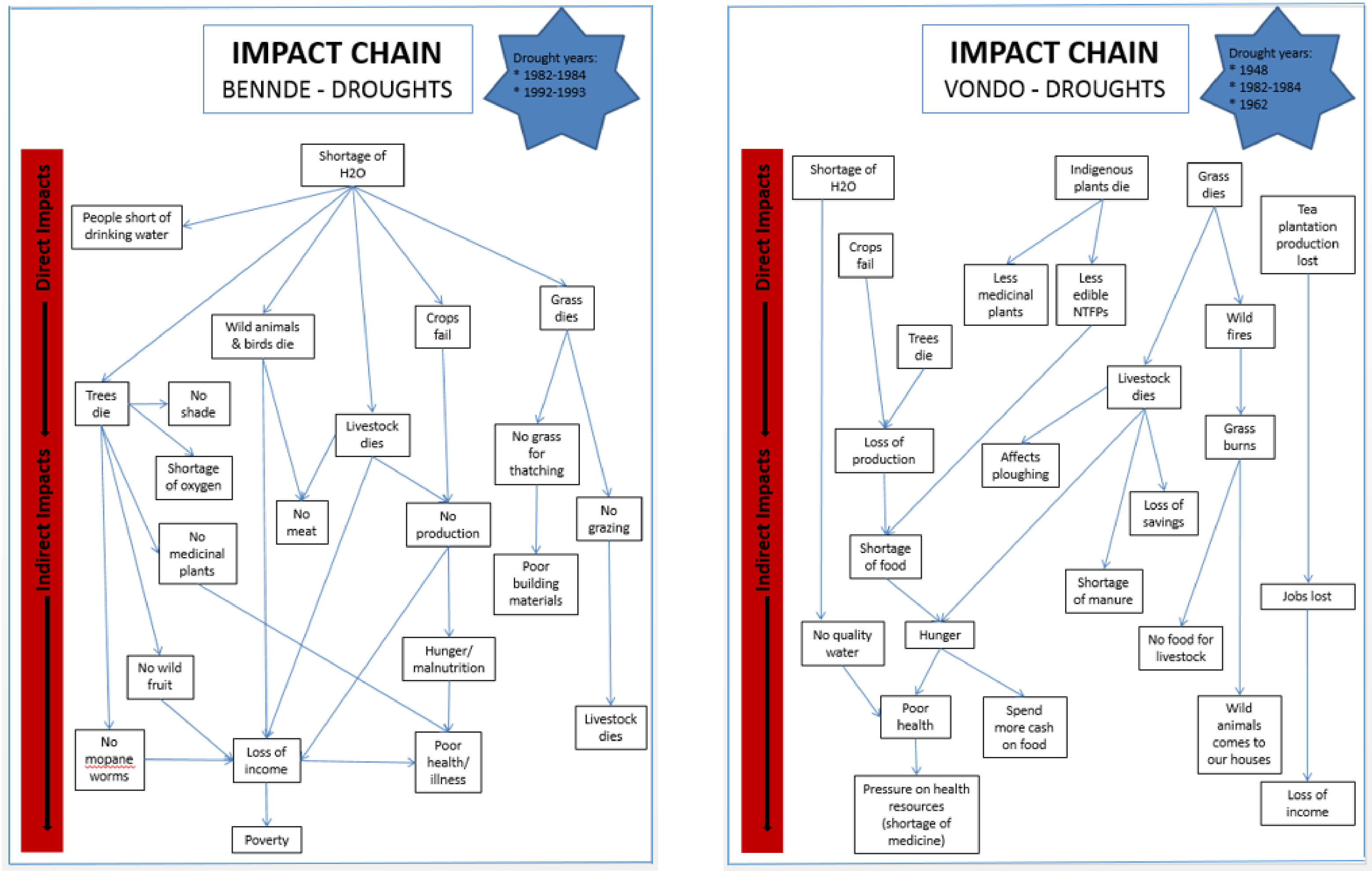
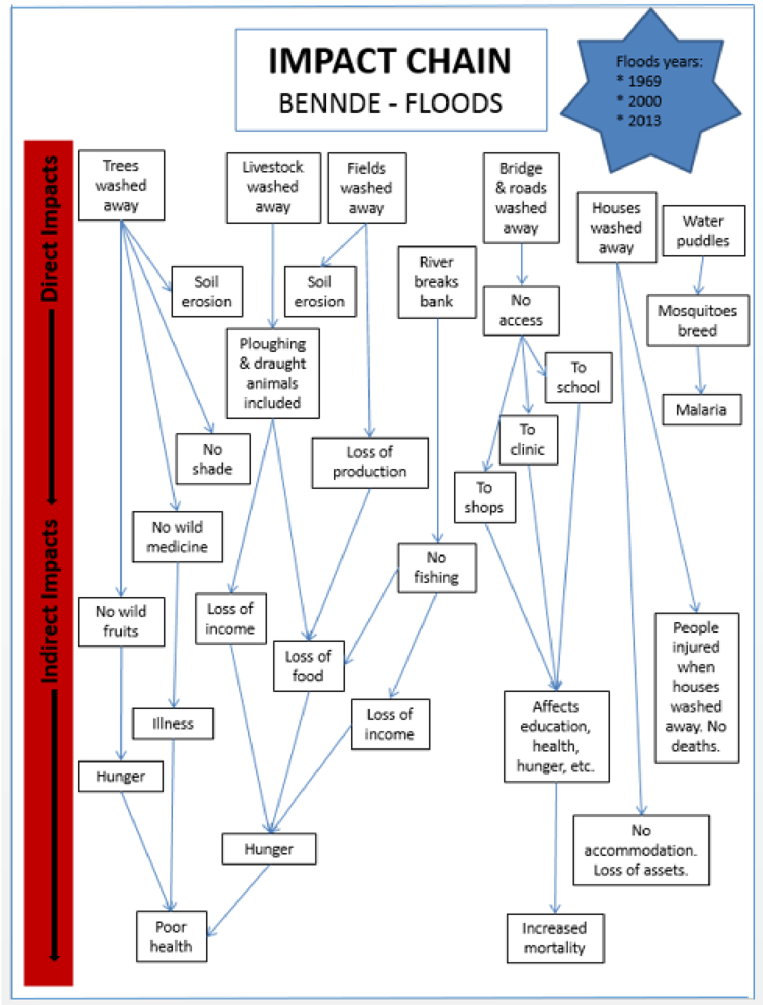


Fig. S3a Impact chains showing the direct and indirect impacts of drought in Bennde (dry site) and Vondo (wet site), including impacts on wild foods

ESM 5:



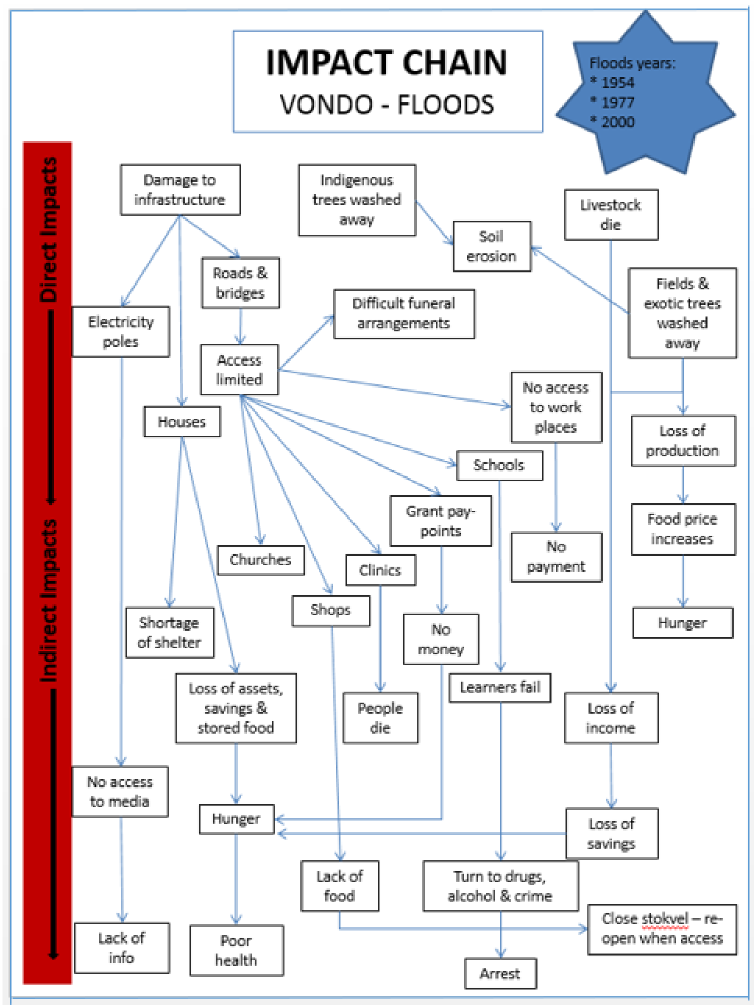


Fig. S3b Impact chains showing the direct and indirect impacts of floods in Bennde (dry site) and Vondo (wet site) including impacts on wild foods

ESM 6:

Vernacular name	Common name	Scientific name
	Wild Edible Fruit	
Dry Site:		
Mahuyu/Mutole/Thole	Sycamore Fig	*Ficus sycomorus*
Mavelo/Mazwilu	Wild Medlar	*Vangueria infausta*
Mububulu	Transvaal Red Milkwood	*Mimusops zeyheri*
Mudoro	Prickly Pear	*Opuntia ficus-indica*
Mufula	Marula	*Sclerocarya birrea* ssp. *caffra*
Muhuhuma	Baboon's Breakfast	*Hexalobus monopetalus*
Mukwakwa	Black Monkey Orange	*Strychnos madagascariensis*
Mulembu	Cross-berry	*Grewia occidentalis*
Munembenembe	Monkey Pod	*Senna petersiana*
Munie	Brown Ivory	*Berchemia discolor*
Munieniane	Red Ivory	*Berchemia zeyheri*
Muparatsheni	Brandy Bush	*Grewia flava*
Muphiphi	African Mangosteen	*Garcinia livingstonei*
Muramba	Green Monkey Orange *OR* Spine-leaved Monkey Orange	*Strychnos spinosa OR Strychnos pungens*
Muredwa/Murabva	White Raisin	*Grewia bicolor*
Murungulu	Num	*Carissa bispinosa*
Musuma	Jackalberry	*Diospyros mespiliformis*
Mutshetshete	Buffalo Thorn	*Ziziphus mucronata*
Mutshikili	Natal Mahogany	*Trichilia emetica*
Mutshili	Large Sourplum	*Ximenia caffra*
Mutshato	Nyala Tree	*Xanthocercis zambesiaca*
Mutumadi	Woodland Waterberry	*Syzygium guineense*
Muvhuyu	Baobab	*Adansonia digitata*
Unknown	Yellow Bitterberry	*Strychnos mitis*
• ***Unidentified species***		
Bongaselo	~ ~ ~	~ ~ ~
Nfafa	~ ~ ~	~ ~ ~
Thahoma	~ ~ ~	~ ~ ~
Thato	~ ~ ~	~ ~ ~
Tswatima	~ ~ ~	~ ~ ~
Wet Site:		
Mavelo/Mazwilu	Wild Medlar	*Vangueria infausta*
Mububulu	Transvaal Red Milkwood	*Mimusops zeyheri*
Muembe	African Custard-apple	*Annona senegalensis*
Mukumululo	Rubber Vine	*Landolphia kirkii*
Mukwakwa	Black Monkey Orange	*Strychnos madagascariensis*
Munombelo	Transvaal Milkplum	*Englerophytum magalismontanum*
Muramba	Green Monkey Orange *OR* Spine-leaved Monkey Orange	*Strychnos spinosa OR Strychnos pungens*

Murondo/Thondo	Strawberry Bush	*Cephalanthus natalensis*
Murungudane	Cape Gooseberry	*Physalis peruviana*
Mutomboti	Rock Alder	*Canthium gilfillanii*
Mutumadi	Woodland Waterberry	*Syzygium guineense*
Muvhula	Mobola Plum	*Parinari curatellifolia*
• ***Unidentified species***		
Mitzeeri	~ ~ ~	~ ~ ~
Thawi	~ ~ ~	~ ~ ~
Respondents in both sites reported the consumption of figs.		

Wild Edible Herbs

Dry Site:

Daledale	Lamb's Quarters	*Chenopodium album*
Delele lupfumo	Wild Jute Plant	*Corchorus tridens*
Delele mandande	Okra *OR* Red Amaranthus	*Abelmoschus esculentus OR* *Amaranthus hybridus*
Delele mukhwayo	Bladder Weed	*Hibiscus trionum*
Muduhwi	Wild Petunia	*Ipomoea obscura*
Mukurukuru	Pigeon Wood	*Trema orientalis*
Murambo	Sweet Potato	*Ipomoea sp.*
Muruthu/Murudi	African Cabbage	*Cleome gynandra*
Museto	Devil's Thorn	*Dicerocaryum eriocarpum*
Mushidzhi	Black Jack	*Bidens pilosa*
Muthanzwa	Soap Nettle	*Pouzolzia mixta*
Mutohotoho	Bastard Mustard	*Cleome monophylla*
Muvhazwi	Mountain Nettle	*Obetia tenax*
Muxe	Wonderberry *OR* Black Nightshade	*Solanum retroflexum OR* *Solanum nigrum*
Ndamba	Benghal Dayflower	*Commelina benghalensis*
Phulule	African Heart Vine	*Pentarrhinum insipidum*
Shashe	Wild Thistle *OR* Common Sowthistle	*Sonchus asper OR* *Sonchus oleraceus*
Thebe	Pigweed *OR* Forest Inkberry	*Amaranthus hybridus OR* *Phytolacca octandra*
Tseto	Devil-Thorn Weed	*Tribulus zeyheri*
Tshibavhe	Balsam Pear *OR* Bitter Gourd	*Momordica balsamina OR* *Momordica charantia*
Tshifhafhe	Unknown	*Momordica boivinii*
Tshinyagu	African Cucumber	*Cucumis africanus*
Vowa	Smooth Pigweed *OR* Pigweed *OR* Indehiscent Pigweed *OR* Forest Inkberry	*Amaranthus dubius OR* *Amaranthus hybridus OR* *Amaranthus standleyanus OR* *Phytolacca octandra*
• ***Unidentified species***		
Dimbisha	~ ~ ~	~ ~ ~
Lurambo lwa khovhe	~ ~ ~	~ ~ ~
Muthevhe	~ ~ ~	~ ~ ~
Nnyo dza	~ ~ ~	~ ~ ~
Tshidanda tsh pfene	~ ~ ~	~ ~ ~

Tshikokoliko	~ ~ ~	~ ~ ~
Tshinawa nawane	~ ~ ~	~ ~ ~
Tshinzie	~ ~ ~	~ ~ ~
Tshipokoto	~ ~ ~	~ ~ ~
Tshitopitopi	~ ~ ~	~ ~ ~
Unknown	*Mushroom/s*	

Wet Site:

Dzaluma	Stinging Nettle	*Urtica dioica OR Tragia sp.*
Muduhwi	Wild Petunia	*Ipomoea obscura*
Mufhongwe	Cocoyam	*Colocasia esculenta*
Mulembu	Four Corners	*Grewia occidentalis*
Muruthu/Murudi	African Cabbage	*Cleome gynandra*
Museto	Devil's Thorn	*Dicerocaryum eriocarpum*
Mushidzhi	Black Jack	*Bidens pilosa*
Muthanzwa	Soap Nettle	*Pouzolzia mixta*
Mutohotoho	Bastard Mustard	*Cleome monophylla*
Muvhazwi	Mountain Nettle	*Obetia tenax*
Muxe	Wonderberry *OR* Black Nightshade	*Solanum retroflexum OR* *Solanum nigrum*
Ndamba	Benghal Dayflower	*Commelina benghalensis*
Nngu	Bitter Apple	*Momordica foetida*
Phulule	African Heart Vine	*Pentarrhinum insipidum*
Shashe	Wild Thistle *OR* Common Sowthistle	*Sonchus asper OR* *Sonchus oleraceus*
Thanga	Pumpkin	*Cucurbita pepo*
Thebe	Pigweed *OR* Forest Inkberry	*Amaranthus hybridus OR* *Phytolacca octandra*
Tshinyagu	African Cucumber	*Cucumis africanus*
Vowa	Smooth Pigweed *OR* Pigweed *OR* Indehiscent Pigweed *OR* Forest Inkberry	*Amaranthus dubius OR* *Amaranthus hybridus OR* *Amaranthus standleyanus OR* *Phytolacca octandra*

- ***Unidentified species***

Lugu	~ ~ ~	~ ~ ~
Lupondela	~ ~ ~	~ ~ ~
Nnyo ya mbudzi	~ ~ ~	~ ~ ~
Nyenda nyendane	~ ~ ~	~ ~ ~
Tshinzie	~ ~ ~	~ ~ ~

Bushmeat

Dry Site:

Masonja	Mopane Worm	*Gonimbrasia belina*
Nari	African Buffalo	*Syncerus caffer*
Nfsa	Grey Duiker	*Sylvicapra grimmia*
Ngwele-ngwele	Waterbuck	*Kobus ellipsiprymnus*
Nyala	Nyala	*Tragelaphus angasii*
Phala	Impala	*Aepyceros melampus*

Phangwa	Common Warthog	*Phacochoerus africanus*
Tshishosho/Mbavhala	Bushbuck	*Tragelaphus sylvaticus*
Unknown	African Bullfrog	*Pyxicephalus adspersus*
Unknown	Rock Monitor	*Varanus albigularis*
Unknown	Tree Squirrel	*Paraxerus cepapi*

- ***Unidentified species***

Magoli	~ ~ ~	~ ~ ~
Malamba	~ ~ ~	~ ~ ~
Unknown	*Mouse/Mice*	~ ~ ~
Unknown	*Tortoise/s*	~ ~ ~

Wet Site:

Mbila	Rock Hyrax	*Procavia capensis*
Muvhuda	Rabbit/Hare	*Sp. Unknown*
Nfsa	Grey Duiker	*Sylvicapra grimmia*
Nguluvhe	Bushpig	*Potamochoerus larvatus*
Tholo	Greater Kudu	*Tragelaphus strepsiceros*
Tshedzi	Greater Cane Rat	*Thryonomys swinderianus*
Tshishosho/Mbavhala	Bushbuck	*Tragelaphus sylvaticus*
Unknown	Cape Porcupine	*Hystrix africaeaustralis*

- ***Unidentified species***

Chipiti	~ ~ ~	~ ~ ~

Respondents in both sites reported the consumption of various bird and fish species as well as insects, including termites, locusts/crickets/grasshoppers, edible stinkbugs and worms/caterpillars. Honey consumption was also reported.

Table S1 List of wild fruit, herb and bushmeat species reported during community workshops in the dry and wet site. These are arranged alphabetically using the vernacular (Venda) names. Studies by Mabogo (1990)[11], Nesamvuni *et al*. (2001)[12], Maanda and Bhat (2010)[13], and Bvenura and Afolayan (2015)[14] were used to identify the English (common) and scientific names. The scientific names were checked against the South African National Biodiversity Institute's Plants of southern Africa database[15]. There are challenges to identifying species in this way, exacerbated by the number of local names often used for the same species and the reporting of sub-categories (e.g. "insects") as opposed to individual species (Botha *et al*. 2001[16]; Hickey *et al*. 2016[17]). In some cases, we were unable to match the Venda name with a common or scientific name. These have been listed as "Unidentified". Although not comprehensive, the list gives an indication of the diversity of species available for collection from the wild.

[11] Mabogo, D.E.N. (1990). *The Ethnobotany of the VhaVenda*. M.Sc. Thesis. University of Pretoria, Pretoria.
[12] Nesamvuni, C., Steyn, N.P. and Potgieter, M.J. (2001). Nutritional value of wild, leafy plants consumed by the VhaVenda. *South African Journal of Science* 97: 51-54.
[13] Maanda, M. and Bhat, R. (2010). Wild vegetable use by Vhavenda in the Venda region of Limpopo Province, South Africa. *International Journal of Experimental Botany* 79: 189–194.
[14] Bvenura, C. and Afolayan, A.J. (2015). The role of wild vegetables in household food security in South Africa: A review. *Food Research International* 76: 1001–1011.
[15] South African National Biodiversity Institute (SANBI). (2016). *Botanical Database of Southern Africa (BODATSA)*. SANBI. http://newposa.sanbi.org. Accessed 27 April 2017.
[16] Botha, J., Witkowski, E.T.F. and Shackleton, C.M. (2001). An inventory of medicinal plants traded on the western boundary of the Kruger National Park, South Africa. *Koedoe* 44: 7-46.
[17] Hickey, G.M., Pouliot, M., Smith-Hall, C., Wunder, S. and Nielsen, M.R. (2016). Quantifying the economic contribution of wild food harvests to rural livelihoods: A global-comparative analysis. *Food Policy* 62: 22–132.

CHAPTER 7

Synthesis and General Discussion

7.1. *Background to the Research*

Social-ecological systems in the African drylands, including the dry forests and woodlands of southern Africa, are considered particularly vulnerable to climate change given high levels of sensitivity and low adaptive capacity (Kotir 2011; Fraser et al. 2011; Niang et al. 2014; De Souza et al. 2015; Abdi et al. 2016; Del Ninno et al. 2016; Van Wesenbeeck et al. 2016; Sietz et al. 2017). In the case of poor, rural communities, who continue to rely on climate-sensitive, land-based livelihood strategies and ecosystem services, climate change is likely to result in increasing vulnerability and inequality, unless households' capacity to cope and adapt is enhanced (IPCC 2014; De Souza et al. 2015; Kok et al. 2016; Sietz et al. 2017; Castells-Quintana et al. 2018). Improving households' capacity to cope and adapt is in line with global goals to reduce and manage the risk of climate change and achieve sustainable development (Brockhaus et al. 2013; IPCC 2014; Castells-Quintana et al. 2018; Vidal Merino et al. 2018). Although households may adapt autonomously, unprecedented climate shocks and long-term changes in climatic conditions are likely to strain existing capacities, underlining the need for locally relevant adaptation and development interventions that enable communities to respond (Kok et al. 2016; Mehar et al. 2016; Jurgilevich et al. 2017). This should include the removal of barriers to local-level adaptation efforts (Brown & Westaway 2011). Currently however, both national adaptation commitments and local-level interventions are undermined by a limited understanding of local-level impacts, vulnerabilities, and existing capacity (IPCC 2014; Ford et al. 2015; McDowell et al. 2016; Jurgilevich et al. 2017).

Within the South African context, although the need to better understand and address climate-related risk at the local level is recognised (e.g. DEA 2019), a review of the literature (from across southern Africa) indicates limited data on the climate-related risk of rural households (see Chapter 1). This supports the findings of McDowell et al. (2016) and Jurgilevich et al. (2017) who's respective literature reviews also point to a dearth of sub-national and local-level risk assessments from sub-Saharan Africa. To support the design, implementation and monitoring of appropriate adaptation and development interventions, there is the need for more context-specific information on local vulnerabilities and capacity to respond (Dáze et al. 2009; Fisher et al. 2010; Brockhaus et al. 2013; IPCC 2014; De Souza et al. 2015; Kok et al. 2016). This should be acquired through a multi-stakeholder process that accounts for the heterogeneity of rural communities, that is cognisant of the most vulnerable groups, and that recognises the value of local knowledge and experience (McDowell et al. 2016; Elum et al.

2017). Using a case study from South Africa, this study sought to contribute towards this data gap, with the overall aim of better understanding households' vulnerabilities and responses to climatic and socio-economic stressors in southern African dry forests and woodlands.

Focusing on two rural communities in South Africa's Limpopo Province, this study used a mixed-method approach to address the aims and objectives outlined in Chapter 1. For the design of the research methodology and the data analysis, I drew from various frameworks, focusing on the Sustainable Livelihoods Framework (DFID 1999) and the Intergovernmental Panel on Climate Change's (IPCC's) recent framework on climate-related risk (IPCC 2014). These frameworks are described in the relevant results' chapters (Chapters 3-6). Two similarly-sized villages were selected from the same district municipality however, to allow for a site-based comparison on local livelihoods, vulnerabilities and responses, I chose villages in different agro-ecological zones (AEZs) with notable differences in mean annual precipitation (MAP). Located approximately 90 km apart, the one village is in a semi-arid zone and the other in an arid zone. Given these differences, the villages were classified as the "wet site" and the "dry site". Villages were selected where households continue to engage in land-based livelihoods, including arable agriculture, animal husbandry and the use and sale of non-timber forest products (NTFPs). The dominant land-based livelihood strategies differ between the sites: arable agriculture is more prevalent in the wet site, while animal husbandry dominates in the dry site (Chapters 4 & 6). The dry site's surrounding communal rangelands and protected areas provide a more extensive habitat for diverse NTFPs (Chapters 3, 5, 6). Rural inhabitants of Limpopo Province, one of South Africa's poorest provinces, are expected to be adversely affected by climate change given their reliance on land-based livelihoods (Turpie & Visser 2013; Thivhafuni 2015). The methods and study sites are described in detail in Chapter 2.

The specific objectives of the study are to: i. assess the nature and heterogeneity of households' climate-related risk; ii. determine whether households' perceptions of climate variability and change align with the meteorological data, and if not, why not; iii. better understand households' broader vulnerability context, focusing on the nature and prevalence of unanticipated shocks; iv. better understand households' existing adaptive capacity, using households' past coping responses, and their existing capital portfolio, as a reflection of this capacity; and v. assess the safety-net role of provisioning services (specifically wild foods) for both climatic and socio-economic shocks. For each of these aspects, the influence of site and various household-level socio-economic and -demographic characteristics was considered. The aims and objectives of each of the four results' chapters (Chapters 3-6) are summarised below.

Chapter 3 explores the heterogeneity of climate-related risk among rural households in dryland systems, based on the assumption that better understanding this risk, both within and between communities, is important for the design, implementation and monitoring of measures aimed at reducing this risk (Kok et al. 2016). Using a cluster-based approach, I identified six differentiated, archetypical, household-level climate-risk profiles using indicators representing the core components of climate-related risk (i.e. hazards, exposure, impacts and vulnerability) (IPCC 2014). The profiles were evaluated, based on the assumption that, i.) if they differ substantially between the two sites, then adaptation interventions need to be site-specific, and ii.) if they are similar, then interventions can be applied more broadly across sites, but may have to be adjusted depending on specific household characteristics.

Chapter 4 considers local perceptions and experiences of climate change and variability in rural South Africa, based on the assumption that these perceptions, and the factors that shape them, may influence households' willingness to adapt, and their adaptation responses. Understanding these perceptions and influencing factors, may help identify households' primary concerns relate to the local climate and support the design and targeting of climate change communications and actions (Cooper et al. 2008; Hitayezu et al. 2017). Within this context, I explored whether these local perceptions, i.) reflect the meteorological data and, ii.) are uniform, both within and between the sites. Where divergences were noted, I considered what factors might explain these.

Chapter 5 considers rural households' broader vulnerability context and coping capacity by investigating the nature and prevalence of unanticipated shocks and the coping strategies used in response to these. The need to enhance households' capacity to cope and adapt has resulted in renewed interest in households' responses to climate-related and other shocks, including whether households manage their coping portfolio in anticipation of future shocks (Eriksen & Silva 2009; Hänke & Barkmann 2017; Castells-Quintana et al. 2018). I used mosaic plots to assess whether there are associations between the shocks experienced and coping strategies used, based on the hypothesis that households apply these strategies arbitrarily irrespective of the shock in question. A multivariate analysis was used to explore whether the adoption of a particular strategy was influenced by explanatory variables related to site and/or various socio-demographic and economic characteristics. The coping strategies were considered in terms of their constraints for covariate, climate-related shocks.

Chapter 6 focuses on the safety-net role of wild foods during periods of food scarcity, related to seasonal shortfalls and climate-related shocks. Given the expectations of the contribution of wild foods (and NTFPs in general) to sustainable and climate-resilient livelihoods, there is the need for a more nuanced understanding of the role they play in households' diet, both on a daily basis and during periods of increased vulnerability (Hunter et al. 2007; Bharucha & Pretty 2010; Sunderland 2011; Pramova et al. 2012; Chivandi et al. 2015; Powell et al. 2015; Ofoegbu et al. 2016; Balama et al. 2017). Within this context, I considered the extent of wild food consumption and sale, the frequency with which households consumed wild foods, both regularly and during times of increased food scarcity, as well as households' perceptions of the importance of the safety-net function of wild foods. Archetypes of wild food users were defined by clustering households based on the frequency with which they consumed wild foods during three food availability periods: i.) when food is plentiful (e.g. after the harvest), ii.) when food is scarce (e.g. during seasonal crop shortfalls), and iii.) during "hungry periods" (e.g. during drought and unanticipated crop failure). The influence of variables such as site and households' socio-demographic and economic characteristics on wild food use was assessed.

The remainder of this chapter is structured as follows: Section 7.2. presents the findings and insights on households' vulnerabilities and responses to climatic and socio-economic stressors, focusing on the broader patterns identified; Section 7.3 explores the influence of site and various household-level socio-economic and -demographic characteristics on households' vulnerabilities and responses; Section 7.4. highlights some key lessons on the methods; Section 7.5. presents some of the key recommendations from the research, including areas for future research and action. Section 7.6. presents the concluding remarks.

7.2. Understanding households' vulnerabilities and responses to climatic and socio-economic stressors in southern African dry forests and woodlands

7.2.1. Understanding households' broader vulnerability context

Rural households face climatic and socio-economic stressors, including unanticipated idiosyncratic and covariate shocks and more predictable periods of hardship, which contribute towards households' vulnerability context (DFID 1999; Bunce et al. 2010; Paumgarten & Shackleton 2011; FAO 2018; Mbiba et al. 2019). Unanticipated shocks are a common feature of rural livelihoods, with households experiencing multiple shocks over a limited period (Chapter 5). In the selected sites, production shocks were the most commonly reported, emphasising the risk associated with households' ongoing reliance on land-based livelihoods. Crop and livestock losses were attributed to unpredictable and extreme weather, including climate hazards, however not all production shocks were climate-driven (Chapters 3-6). For example, livestock losses were associated with attacks by wildlife escaping the neighbouring conservation areas, and with cross-border cattle rustling driven by Zimbabwe's economic crisis (Thornycroft 2017). Unanticipated human shocks (e.g. the death of a household member) and natural hazards were the second and third most commonly reported shocks (Chapter 5). Financial shocks were the least common.

These shocks intersperse more expected hardships. For example, collective food shortages were associated with both unexpected crop losses and predictable seasonal crop shortfalls (Chapter 6). Households perceived increasing difficulties in finding sufficient food, which they attributed to these periods of food scarcity, together with increasing living costs (Chapter 6). Interventions aimed at reducing household-level vulnerability and risk, should recognise this broader vulnerability context and households' need to manage for multiple, often concurrent, climatic and socio-economic stressors (DFID 1999; Dercon 2002; Vincent 2007; Bunce et al. 2010; Sietz et al. 2012; Berrouet et al. 2018; Vidal Merino et al. 2018). A failure to account for the broader vulnerability context, and any complex synergies between climatic and socio-economic stressors, increases the risk of maladaptation, which may increase the vulnerability of the most vulnerable (Bunce et al. 2010; Adger et al. 2011).

7.2.2. Climatic stressors: understanding the heterogeneity of climate-related risk at the household-level

Climate-related risk involves the potential for impacts resulting from the interaction of natural hazards with the exposure and vulnerability of human and natural systems (IPCC 2014). Using a cluster-based approach, with indicators representing the core components of the IPCC's recent climate-risk framework (IPCC 2014), I identified six archetypical patterns of risk (i.e. climate-risk profiles) (Chapter 3). Based on households' experience of hazards, their exposure, the associated impacts, and households' adaptive capacity, two high-, two moderate-, and two low-risk profiles were identified. The profiles provide insights into the heterogenous nature of climate-related risk and give an indication of its extent, highlighting those households that require more immediate support. By revealing a limited number of units of analysis, this cluster-based approach allowed for a more systematic interpretation of the climate-related risk of rural households in dryland systems (Sietz et al. 2012; Kok et al. 2016; Vidal Merino et al. 2018).

Almost a third of the households fall within the high-risk clusters (Chapter 3). High climate-related risk was associated with land-based livelihoods, including exposure and impacts through arable agriculture and animal husbandry. Given their proximity, the two sites have experienced many of the same regional drought and flood events (Chapter 4). Both sites experienced floods shortly before the fieldwork commenced, with the dry site having received more rainfall in one week than its annual average (Pringle et al. 2013) (Chapters 4 & 5). The climate-risk profiles were therefore defined more by floods than drought, with households in the high- and moderate-risk profiles having all reported flood-related impacts, including, in the case of the high-risk households, flood damage to infrastructure and assets. These hazards tend to be well remembered, with strong oral narratives related to their immediate and long-term impacts and the ways households have coped and adapted (Chapter 4).

Households' access to an off-farm income plays a role in distinguishing the high- and low-risk clusters, with the former having limited access to off-farm income. High-risk households also have limited adaptive capacity, associated with their restricted capital portfolio. Other studies have noted similar findings (e.g. Sietz et al. 2012; Vidal Merino et al. 2018). With limited options to diversify off-farm, interventions are needed that increase the resilience of households' land-based livelihood strategies (Vidal Merino et al. 2018). Respondents in both communities suggested possible practical interventions, based on their previous experience (Chapter 3). The IPCC (2014) has described this existing local knowledge as a key resource for climate change adaptation. Households' adaptive capacity is discussed in more detail in the sections below.

Given households' reliance on climate-sensitive, land-based livelihoods, the implications of climate change on household food security is of increasing concern (Delang 2006; Drimie & McLachlan 2013). In more marginal areas, where crop failure and recurrent drought undermine food security, climate-resilient wild foods are receiving increasing attention for their existing and potential contribution to household diets (Burlingame 2000; Delang 2006; Pramova et al. 2012; Powell et al. 2015; Tibesigwa et al. 2016). I considered the frequency with which households consumed wild foods in response to food scarcity associated with seasonal crop shortfalls and unpredictable crop losses (e.g. related to natural hazards) (Chapter 6). The safety-net function of wild foods is discussed in more detail in the relevant sections below but mentioned here as the results reiterate the heterogeneity of household-level vulnerability and risk.

Based on differences in consumption frequency during different food availability periods, three distinct archetypes of wild food users were defined. These were categorised as "Safety", "Dependence" and "Disinterest". Households in the "Safety" cluster consumed wild foods infrequently but increase their consumption in response to food scarcity. This is the largest cluster. Those in the "Dependence" cluster incorporate wild foods in their diet more regularly, however their consumption decreased in response to food scarcity. Respondents noted seasonal variations in wild food availability, and reduced availability during natural hazards, suggesting that for "Dependence" households, wild foods may constitute a poverty trap (Levang et al. 2005). For households in the smallest, "Disinterest" cluster, wild food consumption is driven by availability, rather than need. This availability can transfer vulnerability to other households, as noted in the case of one dry-site household whose chicken-selling business failed because of the availability of bushmeat. As with the climate-risk profiles, the identification of these distinct clusters allowed for a more systematic analysis of the role of wild foods in households' responses to seasonal and shock-related food shortages.

7.2.3. Responding to multiple stressors: household coping strategies and adaptive capacity

Households' capacity to respond to stressors is an important determinant of vulnerability and risk (IPCC 2014). Different aspects of this capacity were considered in this study (Chapters 3, 5 & 6). In Chapter 3, households' access to different types of capital was assumed to reflect their existing adaptive capacity, with the climate-risk profiles described above therefore influenced by households' existing capital. Households past coping strategies were explored in Chapter 5, based on the assumption that better understanding these responses might provide insights into how to enhance coping and facilitate adaptation. The safety-net role of wild foods was unpacked in Chapter 6, with these more climate-resilient wild foods receiving increasing attention for their potential role in climate change adaptation.

Households' informal coping strategies are receiving renewed attention given their potential role in enhancing households' adaptive capacity (Eriksen & Silva 2009; Mehar et al. 2016; Hänke & Barkmann 2017; Castells-Quintana et al. 2018). I explored these *ex-post* (reactive) and *ex-ante* (anticipatory) coping strategies in the context of households' response to unanticipated shocks, including natural hazards (Chapter 5). The strategies were designated as either external or internal responses (Adams et al. 1998; Cooper et al. 2008). External strategies included relying on kinship networks, seeking external assistance (e.g. in the form of government post-disaster support), and acquiring loans. Relying on kinship was the most common response overall. Seeking external assistance was also common, particularly in response to natural hazards. Very few households sought loans to cope, although this strategy was positively associated with financial shocks. Internal strategies included drawing from household savings, reallocating household labour, reducing household spending (and consumption), relying on the safety-net function of natural products, and selling household assets (listed in order, from most to least widely used). Relying on natural products was not the most common strategy, however it was more common than either the sale of assets or loan-seeking.

Households' response to shocks is influenced by the type of shock experienced, although generally these informal coping strategies appear limited in the case of natural hazards (Chapter 5). Asset depletion was the only strategy neither positively nor negatively associated with any of the selected shocks. The influence of shock-type has been noted in other studies, suggesting the need for either a few effective strategies, or a diverse coping portfolio (Paumgarten & Shackleton 2011; Wunder et al. 2014; Börner et al. 2015; Mugido &

Shackleton 2017). It suggests that households selectively choose strategies based on how effectively the strategy buffers against a particular shock, or on households' desire to manage their coping portfolio for future shocks. Households' responses are also influenced by their access to financial, physical, human, social, and natural capital (Chapter 5). Households' informal coping strategies were also considered when defining the archetypes of wild food users (Chapter 6). To describe the archetypes, I fitted binary logistic regressions that related membership in a cluster to variables related to household location, demographics, livelihood activities and incomes, and the coping strategies used in response to unanticipated shocks. Households' capacity to respond to shocks, and their access to different capitals, played a role in distinguishing the clusters of wild food users.

The heterogeneous climate-risk profiles were defined as a function of differences in exposure (and impacts) and vulnerability, with the latter influenced by households' adaptive capacity (i.e. their access to capital) (Chapter 3) (DFID 1999; Adger et al. 2011; IPCC 2014; Jurgilevich et al. 2017; Vidal Merino et al. 2018). It is argued that households' uptake of adaptation (whether autonomously, or in response to adaptation interventions) is likely to be influenced by their access to, and control over, resources (Hahn et al. 2009; de Jalón et al. 2018; Vidal Merino et al. 2018). High-risk households have limited adaptive capacity, with poor access to most capital types other than natural capital (Chapter 3). The low-risk households have higher adaptive capacity. The two moderate-risk clusters also provide insights into households' risk and adaptive capacity. Although both face moderate risk, the clusters differ in terms of households' exposure, the impacts faced, and their access to capital. Households in the one cluster experienced exposure and impacts through their land-based livelihoods but faced lower risk due to their diverse capital portfolio (i.e. high adaptive capacity). Households in the other cluster had low adaptive capacity (i.e. they were capital-constrained) but experienced low exposure and impacts given their limited engagement in land-based livelihoods. This low exposure distinguishes these capital-constrained households from those in the high-risk clusters. The distinctions between the two moderate-risk clusters raise questions on whether diversification is a source of resilience or vulnerability (Sietz et al. 2012; Kok et al. 2016). This needs to be explored further. Recognising these different adaptive capacities is important for the targeting of adaptation interventions (Vincent 2007; Birkmann et al. 2013; Joakim et al. 2015).

7.3. The influence of site and various household-level socio-economic and -demographic characteristics on households' vulnerabilities and responses to climatic and socio-economic stressors in southern African dry forests and woodlands

I considered the influence of site and various household-level socio-demographic and -economic characteristics on households' vulnerabilities and responses. These factors are discussed below: Section 7.3.1. discusses the influence of site. Section 7.3.2. discusses the influence of households' socio-demographic characteristics. Section 7.3.3. discusses the influence of households' existing capital portfolio. Of these various factors, site appears to have the greatest influence in determining households' vulnerabilities and responses, however certain household characteristics, including households' existing capital, also have an influence. These results confirm that given the heterogenous nature of rural communities, different individuals and groups are likely to experience varying degrees of vulnerability and risk (DFID 1999; Kasperson & Kasperson 2001; Sietz et al. 2012; IPCC 2014; Castells-Quintana et al. 2018)

7.3.1. The influence of site and agro-ecological zone on households' vulnerabilities and responses to climatic and socio-economic stressors

Clear site-related distinctions were noted in the climate-risk profiles (Chapter 3), in people's perceptions of climate change and variability (Chapter 4), and in households' coping responses (Chapters 5 & 6).

Higher vulnerability levels were associated with harsher conditions, as noted in other dryland vulnerability studies (e.g. Kok et al. 2016; Vidal Merino et al. 2018). In terms of the climate-risk profiles, three were dominated by dry-site households and three by wet-site households. As noted above, the sites experience many of the same natural hazards although these tend to be more extreme in the dry site (Chapters 2, 4 & 6). Both sites experienced floods shortly before the fieldwork commenced, however while all the dry-site clusters were characterised by the experience of floods and flood-related damage to infrastructure and assets, only one wet-site cluster was (Chapters 3 & 4). This wet-site cluster consisted of high-risk farming households with limited capital (other than natural capital) (Chapter 3). The remaining two wet-site clusters were both low-risk, consisting of households who reported limited hazards and impacts, despite some exposure through their engagement in arable agriculture (Chapter

3). The dry-site clusters included two moderate- and one high-risk cluster. The latter consisted of high-risk pastoralist households who reported flooding, exposure and impacts through their livestock, and damage to infrastructure and assets. Given the site-related differences in the dominant land-based livelihood strategies, the dry-site clusters tend to face exposure and impacts through animal husbandry, and the wet-site clusters through arable agriculture.

Local perceptions of climate variability and change also diverge strongly by site, influenced by differences in the exposure and sensitivity of local livelihoods (Chapter 4). For example, despite recent floods, as well as meteorological evidence of a significant increase in rainfall in the dry site (for 2004-2013), the respondents in this site tended to perceive a declining rainfall trend (Chapter 4). These perceptions appear to be influenced by severe droughts in the 1980s and 1990s, with strong oral narratives related to the associated impacts (i.e. the affect heuristic outweighs the availability heuristic (Tversky & Kahneman 1973)). Factors such as overgrazing and poor water supply infrastructure may have entrenched perceptions of drying conditions, although this requires further research (Maddison 2007; Mertz et al. 2009; Moyo et al. 2012; Simelton et al. 2013; Muller & Shackleton 2014). Conversely, households in the wet site, particularly those cultivating tree crops, were more likely to perceive an increase in precipitation (despite no significant trend), because of the impacts of heavy rains on orchards, houses, and roads. Other studies have noted this association between perceptions and bio-physical vulnerability in higher rainfall areas (Mubaya et al. 2012; Gandure et al. 2013; Muller & Shackleton 2014; Hitayezu et al. 2017). Generally, changes in the local climate were widely perceived but these perceptions differed from the meteorological data. Respondents were inclined to perceive worsening conditions, as noted in other southern African studies (e.g. Simelton et al. 2013; Hitayezu et al. 2017). Although perceptions diverged most strongly by site, they were not uniform within each site (Chapter 4). Concerns exist that these perceptions may have more influence than the actual climate trends on households' adaptation responses (IPCC 2014; Devkota et al. 2016; Elum et al. 2017).

The climate-risk profiles (Chapter 3) and households' informal coping strategies, including the safety-net function of NTFPs (specifically wild foods) (Chapters 5 & 6), were influenced by distinct site-related differences in households' access to different capitals. The clearest distinction relates to natural capital, although site-related differences were also noted in households' physical and social capital (see the relevant sections below). The wet-site clusters had better physical and social capital, most likely related to better access to an off-farm income. The reasons for this require further investigation (Chapter 3). The AEZ and, related to this, the key land-based livelihood strategies in each site, influenced households' available natural capital. All the dry-site clusters have high NTFP-based natural capital while the wet-site clusters are defined more by households' access to private tree crops (see Natural Capital section). The patterns of wild food use emphasise the site-related differences in access to NTFP-based natural capital, as well as the influence of households' land-based livelihood strategies on their NTFP use (Chapter 6). While the odds of consuming wild edible herbs are higher in the wet site, households in the dry site were more likely to consume and sell bushmeat, and to perceive wild foods as "very important" for coping with food shortages (see Natural Capital section). Households in the dry site were more likely to fall in the "Safety" cluster of wild food users, while the "Disinterest" cluster consisted of more wet-site households. The odds of being the "Safety" cluster were also higher if the household had livestock, and lower if the household engaged in arable agriculture, while the inverse applied for households in the "Disinterest" cluster. The association between wild food use and households' land-based livelihood strategies is emphasised by the fact that households with livestock were more likely to consume wild foods and consider wild foods as "important" for coping with hungry times. Households without livestock considered wild foods as "not important". The association between livestock herding and the harvesting of NTFPs from communal rangelands has been well documented (e.g. McGarry & Shackleton 2009).

Site had some influence on households' informal coping strategies, specifically on spending reductions and asset depletion (Chapter 5). Households in the dry site were more likely to reduce household consumption and spending. Consumption and spending reductions can have negative implications on household welfare (e.g. if households cut down on the quantity and quality of meals). Access to NTFPs can play an important role in buffering households against these reductions, which may explain why households in the dry site, and those already engaged in the sale of NTFPs, were more likely to rely on this coping strategy. Others have similarly noted increased NTFP extraction associated with consumption decreases (e.g. Mugido & Shackleton 2017). Households in the dry site were also less likely to deplete assets, despite livestock ownership being more prevalent in this site (see Physical Capital section). This finding suggests that although households value their livestock for its insurance function, they prefer, if possible, to maintain their livestock for other purposes (i.e. livestock is multi-functional) or, they face barriers to the sale of livestock (Hänke & Barkmann 2017).

None of the other strategies showed a positive or negative association to site, although they were influenced by other factors related to households' socio-demographic and -economic characteristics (see relevant sections below).

7.3.2. The influence of households' socio-demographic characteristics on households' vulnerabilities and responses to climatic and socio-economic stressors

The relationship between households' socio-demographic characteristics and their vulnerabilities and responses to climatic and socio-economic stressors was explored, revealing patterns related to the gender and education of the household head, the age of the household, and the size and composition of the household (i.e. the number and age of the resident members).

Female-headed households are generally more vulnerable than male-headed households. Their livelihood, coping and adaptation options are often restricted by specific gender-related barriers, including their household and child-care responsibilities (Posel 2001; Takasaki et al. 2004; Börner et al. 2015; Tran 2015; Mehar et al. 2016). Development and adaptation interventions need to recognise the different challenges and opportunities faced by female- and male-headed households (Eriksen et al. 2005; Sietz et al. 2012). According to my results, gender of the household head (henceforth "gender") influences households' vulnerabilities and responses: the climate-risk profiles (Chapter 3) and households' coping strategies (Chapter 5) were affected by gender. The two lowest risk clusters were differentiated by gender. Households in the lowest risk cluster had a more educated, male household head. Unexpectedly, households in the second lowest risk cluster were female-headed. A key factor here is the households' access to regular remittances, which contribute to reduced risk (see Financial Capital section). Assuming that the remitting migrant is the de jure (male) household head, then these are de facto female-headed households. In retrospect, distinguishing between de facto and de jure female-headed households may have provided greater insights into the vulnerability and risk of female-headed households.

This nuanced view of gender would have also improved our understanding of households' coping strategies (Chapter 5). Female-headed households were unlikely to respond to unanticipated shocks by selling assets or relying on NTFPs. It is unclear whether these households were unable to rely on these strategies because of gender-related barriers to accumulating/selling assets and to accessing NTFPs, or whether they could avoid these strategies because of their access to remittances. As the presence of a remitting migrant influences households' capacity to cope and adapt (see Financial Capital section), the distinction between de facto and de jure household head needs to be considered.

The age of a household influences their ability to cope and adapt, although as with gender, there are nuances which require further investigation. The climate-risk profiles show distinctions related to household age, particularly in the dry site (Chapter 3). More well-established households have assembled a more diverse portfolio of livelihood and coping strategies. While they face greater exposure through their diverse livelihood strategies, their adaptive capacity is higher. Their capital portfolio includes high NTFP-based natural capital (Chapter 3). This existing traditional ecological knowledge (TEK) may explain why older households were more likely to increase their wild food consumption in response to food scarcity (Chapter 6). Having said that, there was no association between age and using NTFPs to cope with unanticipated shocks (Chapter 5). The reasons for this distinction are unclear. A possible explanation is that the harvesting and consumption of wild foods require more specific skills and preferences than other NTFPs. Household age did however influence the use of other coping strategies. Older households were less likely to reduce household spending and consumption, and more likely to use their savings and sell assets to cope (Chapter 5). This reflects their accumulated capital, and possibly previous experience in selling assets (e.g. they might have established livestock markets).

In both sites, the recently established households (e.g. young or migrant households) have an off-farm income and limited engagement in land-based livelihoods, although those in the wet site face lower risk. These wet-site households have a more diverse capital portfolio than their dry-site counterparts, although their NTFP-based natural capital is low (see Chapter 3 for possible explanations). These households most likely fall into the "Disinterest" cluster of wild food users. The odds of being in this cluster are higher for younger households, households in the wet site, and households who avoid using NTFPs to cope (Chapter 6).

Other socio-demographic characteristics which appear to influence households' vulnerabilities and responses to climatic and socio-economic stressors include, i.) the size of the household, ii.) the education of the household head, and iii.) the composition of the household members (i.e. number of adults vs. children). As these characteristics relate to households' human capital, they are discussed in the relevant section below. Of households' informal coping strategies, kinship was the only strategy not influenced by site or households' socio-demographic characteristics. Although these various socio-demographic characteristics influence households' vulnerabilities and responses, they do not appear to influence households' perceptions of climate change and variability (Chapter 4). Other South African studies have noted an association between perceptions and households' socio-demographic characteristics (Gbetibouo 2009; Hitayezu et al. 2017), however I found location, households' engagement in land-based livelihoods, and their previous experiences of extreme events to have a greater influence.

7.3.3. The influence of households' capital portfolio on households' vulnerabilities and responses to climate and socio-economic stressors

The IPCC's (2014) definition of vulnerability encompasses households' susceptibility to harm and their capacity to cope and adapt (Chapters 1 & 3). This capacity is influenced by households' access to capital, as defined in the Sustainable Livelihoods Framework (SLF) (DFID 1999; IPCC 2014; Vidal Merino et al. 2018). Using a conceptual framework which incorporated the IPCC's (2014) climate-risk framework and the SLF, I explored the influence of households' capital on their climate-related risk, based on the assumption that there is a negative correlation between access to capital and risk (Chapter 3). Various indicators were selected for households' financial, physical, human, social, and natural capital (DFID 1999; Ahsan & Warner 2014; Vidal Merino et al. 2018). The influence of this capital on households' coping responses (Chapters 5 & 6), and to a lesser degree, on their perceptions of climate change (Chapter 4), was also explored. These results are discussed in the sub-sections below. For practical purposes, the different capital types are discussed separately, although there are overlaps and interlinkages.

Financial capital

Financial capital includes the regular cash inflows and available stocks (e.g. savings) households use to pursue their livelihood outcomes (DFID 1999). For cash inflows, I considered access to government social grants and migrant remittances, accounting for (where possible) the reliability and amount of these inflows (DFID 1999; Gautam & Andersen 2016; Vidal Merino et al. 2018). Off-farm income, through local employment and self-employment, was used as an indicator of households' available labour and skills and is therefore discussed under the section on human capital (Dercon 2002; Sietz et al. 2012). For available stocks, I considered households' formal and informal savings. The latter includes savings clubs, burial societies, and so forth. Although financial capital is the most versatile capital-type, it is usually the least available to the poor, increasing their dependence on other forms of capital (DFID 1999).

Of the five capital types, financial capital had the least influence in defining the climate-risk clusters (Chapter 3). Of remittances, government grants and formal savings, only remittances played a role in distinguishing the high- and low-risk clusters. Households receiving more regular remittances faced lower risk than those with migrants who remit infrequently or not at all. Remittance-receiving households are less dependent on climate-sensitive, land-based livelihoods, and more likely to perceive wild foods as only "somewhat important" for coping with hungry periods associated with natural hazards (Chapter 6). Remittances may provide alternative means of coping with these food shortages, however the limited dependence on wild foods could also reflect labour constraints associated with the migration of productive members (Chapter 6). These households were more likely to seek loans to cope, although loan-seeking was generally uncommon (Chapter 5). Better access to credit and the ability to repay loans might account for this, although labour constraints may also be a factor (Ofoegbu et al. 2016). Although remittances may improve households' capacity to cope and adapt, our results suggest limitations to migrants' capacity to provide support: households with remitting migrants still reduced spending to cope with unanticipated shocks (Chapter 5). Having a migrant member, had no influence on households' perceptions of climate variability and change (Chapter 4).

Drawing from savings was the only internal coping strategy positively associated with natural hazards (Chapter 5), indicating that access to this form of financial capital helps reduce climate-related risk. Having said that, access to formal savings had limited influence in defining the climate-risk profiles, suggesting the need for further research (Chapter 3). For example, information on the influence of the amount saved and the accessibility of these savings might be useful. Although using savings was a common response to unanticipated shocks, my results suggest that, when possible, households try to protect and maintain their financial capital by relying on alternatives, particularly their social and natural capital (Chapter 5). In the case of natural hazards, households' reliance on savings intimates possible limitations to these alternative coping strategies for covariate, climate-related shocks (see relevant sections). The dependence on savings for coping with natural hazards is concerning, particularly given expectations of more frequent, intense climate-related shocks (IPCC 2014).

Unless households' adaptive capacity improves, households' ability to accumulate savings will be hindered, undermining their efforts to secure a sustainable livelihood, reducing their overall coping capacity, and limiting their ability to make investments in adaptation (Adger et al. 2011; Adimassu & Kessler 2016; Castells-Quintana et al. 2018).

The insurance function of households' savings requires a nuanced understanding. When defining the climate-risk profiles, the influence of both formal savings and of households' membership in informal saving schemes was considered (Chapter 3). Participation in these schemes was used as an indicator of social capital, highlighting the overlaps between different capitals. Unlike formal savings, households' involvement in these saving schemes played a role in differentiating the low- and high-risk clusters. Access to informal saving schemes was associated with lower risk. Households with informal savings were less likely to use NTFPs to cope (Chapter 5). Households in the three more high-risk clusters had limited participation in these schemes, suggesting possible entry barriers. Other findings from this study indicate possible constraints to this insurance option: households with informal savings were unlikely to draw from these to cope with unanticipated shocks (Chapter 5). Informal, community-based savings schemes often have conditions to use, making them better suited to more anticipated periods of hardship (Paumgarten & Shackleton 2011). For example, rotating savings clubs pool members' contributions, allocating the pool in rotation, not as a loan when needed (Bouman 1995). Therefore, when assessing the contribution of financial capital to households' coping and adaptive capacity, liquidity should be considered (DFID 1999). Within the context of coping and adaptation, the social capital contribution of these saving schemes needs to be understood and compared to their financial capital contribution. There is also the need to consider how effectively these savings buffer against covariate shocks which affect several members simultaneously (Gao & Mills 2018).

Contrary to expectations, households with formal savings still relied on external assistance (from government, NGOs, etc.), with this being the only other coping strategy positively associated with natural hazards (Chapter 5). Households may seek external assistance to protect their savings. Alternatively, both the assistance available and households' savings may be insufficient, compelling households to rely on multiple options. Worryingly, more vulnerable household without formal savings appear not to rely on this external assistance (Chapter 5). This is reiterated in Chapter 6: households in the "Dependence" cluster of wild food users were less likely to seek external assistance to cope while households in the

"Safety" cluster did so. Do more vulnerable households face barriers to accessing these external resources or are they more vulnerable because they are ineligible? Whilst improved access to robust external safety-nets is important for vulnerable households, it should be recognised that this assistance also allows households with other coping strategies to retain these for future shocks (Dercon 2002; Mugido & Shackleton 2017; Gao & Mills 2018). I distinguished between emergency (post-disaster) assistance and households' access to regular government grants. These grants had limited influence in defining the climate-risk clusters (Chapter 3) but did influence households' coping strategies, specifically their reliance on wild foods (Chapter 6). Households receiving less income through state grants were more likely to increase their wild food consumption during hungry periods while those with more child grants were likely to be in the "Disinterest" cluster. According to Satumba et al. (2017), these social grants have significantly reduced poverty levels in rural areas in Limpopo Province, particularly amongst female-headed households.

Physical capital

Physical capital includes the basic infrastructure and producer goods required to support livelihoods (DFID 1999). I focused on privately owned physical capital including households' access to secure shelter, their ownership of tools and equipment (and the value of these), and their available storage facilities (i.e. for water, crops, etc.). For secure shelter, the construction materials used were taken as an indicator of the buildings' sturdiness (Vincent 2007; Ahsan & Warner 2014). Although the focus was on peoples' homes, respondents also described flood damage to other privately-owned infrastructure (e.g. fences and irrigation pumps) and to public infrastructure such as electricity poles, telecommunication infrastructure, roads, schools, etc. (Chapters 3 & 5).

Households' access to secure shelter influenced the climate-risk profiles (Chapter 3). Higher-risk households tended to have traditionally constructed homes which were susceptible to flood damage. These homes are more common in the dry site, influenced by poor access to building materials and better access to thatching grass (natural capital). Households with sturdier homes faced lower risk, with the ownership of sturdier homes associated with access to off-farm income. In addition to flood-related impacts, respondents noted damage associated with heavy winds, severe storms, and tornadoes (Chapters 3 & 5). Vincent (2007) similarly noted an inverse relationship between the quality of peoples' homes and vulnerability. The nature of peoples' homes also influences their perceptions of climate change, although this was only the case in the wet site amongst the small group of households with traditionally constructed homes (Chapter 4).

Although the lower-risk households tended to own high-value equipment, owning high-value equipment was not exclusively linked to low-risk (Chapter 3). One of the highest-risk clusters consisted of pastoralist households with high-value draught equipment (e.g. carts and ploughs), but limited access to other capital. Households with high-value equipment were however less likely to rely on external assistance or to reduce spending and consumption or to cope (Chapter 5). Asset accumulation has been described as an *ex-ante* risk management strategy, giving households the option to sell assets (DFID 1999; de Jalón et al. 2018). I found however, that the ownership of high-value equipment had no influence on the likelihood of households selling assets to cope (Chapter 5). For households with high-value equipment, the sale of assets is either a “last resort” option, or they have alternative coping strategies and don’t need to sell their assets (i.e. they’re lower-risk households), or they own equipment for which there is a limited market (e.g. high-value draught equipment). For high-risk pastoralist households, the sale of assets such as ox-drawn carts ultimately threatens their future livelihood and coping options (Dercon 2002; Kazianga & Udry 2006; Deressa et al. 2009; Del Ninno et al. 2016).

For practical purposes, the sale of assets (including livestock), as an *ex-post* coping response, is discussed in this section, although this could also fall under financial capital. Although households sold various assets, livestock was the most commonly sold in response to unanticipated shocks (Chapter 5). Households already engaged in the sale of livestock were more likely to sell assets to cope. Livestock is often highly valued for this insurance function, however, households in the dry site were less likely to sell assets to cope, despite greater livestock ownership. The multiple functions of livestock, veterinary controls on livestock movement, and limited markets may discourage sales (Ofoegbu et al. 2016). While some households may have accumulated assets as an *ex-ante* risk management strategy, others sold assets because of greater need and limited alternative coping strategies. For example, older and larger households and those with non-remitting migrants sold assets (see Chapter 5 and relevant sections). Female-headed households, those with labour engaged in water collection, and those selling NTFPs were however unlikely to rely on this strategy (Chapter 5). These households may face gender- and labour-related barriers to the accumulation and sale of assets. Households selling NTFPs may also be able to avoid asset depletion by relying on natural capital. This coping strategy had no influence on defining the clusters of wild food users (Chapter 6). Generally, the sale of assets was an unpopular strategy, neither positively nor negatively associated with the identified shocks (Chapter 5).

Finally, households' available physical capital has some influence on their perceptions of climate change and variability (Chapter 4). Specifically, perceptions appear to be influenced by households' access to irrigation equipment and to telecommunications infrastructure and assets (e.g. radios and cellphones), with the latter affecting households' access to weather information.

Human capital

Human capital reflects the labour and skills households have at their disposal to pursue alternative livelihood, coping and adaption options (DFID 1999). It is factor of the amount and quality of labour available, and influences households' ability to turn to labour-intensive options (e.g. harvesting NTFPs) or to diversify into less climate-sensitive, off-farm livelihoods (DFID 1999, McSweeney 2005; Sietz et al. 2012). The influence of human capital on both households' adaptive capacity, as reflected in the climate-risk profiles (Chapter 3), and on their coping strategies (Chapter 5 & 6), was explored. Both the amount and quality of available labour had an influence on households' capacity to cope and adapt.

- The amount of labour available: household size and composition

Two climate-risk clusters were distinguished by household size (Chapter 3). The second lowest-risk cluster consisted of smaller households, with a female-head and a remitting migrant (see sections on gender and Financial capital). Although these households faced lower risk given their access to remittances, they are labour constrained because of the migration of productive members. This limits their livelihood, coping and adaptation options, and leaves the household vulnerable to shocks affecting the migrant (Chapters 3 & 5). One of the more moderate risk clusters was distinguished by larger households, with a diverse livelihood and capital portfolio (Chapter 3). It is unclear whether this diversification was enabled by access to labour (i.e. high human capital), or whether the households have grown subsequently.

Labour constraints influence households' coping options: households with labour occupied in water collection were more likely to reduce spending and consumption; households with labour occupied in NTFP collection were unlikely to reallocate labour, relying instead on kinship and loans; and households with non-remitting migrants were more likely to sell assets, being disadvantaged by the loss of a productive member without compensatory remittances (Chapter 5). Larger households, while not labour constrained, also face challenges to coping (Chapter 5). These households also sold assets and reduced spending and consumption, strategies which potentially undermine households' long-term well-being, and that imply greater need. Seeking external assistance or loans were uncommon responses (see Financial Capital). Contrary to expectations, labour-intensive coping strategies, such as the reallocation of labour and an increased reliance on NTFPs, were not positively associated with larger households. Although larger households incorporate wild herbs and fruit in their diet on a regular basis, they were not more likely to increase their wild food consumption in response to food scarcity (Chapter 6) (Angelsen & Wunder 2003; Hunter et al. 2007; Baiyegunhi & Oppong 2016).

Households' coping strategies are influenced by the composition of household members. For example, households with a high proportion of children, relative to adults, were unlikely to reallocate labour to cope (Chapter 5). Worryingly, they were more likely to reduce spending and unlikely to seek external assistance or apply for loans. Households with older members were more likely to fall in the "Dependence" cluster of wild food users, decreasing their wild food consumption in response to food scarcity. Older members may be unable to maintain (or increase) their harvesting levels during hungry periods, particularly if weakened by hunger, and if resource scarcity and harvesting pressure result in the need to travel further afield (Baiyegunhi & Oppong 2016).

- The quality of labour available: household skills (education and access to employment)

The lowest-risk cluster consists of households with a more educated household head, whose members are locally employed or self-employed (Chapter 3). Households in the second lowest-risk and moderate-risk clusters also have employed (locally or as migrants) or self-employed members, however, in these cases, the household head's education is not a distinguishing feature. The two high-risk clusters consist of households with limited access to local employment and self-employment opportunities, with no remittances (see Financial Capital), and with less educated household heads. Households' engagement in off-farm livelihood strategies, and the education of the household head, had no influence on households' perceptions of climate variability and change (Chapter 4). The influence of education on households' coping strategies was not considered, however these strategies are influenced by the number of locally employed or self-employed members (Chapters 5 & 6). Households with a greater number of locally, formally employed members were more likely to draw from their savings and to fall within the "Disinterest" cluster of wild food users (Chapters 5 & 6). Households with fewer formally employed members were more likely to perceive increasing challenges to finding sufficient food (Chapter 6). Households with more self-employed members were more likely to reallocate labour to cope, suggesting benefits to the flexibility of self-employment. These households were less likely to rely on kinship. I did not consider the education and skills of households' migrant members, however, given that households with a remitting migrant face lower risk, and engage in different coping strategies, to those with a non-remitting migrant, this information might have provided insights into whether investments in education and skills increase the likelihood of migrants finding work.

"Labour reallocation" was explored as a strategy in itself (Chapter 5). As an *ex-post* response to unanticipated shocks, this was the second most commonly reported internal coping strategy. It was positively associated with idiosyncratic human shocks but negatively associated with production shocks and natural hazards. Households' possibly choose to retain their labour locally to cope with the impacts of these (Osbahr et al. 2008; Ofoegbu et al. 2016; Gao & Mills 2018). They may also be unable to reallocate labour quickly enough to cope with the immediate impacts of covariate hazards, particularly given limited local employment opportunities and the costs of out-migration (Castells-Quintana et al. 2018; Gao & Mills 2018). The human health impacts of natural hazards (e.g. drought-related hunger) may also limit the option to reallocate labour. My results indicate that households who have successfully traded labour in the past, through migration and self-employment, were more likely to reallocate labour to cope, while those with labour constraints (i.e. low human capital) were less likely to do so (Hänke & Barkmann 2017). This coping strategy also plays a role in distinguishing the clusters of wild food users. Households in the "Safety" cluster were more likely to use labour reallocation as a coping strategy, than those in the "Dependence" cluster, which may reflect the labour constraints of the latter (i.e. the "Dependence" households have older members).

Social capital

Households develop “social capital” through networks and connectedness, through their membership in more formalised groups, and through relationships of trust, reciprocity, and exchange (DFID 1999). Households may draw from these social resources in pursuit of their livelihood objectives, and for poor, vulnerable households with limited access to other capital, social capital is often an important safety-net (DFID 1999; Vincent 2007; Paumgarten & Shackleton 2011; Ahsan & Warner 2014; Mbiba et al. 2019). I considered the extent to which households rely on their social networks (henceforth referred to as “kinship”) to cope with shocks and noted that this coping strategy is not restricted to households with limited options. Although households with limited options, including those with labour engaged in NTFP collection, may depend on this coping strategy, households with alternative options (i.e. formal savings and livestock) may purposefully turn to kinship as a strategic means of managing their future coping strategies (Chapter 5). Households with self-employed members were less likely to rely on kinship. Together with drawing from savings, kinship was the most commonly reported response to unanticipated shocks, although it was only positively associated with financial shocks (Chapter 5). There was no association between kinship and natural hazards, although kinship networks may become increasingly strained in the face of increasing hazards. This has implications for more vulnerable households with limited alternatives, but also for households who use their social capital to protect their broader capital portfolio. Other studies have suggested limitations to kinship for coping with covariate, climate-related shocks (Börner et al. 2015; Gao & Mills 2018).

Family-based networks were distinguished from non-family networks, and the role played by these different networks in reducing household-level vulnerability and risk was assessed. For family-based networks, I considered households’ reliance on extended family within the village. For non-family networks, I considered households’ membership in various associations and groups, including informal saving schemes (see section on Financial Capital). Although I was unable to gauge the “strength” of the social capital associated with these different networks, my results suggest that some forms of social capital may be better than others. For example, households with family-based networks were less likely to reduce spending and consumption while those with non-family networks still relied on their savings (i.e. financial capital) to cope with unanticipated shocks (Chapter 5). Interestingly, households with family-based networks were more likely to sell assets and seek loans to cope. This may indicate limitations to the safety-net function of these networks however, it is also possible that households sell their assets within, or get loans from, their networks. These networks may provide a local market, with fewer entry barriers, enabling households to sell assets more easily. It is also possible that selling within these networks gives households the option to re-purchase their assets at a later date. This requires further research.

The need to account for the nature of households' social capital is emphasised by the climate-risk clusters (Chapter 3). Although households' access to family-based networks had limited influence on defining the clusters, the high- and low-risk clusters were clearly distinguished by households' access to non-family networks. The high-risk clusters had low social capital associated with their limited participation in community-based groups and informal saving schemes. Conversely, the low-risk clusters had high social capital related to these groups. The clusters with high participation in these groups had access to an off-farm income (see Financial Capital section). Poor households face barriers to participating in these groups, particularly those groups which require a membership fee (DFID 1999; Pelling & High 2005; Vincent 2007). Although social capital is considered particularly important for poor households with limited coping strategies, my results indicate that less vulnerable households have better social capital (Chapter 3). Others have similarly suggested that individuals and households with better social capital, cope better (Brown & Westaway 2011; Ofoegbu et al. 2016). More vulnerable households may be more dependent on social capital, but their access to diverse social capital is limited by their weak financial capital and their inability to reciprocate (Paumgarten & Shackleton 2011). These households are therefore particularly dependent on family-based networks which is concerning as increasing climate shocks, climate-related migration, etc. may all undermine the capacity of these family-based networks to provide support to these vulnerable households. Brown and Westaway (2011) highlight the need for both individual and collective resilience.

Natural capital

For natural capital I considered natural products collected from non-cultivated ecosystems (specifically NTFPs), but also households' access to various water sources and their ownership of private tree stocks. The latter included exotic and indigenous fruit trees cultivated/maintained in home-gardens and fields. With respect to NTFPs, I considered both the use and sale of these products, with both these activities used to define the NTFP-based natural capital indicator used in Chapter 3. I examined the influence of natural capital in defining the climate-risk profiles (Chapter 3), whether access to natural capital influences households’ perceptions of climate change (Chapter 4), and the contribution of natural capital to households’ coping strategies (Chapters 5 & 6). For the latter I explored the safety-net function of NTFPs (Chapter 5), including wild foods (Chapter 6).

High-risk households have limited access to most capital types except for natural capital, while the moderate-to-low risk households rely on natural capital despite access to alternatives (Chapter 3). Only the lowest-risk cluster had notably low natural capital, particularly in terms of households’ limited reliance on NTFPs. Natural capital, like social capital, is often of greater importance to vulnerable, capital-constrained households, although less vulnerable households may still rely on it (Paumgarten & Shackleton 2011; Ofoegbu et al. 2016; Tibesigwa et al. 2016; Mugido & Shackleton 2017). Households’ available natural capital is influenced by the site (i.e. AEZ), and related to this, the dominant land-based livelihood strategies (see Section 7.3.1). In the wet site, natural capital is associated with the ownership of private tree crops, reflecting the extensive cultivation of exotic fruit trees (Chapter 3). Comparatively, NTFP-based natural capital is low. Conversely, all the dry-site clusters, irrespective of their risk level, had high NTFP-based natural capital. The site’s surrounding communal rangelands and the adjacent protected areas provide a more extensive habitat for diverse NTFPs, including wild foods (McGarry & Shackleton 2009; Mugido & Shackleton 2017).

Given the widespread use of NTFPs, the sale of various products most likely distinguishes households with high NTFP-based natural capital (in the dry site) from those with low NTFP-based natural capital (in the wet site) (Chapter 3). Archetypical households reported selling bushmeat, medicinal plants, fuelwood, and thatching grass, with bushmeat being the most commonly sold. Therefore, the high NTFP-based natural capital associated with the dry-site clusters probably relates to households’ access to bushmeat. The patterns of wild food use emphasise the role of bushmeat in the dry site: the consumption and sale of bushmeat (particularly Mopane worms) is more widespread in this site (Chapter 6). The sale of essentially “free” NTFPs reflects either the presence of a market or possible collection barriers which increase people’s willingness to pay. These may include time and labour constraints, skill and equipment requirements, and risk and/or illegality concerns (Dzerefos & Witkowski 2015; Baiyegunhi & Oppong 2016; Sylvester et al. 2016). High-risk households may be more willing to discount these barriers, given their limited access to alternative capital.

NTFPs fulfil a daily- and safety-net function (Chapters 5 & 6). The former is highlighted, for example, by the widespread and frequent consumption of wild foods (Chapter 6). This implies widespread need, or that wild foods are collected opportunistically or in response to dietary preferences and cultural traditions (Hunter et al. 2007; Trefry et al. 2014; Sylvester et al. 2016). The increase in the frequency of wild food consumption during periods of food scarcity, highlights their safety-net role (McSweeney 2005; Baiyegunhi & Oppong 2016; Tibesigwa et al. 2016). As previously mentioned, I defined three archetypes of wild food users based on their frequency of consumption, both regularly and in response to seasonal- and extreme-event-related food shortages (Chapter 6). The "Safety" cluster was the biggest of the three. Households in this cluster consumed wild foods infrequently during normal conditions but increase their consumption in response to food scarcity. These were predominantly dry-site households, who perceived wild foods as more important for coping than those in the wet site; households engaged in livestock rearing; and those who reduced household spending to cope (Chapter 6). Mugido and Shackleton (2017) similarly identified NTFPs as a common coping strategy in low-potential agro-ecological zones. The size of the "Safety" cluster highlights the benefits associated with access to natural capital, emphasising that effective ecosystem management could play a key role in helping households cope with, and adapt to, climate change (Fisher et al. 2010; Paumgarten & Shackleton 2011; Ofoegbu et al. 2016; Balama et al. 2017).

The safety-net function of NTFPs was assessed as one of several coping strategies used in response to unanticipated shocks (Chapter 5). Relying on NTFPs was more commonly used than either the sale of assets or loan-seeking. My findings emphasise the importance of NTFPs to households with limited options, but also that other households benefit from this option. Access to NTFP-based natural capital, both as a daily- and a safety-net, provides households with a means to strategically manage and maintain their alternative coping strategies (Skoufias 2003; Boafo et al. 2016). For example, households in the lowest-risk of the three dry-site clusters, reported the use and sale of NTFPs despite access to other capital (Chapter 3). Households in the dry site consumed bushmeat despite access to livestock. This may be due to availability and dietary preferences, but it also gives households the option to maintain their livestock as insurance (Chapter 6). Households relied on the safety-net function of NTFPs despite access to formal savings and livestock (Chapter 5). Households selling NTFPs were more likely to use NTFPs to cope and less likely to draw from their savings or sell assets (Chapter 5). Households in the dry site, with better access to NTFPs, and households engaged in the sale of NTFPs, were more likely to reduce spending and consumption to cope. Other studies have noted an association between spending and consumption decreases, and increased NTFP extraction (McGarry & Shackleton 2009; Mugido & Shackleton 2017).

Despite the benefits associated with the daily- and safety-net role of NTFPs, my results also indicate certain limitations and the need for more tempered expectations of the role of NTFPs in coping and adaptation (Pramova et al. 2012; Wunder et al. 2014; Depietri 2019). Although most households reported using NTFPs, less than half turned to NTFPs in response to unanticipated shocks (Chapter 5), while just over half perceived wild foods as only "somewhat important" or "not important" for coping with hungry periods (Chapter 6). While the safety-net function of NTFPs was positively associated with production shocks that temporarily affect food supplies and infrastructure, it was negatively associated with natural hazards (Chapter 5). Households in the "Dependence" cluster of wild food users (i.e. a quarter of the sample) decreased their wild food consumption in response to hazard-related food scarcity, which is alarming given their apparent reliance on wild foods and indications of limited alternative coping strategies (Chapter 6). According to respondents, reduced NTFP availability during drought and floods results in competition for scarce resources and the need to travel further afield to harvest and market. Börner et al. (2015) similarly noted a lower than expected reliance on natural resources, suggesting limitations to this coping strategy for covariate, climate-related shocks. Relying on natural resources to cope may constitute a poverty trap in cases where the resource is limited, demand is high, and alternatives are lacking (Levang et al. 2005; Bunce et al. 2010; Wunder et al. 2014). For vulnerable, natural resource dependent households likely to face increasing risk due to climate change (e.g. the "Dependence" and high-risk households), it may be necessary to consider alternative insurance (Hickey et al. 2016). My results suggest that access to natural capital plays a less direct role in buffering households against natural hazards: by using natural capital, generally and in response to other shocks, households are able to retain their other capital (particularly their household savings) to cope with natural hazards.

In addition to reduced availability during floods and drought, other factors influence, and undermine, the safety-net function of NTFPs. These include labour intensity, gender, households' existing experience and knowledge, declining resource availability, and seasonality (Chapters 5 & 6). Households with limited labour may have insufficient capacity to collect over and above their usual consumption needs. This may explain why households with labour engaged in more regular NTFP collection turned to other coping strategies in response to unanticipated shocks (Chapter 5), and why "Dependence" households, consisting of older members, decreased their wild food consumption during times of food scarcity (Chapter 6) (see Human Capital section). Gender-related barriers to the collection and sale of NTFPs may limit this coping option for female-headed households (see Section 7.3.2). These households also face labour constraints associated with women's specific household and child-care responsibilities and the absence of migrant members (Chapters 3 & 5). Households already engaged in the sale of NTFPs were more likely to rely on NTFPs to cope, having an existing knowledge of harvesting areas and markets (Chapter 5) (Boafo et al. 2016; Ofoegbu et al. 2016; Mugido & Shackleton 2017). This might also explain why older households were more likely to increase their reliance on wild foods to cope, while younger households were more likely to fall in the "Disinterest" cluster, consuming NTFPs in response to availability rather than need (Hickey et al. 2016) (Chapter 6). Changing lifestyles and preferences were associated with a loss of TEK (Weyer et al. 2017). Respondents attributed declining resource availability to land expropriation, land conversion, overharvesting, competing land-uses, and the (perceived) decline in rainfall. This undermines the safety-net function of NTFPs, as does the seasonality of various products (Powell et al. 2015; Hickey et al. 2016; Ncube et al. 2016) (Chapter 6).

Ultimately, given increasing expectations of the contribution of NTFPs towards sustainable, climate-resilient livelihoods in the drylands, there is the need for a more nuanced understanding of this livelihood, coping, and adaptation option (Fisher et al. 2010; Ofoegbu et al. 2016).

7.4. Lessons from the methods

Various assessment studies have sought to understand the drivers and heterogeneity of vulnerability, both generally and within the climate change space (e.g. Füssel & Klein 2006; Hahn et al. 2009; Sallu et al. 2010; Ahsan & Warner 2014; McDowell et al. 2016) (Chapters 1 & 3). More recently, cluster-based approaches have been used to identify patterns of dryland vulnerability, guided by indications of distinct vulnerability-creating mechanisms (Safriel & Adeel 2008; Kok et al. 2016; Sietz et al. 2017; Vidal Merino et al. 2018). I used cluster-based approaches to i.) assess the heterogeneity of climate-related risk at the household-level (Chapter 3), and to ii.) define archetypes of wild food users, based on households' consumption of wild foods in response to increasing food scarcity (Chapter 6). In both cases, the approach used successfully reduced complexity by revealing a limited number of units of analysis which could be interpreted more systematically, providing rich detail without getting caught up in the intricacies of the individual household (see Chapter 3 for more detail) (Sietz et al. 2012; Kok et al. 2016). The differential insights contribute towards our improved understanding of the heterogeneity of vulnerability and risk among rural households in dryland systems. This supports the design of more targeted interventions, while the identified profiles set a baseline against which interventions can be monitored (Vincent 2007; Kok et al. 2016; Vidal Merino et al. 2018). The conceptual framework presented in Chapter 3 provides a useful tool to assess climate-related risk at the household level, although wider testing is recommended. This framework provides a means of operationalising the IPCC's revised climate-risk framework, which has rarely been applied at the local level (Karim 2018).

In Chapter 3, rather than using a cluster-based approach with quantitative data, we could have applied another set of multivariate analyses called ordination or gradient analyses. Actually, some of the variables we used for clustering were assessed using ordinal scales (e.g., 0 for no, 1 for a few, 2 for many) and could be better analyzed with ordination methods, which apply techniques such as principal components analysis (PCA), non-metric multidimensional scaling (NMDS), or correspondence analysis (CA), to ordinal data to order or organize objects graphically so that similar objects are near each other. The pros and cons of clustering and ordination approaches have been discussed in the literature (Wildi, 2017). We did not explore ordination approaches because our clustering methods yielded interesting and interpretable results.

7.5. Recommendations for future research and action

7.5.1. Future Research

Based on the respective results chapters (Chapters 3-6), I suggest that the following aspects of households' vulnerabilities and responses to climatic and socio-economic shocks require further research:

1. The cluster-based approach used in Chapter 3 should be applied to different circumstances to test its broader applicability. For example, the approach could be:
   a. Applied to more villages within the same AEZs to assess whether the profiles are consistent across each zone, or specific to the selected sites. If the profiles are related to site, not the AEZ, then the influence of other contextual factors should be explored.
   b. Applied to villages across a spectrum of AEZs to assess whether different profiles emerge in other zones. The identification of a limited number of profiles, linked to specific AEZs, would support the targeting of risk-reduction interventions.
   c. Tested for a range of natural hazards to assess the influence of hazard type. The identified profiles were influenced by floods, with the sturdiness of peoples' homes therefore affecting the risk profiles. This is unlikely to be a determining factor in the case of drought.
2. This study tended to focus on shocks as isolated events, however, there may be interactions between the shocks, as well as multiple shocks occurring simultaneously. The implications of these possible interactions and of synergistic shocks need to be explored further. Related to this, is the issue of tipping points, where multiple shocks occur with increasing frequency and intensity pushing the social-ecological system beyond a threshold, where it is no longer able to function as it did. Under such circumstances, transformative adaptation may be necessary. The implications of this require additional research.
3. The nuances related to the gender of the household head should be explored, specifically whether there are differences in the climate-related risk of de jure and de factor female-headed households. Although this study gave some consideration to the influence of structural aspects such as gender, these aspects should be better understood.
4. Limitations and barriers to households' informal coping strategies need to be better understood. These include:
   a. Gender- and labour-related barriers to the accumulation and sale of assets.
   b. Barriers to the maintenance and sale of livestock. It would also be useful to understand what support services might enhance the insurance value of livestock.
   c. Barriers to accessing informal savings schemes, particularly for more vulnerable households. What role might these informal savings schemes play in increasing households' adaptive capacity? Given households' reliance on savings to cope with natural hazards, and considering the limited availability of formal financial services,

how can these informal savings schemes be enabled to support a greater diversity of households?

   d. Barriers to accessing existing external safety-nets (i.e. government post-disaster relief), particularly for more vulnerable households. It is unclear why these households were less likely to rely on external safety-nets.

5. There is mixed evidence on the influence government social grants on households' coping responses. Within the South African context, where almost a fifth of the population receives a monthly government grant, I recommend a more detailed assessment on the existing (and potential) role these grants play in households' coping and adaptive capacity. This assessment should consider distinguishing between the different grant types (e.g. old age pension versus child-care grant).
6. The safety-net function of wild foods requires further investigation. Exploring some of the following aspects in more detail would improve our overall understanding of the daily- and safety-net functions of wild foods:
   a. What is the proportional contribution of wild foods relative to other food sources (in terms of quantity and nutritional value) during different food availability periods?
   b. Do households who use wild foods experience less of a decline in food security during/after natural hazards?
   c. How is the availability (and diversity) of wild foods affected by natural hazards? How might this availability be affected by climate change? What are the implications for high-risk households with limited access to alternative capital? What alternative coping and adaptation options are available to these households?
   d. To what extent does households' cultural preference for wild foods determine their reliance on wild foods as a safety-net? Does this influence the categorisation of wild food users identified in this study, particularly the "Dependence" cluster?

   In addition to the above, it may be worth disaggregating the broader categories of wild food (i.e. wild edible herbs, fruits and bushmeat) into sub-categories based on their availability. For example, "bushmeat" could be disaggregated into invertebrates and vertebrates given that invertebrates such as insects are likely to fluctuate more in abundance in relation to year-to-year rainfall and temperature.

7.5.2. Practical Recommendations (for policy and practice)

Climate-related risk (and its components) needs to be understood and addressed at the local-level, however interventions (and the policies that support them) should account for the heterogeneity of this risk as well as households' broader vulnerability context. Related to this, interventions should account for households' existing capacity to respond and any barriers to this. More specifically, development and adaptation interventions should:

1. Be site-specific while still accounting for certain household-level characteristics. For example, younger households may be uninterested in interventions that support land-based livelihoods while female-headed households might benefit from gender-sensitive interventions that reduce their reliance on migrant remittances.
2. Contribute towards households' improved understanding of climate variability and change to allow for informed decision-making on how best to cope and adapt.
3. Address existing barriers to accessing external safety-nets (i.e. post-disaster relief) and ensure that this external assistance, and the institutions that provide it, is robust, appropriately targeted, and accessible to the most vulnerable.
4. Contribute towards "climate-proofing" private and public infrastructure. For example, households would benefit from improved settlement planning, including better access to materials for the construction of flood-resilient homes.
5. Account for limitations to the quantity and quality of available human capital. For example, households with a high proportion of children (relative to productive adults) may be unable to pursue labour-intensive adaptation options, unless they are able to hire labour or access it through collective action. Interventions that support economic integration, skills development, and the creation of local, climate-resilient jobs, and that free-up household labour would be beneficial.
6. Facilitate households' access to liquid financial capital through the development of appropriate financial services and products. Given households' dependence on their formal savings to cope with climate-related shocks, households' either need access to alternative forms of financial capital, or to other coping and adaptation options altogether.
7. Take greater cognizance of the opportunities as well as the constraints associated with the safety-net function of NTFPs, including wild foods. Although NTFPs may provide coping and adaptation options, particularly in more marginal areas, unsustainable use needs to be avoided. This is particularly important given vulnerable households' overall reliance on this form of capital. For these households, this reliance on NTFPs may constitute a poverty

trap if access to crucial resources becomes constrained, either permanently (e.g. through unsustainable use) or temporarily (e.g. during certain seasons and extreme events). Associated with this is the risk of maladaptation, where an adaptation strategy that benefits one group, creates vulnerabilities for others. For example, without well-defined property rights, effective local management, and efforts to avoid elite-capture, adaptation strategies designed around NTFPs may undermine those households who depend on these resources the most. Under certain circumstances it may be necessary to provide these households with off-farm coping and adaptation options.

When designing and implementing response strategies to climate variability and change, care needs to be taken to ensure that the strategies do not result in maladaptation. The probability of maladaptation is higher if the broader vulnerability context is not considered, particularly in the case of complex social-ecological systems (Brown & Westaway 2011). Policy and practice responses, at different scales, that address one stressor, may inadvertently undermine the capacity of the social-ecological system to respond to other stressors, thereby undermining its overall resilience (Bunce et al. 2010; Adger et al. 2011). Investments in resilience-building should seek to increase the systems' ability to respond to multiple stressors (Adger et al. 2011; Brown & Westaway 2011).

This study highlights local-level nuances that should be considered, however there are challenges associated with implementation at such a fine resolution. Policymakers and practitioners may similarly lack capacity to act across scales, over the long-term (Bunce et al. 2010). To address vulnerability in complex social-ecological systems multi-level governance, inclusive decision-making, adaptive management, and flexible institutions are recommended (Bunce et al. 2010; Adger et al. 2011). Bunce et al. (2010) recommends that investments be made not only in improving the adaptive capacity of communities, but also of various other stakeholders (e.g. NGO, government, etc.).

Finally, a key aspect not addressed in detail in this thesis, but which deserves consideration in future research and in both policy and practice around climate change adaptation, is the issue of resilience versus transformative adaptation. Although the application of resilience concepts to social-ecological systems, particularly in the context of global environmental (and climate) change, has become increasingly popular, there are questions as to whether the focus on resilience may detract from the need for more fundamental change (Brown 2014; Brown

2016). More profound changes, or transformation, may ultimately be required for persistence (Brown & Westaway 2011; Brown et al. 2014). The opportunities and constraints of planning for resilience, versus working towards a reorganization of the system (i.e. transformation) need to be explored.

7.6. Concluding statement

Rural households in the dry forests and woodlands of southern Africa are exposed to various climatic and socio-economic stressors that contribute towards their overall vulnerability context. These include unanticipated shocks and more expected periods of hardship. Given households' ongoing reliance on climate-sensitive, land-based livelihoods, they are particularly susceptible to production shocks. These multiple stressors are common feature of rural livelihoods, for which households have adopted a range of informal coping strategies, often selecting particular strategies to cope with particular shocks. There are however indications that in the case of natural hazards, these strategies may be limited, and that ultimately, households' capacity to respond may be undermined by climate change. To avoid increasing levels of vulnerability there is the need to enhance households' ability to cope and adapt.

Increasing rural households' capacity to cope and adapt requires appropriate and targeted development and adaptation interventions. However, policy and practice interventions are typically designed at a broader level, often failing to account for local nuances. In dryland social-ecological systems, interventions need to account for the system's complexity, the risks it faces, and the factors that undermine or enable its ability to cope with, adapt to, and recover from stressors. This more nuanced understanding of local-level vulnerabilities and responses is particularly important in developing countries, where funds and capacity are limited, and where climate change threatens to reverse the sustainable development gains made to date.

This study has provided various insights into the heterogeneity of vulnerability and climate-related risk of rural households in the dry forests and woodlands of southern Africa, focusing on two communities in the Vhembe district municipality of South Africa's Limpopo Province. Villages with different local climates were purposely selected, with one village located in a semi-arid agro-ecological zone and the other in an arid zone. This was to allow for a site-based comparison, in addition to an assessment of the influence of households' socio-demographic and -economic characteristics on their vulnerabilities and responses. With the overall aim of better understanding these vulnerabilities and responses, this study assessed the nature and heterogeneity of climate-related risk, households' experiences and perceptions of climate variability and change, the prevalence and nature of unanticipated shocks, and households' existing coping responses, including the safety-net function of non-timber forest products.

The results, including distinct patterns related to households' climate-related risk and the safety-net role of wild foods, provide various insights for the development and targeting of adaptation interventions. The clearest of these relates to the influence of site (and potentially agro-ecological zone) on households' vulnerabilities and responses. Although the study considered villages within the same district municipality, the site-related differences suggest that even interventions designed and implemented at the municipal-level may not be sufficiently nuanced. Interventions may need to be more site-specific, although wider testing of the methods and frameworks used in the study is recommended to determine if the patterns identified here are consistent across a broader area, making the lessons noted here more broadly applicable.

Households' vulnerabilities and responses, and to a lesser degree, their perceptions of climate change, are also influenced by various socio-demographic and -economic characteristics, emphasising the heterogeneity of rural communities. Interventions need to account for this heterogeneity and recognise that certain households may face barriers to pursuing certain adaptation options. Although the results emphasise the need to consider aspects such as the gender of the household head in adaptation planning, they also suggest the need for further research into the influence of these various characteristics.

Households' capacity to respond to stressors is a determinant of risk, with this capacity influenced by households' access to capital. The findings of this study suggest that, when possible, households actively manage their coping strategy (and capital) portfolio, both in response to the shock experienced and in anticipation of future shocks. Interventions should support these existing efforts. Additionally, to better support households' ability to make strategic, long-term adaptation decisions there is the need for more targeted and appropriate climate change communications. In terms of households' adaptive capacity, poorer, more high-risk households have limited access to most capital types, except for natural capital, however this reliance may constitute a poverty trap in the case of natural hazards. Alternative options may be necessary.

Enhancing households' capacity to cope and adapt is in line with global goals to reduce and manage the risk of climate change and achieve sustainable development. Better understanding households' existing vulnerabilities and responses is a necessary step towards achieving this. This study has contributed towards this improved understanding in local, social-ecological systems in the dry forests and woodlands of Africa.

7.7. References

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APPENDICES

APPENDIX 1: Science Direct review of research articles addressing aspects of the climate-related risk of rural households in Southern Africa

The literature review considered articles for each of the Southern African countries, using the terms “IPCC”, “climate change”, “vulnerability”, “adaptive capacity”, “rural” and “household”. Of the 177 articles listed below, only 17 actually included research in the respective countries, at the local level (*see articles marked with red tick; see Table A1-1 for details*)

Angola (7 articles in the initial search; 0 articles in the refined search)

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Resilience of coastal agricultural systems in Bangladesh: Assessment for agroecosystem stewardship strategies
Ecological Indicators, Volume 106, November 2019, Article 105525
Ranjan Roy, Animesh K. Gain, Narimah Samat, Margot Hurlbert, ... Ngai Weng Chan
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Global Environmental Change, Volume 40, September 2016, Pages 50-59
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Weather and Climate Extremes, Volume 7, March 2015, Pages 8-23
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Table A1-1: Detailed list of the 17 research articles from across Southern Africa, published since the release of the IPCC's 5th Assessment Report (i.e. from 2015 onwards), which address aspects of the climate-related risk of rural communities.

Article Details	Country	Study Site, Sample & Data Collection Method
1. Basupi, L.V., Quinn, C.H. & Dougill, A.J. (2019) Adaptation strategies to environmental and policy change in semi-arid pastoral landscapes: Evidence from Ngamiland, Botswana. *Journal of Arid Environments* 166:17-27	Botswana	112 households (HH) across 6 villages in Ngamiland District. Data collected via a PRA, key informant interviews, focus group discussions, and a semi-structured HH survey.
2. Shinn, J.E. (2016) Adaptive environmental governance of changing social-ecological systems: Empirical insights from the Okavango Delta, Botswana. *Global Environmental Change* 40: 50-59.	Botswana	230 HH across 2 villages in the North-West District. Data collected via a semi-structured HH survey and key informant interviews.
3. Adenle, A.A., Ford, J.D., Morton, J., Twomlow, S. *et al.* (2017) Managing climate change risks in Africa – A global perspective. *Ecological Economics* 141: 190-201.	Lesotho	Semi-structured interviews with multiple stakeholders, at different scales, across various African countries. The stakeholders included 23 farmers in Lesotho.
4. Mutenje, M.J., Rozel Farnworth, C., Stirling, C., Thierfelder, C. *et al.* (2019) A cost-benefit analysis of climate-smart agriculture options in Southern Africa: Balancing gender and technology. *Ecological Economics* 163:126-137.	Malawi, Mozambique & Zambia	3584 HH across different districts in Malawi (1440 HH), Mozambique (696 HH) and Zambia (1448). Data collected via a mixed-method approach, including farm trials, HH surveys and focus group discussions.
5. Bezner Kerr, R., Kangmennaang, J., Dakishoni, L., Nyantakyi-Frimpong, H. *et al.* (2019) Participatory agroecological research on climate change adaptation improves smallholder farmer household food security and dietary diversity in Malawi. *Agriculture, Ecosystems & Environment* 279: 109-121.	Malawi	425 HH across 31 villages in northern and central Malawi. Data collected via a HH survey and PRA.
6. Mulwa, C., Marenya, P., Bahadur Rahut, D. & Kassie, M. (2017) Response to climate risks among smallholder farmers in Malawi: A multivariate probit assessment of the role of information, household demographics, and farm characteristics. *Climate Risk Management* 16: 208-221.	Malawi	1786 HH across 16 districts across Malawi. Data collected via a HH survey.
7. Mwale, F.D., Adeloye, A.J. & Beevers, L. (2015) Quantifying vulnerability of rural communities to flooding in SSA: A contemporary disaster management perspective applied to the Lower Shire Valley, Malawi. *International Journal of Disaster Risk Reduction* 12: 172-187,	Malawi	13 rural communities across 2 districts. Data collected via focus group discussions and HH surveys (using national census data).
8. Thornton, P.K., Kristjanson, P., Förch, W., Barahona, C. *et al.* (2018) Is agricultural adaptation to global change in lower-income countries on track to meet the future food production challenge? *Global Environmental Change* 52: 37-48.	Mozambique	6300 HH in 315 villages across 21 countries, including 2 villages in Mozambique. Data collected via a HH survey.

9. Mabuku, M.P., Senzanje, A., Mudhara, M., Jewitt, G.P.W. *et al*. (2019) Strategies for coping and adapting to flooding and their determinants: A comparative study of cases from Namibia and Zambia. *Physics and Chemistry of the Earth, Parts A/B/C* 11: 20-34.	Namibia & Zambia	207 HH across 2 districts, the Mwandi District in Zambia, and the Eastern Zambezi Region of Namibia. Data collected via focus group discussions and a HH survey.
10. Radingoana, M.P., Dube, T., Mollel, M.H.N. & Letsoalo, J.M. (2019) Perceptions on greywater reuse for home gardening activities in two rural village of Fetakgomo Local Municipality, South Africa. *Physics and Chemistry of the Earth, Parts A/B/C* 112: 21-27.	South Africa	182 HH from 2 villages in South Africa's Limpopo Province. Data collected via mixed-method approach, including HH surveys.
11. Senyolo, M.P., Long, T.B., Blok, V. & Omta, O. (2018) How the characteristics of innovations impact their adoption: An exploration of climate-smart agricultural innovations in South Africa. *Journal of Cleaner Production* 172: 3825-3840.	South Africa	Interviews with various climate-smart agriculture experts and stakeholders in South Africa
12. Elum, Z.A., Modise, D.M. & Marr, A. (2017) Farmer's perception of climate change and responsive strategies in three selected provinces of South Africa. *Climate Risk Management* 16: 246-257.	South Africa	150 randomly selected cabbage and potato farmers from various communities in South Africa's Gauteng, Limpopo, and Mpumalanga provinces. Data collected via a structured questionnaire.
13. Ofoegbu, C., Chirwa, P.W., Francis, J. & Babalola, F.D. (2016) Assessing forest-based rural communities' adaptive capacity and coping strategies for climate variability and change: The case of Vhembe district in South Africa. *Environmental Development* 18:36-51.	South Africa	366 HH from 21 rural communities in the Vhembe District Municipality of South Africa's Limpopo Province. Data collected via a HH survey.
14. Makondo C.C. & Thomas, D.S.G. (2018) Climate change adaptation: Linking indigenous knowledge with western science for effective adaptation. *Environmental Science & Policy* 88: 83-91.	Zambia	100 respondents from central and southern Zambia. Respondents considered local experts on traditional/indigenous knowledge. Of these, 18 were selected for further questioning. Data collected via interviews.
15. Sitko, N.J. & Chamberlin, J. (2016) The geography of Zambia's customary land: Assessing the prospects for smallholder development. *Land Use Policy* 55: 49-60.	Zambia	8839 HH from across Zambia. Data collected via a large-scale HH survey.
16. Makuvaro, V., Walker, S., Masere, T.P. & Dimes, J. (2018) Smallholder farmer perceived effects of climate change on agricultural productivity and adaptation strategies. *Journal of Arid Environments* 152: 75-82.	Zimbabwe	60 farmers from 6 villages in Zimbabwe's Mdubiwa and Nyama Wards. Data collected via focus group discussions.
17. Mubaya, C.P. & Mafongoya, P. (2017) The role of institutions in managing local level climate change adaptation in semi-arid Zimbabwe. *Climate Risk Management* 16: 93-105.	Zimbabwe	200 HH from the Kariba Rural District in Zimbabwe. Data collected via focus group discussions, key informant interviews and a semi-structured HH survey.

APPENDIX 2: Community workshop (PRA) programme

PROGRAM – OVERVIEW

DAY 1

08:00 - Arrival

08:30 - Start

08:40 - Introduction and registration

- Explanation of community workshops

09:10 - Identification of, and discussion on, key livelihood strategies

09:40 - Mapping exercise

- Seasonal calendar exercise

10:40 - Tea break

11:00 - Presentation of maps and seasonal calendars

11:40 - Discussion on vulnerability

12:40 - Explanation of the time trend and historical profile exercises

13:00 - Lunch and close

DAY 2

08:00 - Arrival

08:30 - Start

08:40 - Time trend exercise

- Historical profile exercise

09:40 - Presentation and discussion of the time trends and historical profiles

10:40 - Tea break

11:00 - Explanation of impacts and the impact chain exercise

12:00 - Additional general questions and discussions

13:00 - Lunch and close

DAY 3

08:00 - Arrival

08:30 - Start

08:40 - Impact chain exercise

10:10 - Tea break

10:30 - Presentation and discussion of impact chains

12:00 - Explanation of problem tree exercises

12:30 - Outstanding questions and discussions from the previous exercises

13:00 - Lunch and close

DAY 4

08:00 - Arrival

08:30 - Start

08:40 - Problem tree exercise

09:40 - Presentation of, and discussions on, the problem trees

10:10 - Tea break

10:40 - Continue discussions on the problem trees

11:10 - Discussion on coping and adaptation

13:00 - Lunch and close

DAY 5

08:00 - Arrival

08:30 - Start

08:40 - Discussion on NTFPs, droughts and floods

10:40 - Tea break

11:00 - Coping and adapting to impacts

13:00 - Lunch and close

DETAILED PROGRAM – COMMUNITY WORKSHOPS

DAY 1

08:00 - Arrival

08:30 - Start

08:40 - Introduction and registration
- Explanation of community workshops

09:10 - Identification of, and discussion on, key livelihood strategies

Ask participants to describe and explore the main land-based and off-farm livelihood strategies relied on in the community. For example:

- Out-migration (and migrant remittances): Where are the main working areas? What are the advantages and disadvantages to this strategy?
- Off-farm employment: What opportunities are available locally? Are there challenges to finding off-farm employment opportunities?
- Arable agriculture: What are the preferred crop types and why? Do people have access to agricultural extension officers and agricultural subsidies? Where are the closest input/output markets for agricultural produce? Do people irrigate? What are the major challenges farmers face?
- Animal husbandry: What are the preferred livestock types and why? Do people have access to extension/veterinary support for livestock? Where do people find grazing/fodder for their livestock? Is this available throughout the year? Is there conflict over grazing land? What are the major challenges livestock owners face?
- Provisioning services, focusing on NTFPs: Discuss the main products used. Ask participants to list the various NTFPs used (try to get local and English names). Are the resources easy to access? Is there sufficient availability of key resources? Are they sold? Are there challenges to the use and sale of these products? Are these products still important to sustaining rural livelihoods (including food security)?

Assuming respondents identify a mix of off-farm and land-based strategies, ask the participants why households diversify their livelihoods? If households do not diversify what are the barriers to engaging in particular activities? Ask participants whether any of the identified strategies are climate sensitive.

Ask participants for the following contextual information:

- How many households are there?
- Do the households have access to electricity, potable water, etc.? If not, what are the alternative sources of energy and water relied on (e.g. fuelwood, communal taps, etc.)?
- Are there any water storage schemes in the village?
- What access does the community have access to health facilities, schools, shops, etc.?
- Where are the closest markets for agricultural inputs and outputs?
- Is there a formal bank/credit institution nearby? Are there informal credit institutions in the village?
- Is the village accessible throughout the year?
- Does the village have good cell phone, TV, and radio reception? (i.e. allowing them access to information).
- Does government assist in any way? (e.g. extension services, food aid and public welfare programmes, etc.)
- What are main ethnic groups/tribes in the village?
- What are the main languages spoken?

09:40 - Mapping and seasonal calendar exercises

Ask participants to draw their landscape. Their maps should include the following:

- Water sources (indicate those that are permanent/temporary) – for people, irrigation, and livestock
- Sources of key provisioning services (fuel, fibre, food, medicine) – NTFPs
- Grazing land
- Infrastructure – church, school, clinic, roads, market, etc.
- Agricultural land – fields and gardens
- Residential plots
- Points of cultural importance
- Areas damaged by past natural hazards

Ask participants to complete a seasonal calendar for the preceding year, looking at changes in various aspects of livelihood activities (see Table A2-1 below).

10:40 - Tea break

Table A2-1 Pre-selected variables for the seasonal calendar exercise

Rainfall	Grazing availability
Temperature	Livestock sales
Planting (fields)	Hungry season (food shortages)
Planting (home-gardens)	Human diseases
Harvesting (fields)	Expenditure
Harvesting (home-gardens)	Wild food use
Crop pests	Wild food sales
Crop sales	Fuelwood use
Livestock diseases	Fuelwood sales

11:00 - Presentation of maps and seasonal calendars

Ask each group to present their map to the remaining participants. Ask the participants to decide on the most comprehensive and accurate map. Finalise and discuss the maps.

Discuss the different components of the seasonal calendars. Ask participants to explain their calendars and any relationships between the patterns noted in the different variables.

Participants should also consider the following:

- During which months does the village experience greatest hardship? Why?
- How did the rainfall over the past 12 months compare with a normal year? *[well below normal (<50%); below normal (50%-90%); normal (90%-110%); above normal (110%-150%); well above normal (> 150%)]*
- How did the average temperature over the last 12 months compare with a normal year? *[warmer than normal; cooler than normal; normal]*
- When during the year are high/low rainfall and high/low temperatures a blessing or a curse? I.e. what does a good rainfall and temperature year look like and what does a bad rainfall and temperature year look like?
- When does rain/temperature cause problems? (Consider late/early onsets, mid-season dry spells, etc.)

- Is grazing and water for livestock available all year?

11:40 - Discussion on vulnerability

Start to discuss vulnerability. Explain that vulnerability includes household-level vulnerability and community-level vulnerability. Consider multiple stressors to better understand the existing challenges and how climate variability and change might exacerbate existing vulnerability. Bear in mind the IPCC's (2007)[18] definition of vulnerability (see Box A2-1).

Box A2-1 IPCC's definition of vulnerability

Vulnerability to climate change and variability has been described to consist of the components of "exposure", "sensitivity" and "adaptive capacity", whereby:

- "Exposure" – is the nature and degree to which a system is exposed to significant climatic variation,
- "Sensitivity" – is the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli, and
- "Adaptive capacity" – is the ability of a system to adjust for moderating damages, taking advantage of opportunities or coping with consequences.

Consider the following:

- What are the top 5 causes of vulnerability/hardship in the area?
- What are the top 5 development challenges in the area?
- Has the village experienced any crises over the last 10 years that have affected several households (i.e. not events that have just affected one or two)?
- What climate-related risks have occurred in the past?

Ask the participants to consider the range of stressors experienced. Examples of possible stressors to consider, include:

- Weather and climate: including severe storms, hail, wind, frost, floods, droughts, changes in rainfall and temperature (amount, intensity, timing, etc.) and the related impacts on growing season (e.g. mid-summer droughts).

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[18] Intergovernmental Panel on Climate Change (IPCC). 2007. Climate change 2007: Impacts, Adaption and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core writing team, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van den Linden and C.E. Hanson (eds.)]. Cambridge University Press, Cambridge.

- Wild fires (in crops/forest/grasslands, etc.)
- Macro-economic situation (employment, unemployment, retrenchment, weak markets, difficulty starting own businesses, etc.)
- Increased expenditure (food, fuel, agricultural inputs, inflation, waged labour, etc.)
- Decline in output prices (e.g. agricultural produce, NTFPs, etc.)
- Political/civil unrest, decreased security (e.g. theft), and discrimination, changes in administration, harassment by officials, etc.
- Water availability and quality: water shortages, reduced water quality, unpredictable water supply and conflict over water
- Food insecurity/malnutrition (availability and accessibility). Periods of hunger.
- Poor health: human disease, epidemics and increased mortality, poor access to healthcare. Death.
- Increase in the number of dependents (including orphans)
- Poor infrastructure and assets: damage to infrastructure and assets, lack infrastructure development, inappropriate infrastructure developments, etc.
- Availability of land: decreased land quality (erosion, bush encroachment, ecosystem change), land expropriation/redistribution (by traditional and government), competition for settlement, grazing, agricultural and natural resource (communal) land. Changes in land use and tenure.
- Availability of NTFPs and provisioning services. Conflicts over provisioning services (fuel, medicines, water, food and fibres). Limited resources, overuse, etc.
- Widespread crop pest/disease and/or animal disease (and loss). Crop failure. Yield reductions. Wildlife predation on livestock.
- Refugee/migrant infusion or exodus

Are certain groups considered more vulnerable than others? Bear the following vulnerability indicators in mind:

- Wealth, gender, age, level of education, race, and ethnicity
- Health, nutrition, and disabilities
- Physical infrastructure
- Institutions, governance, and social capital
- Access to extension, credit, and information (including climate change information)

- Geographic and demographic factors
- Dependence on agriculture, on natural resources and ecosystems
- Technological capacity
- Crop risk (e.g. length and variability of growing season)
- Income risk (e.g. income variability)

12:40 - Explanation of the time trend and historical profile exercises

Explain the purpose of the time trend and historical profile exercises to the participants so that these exercises can be conducted on Day 2.

13:00 - Lunch and close

DAY 2

08:00 - Arrival

08:30 - Start

08:40 - Time trend and historical profile exercises

For the time trend exercise, ask participants to identify changes in the categories outlined in Table A2-2 below, over the different decades from the time each village was established.

Table A2-2 Pre-selected variables used for time trend exercises

Rainfall	Fuelwood use
Temperature	Wild food availability
Number of fields	Wild food use
Number of home-gardens	Cost of living
Number of cattle	Population size
Number of goats	Population health
Grazing availability	Available infrastructure
Water availability	Employment opportunities
Fuelwood availability	Education levels

For the historical profiles, ask participants to identify key historical events going as far back as they can remember. Participants should mark major events including natural, physical/infrastructural, economic, social and political events that have had a significant impact on livelihoods.

09:40 - Presentation and discussion of the time trends and historical profiles
Based on the time trend and historical profile exercises, ask participants to discuss the following, focusing on climate variability and change:

- Have you noted changes in temperature (increase, decrease, none) over the past 10 years?
- Have you noted changes in rainfall (increase, decrease, none) over the past 10 years?
- Have you noted a change in the onset of the rains? Do they start at the same time every year? Do they start earlier or later than they used to? Is the onset more erratic?
- Do the rains end at the same time as they used to or has this changed? Has there been a change in the length of the rainy season?
- Once the rains start, does it rain throughout the season or are there dry spells? Has the duration, regularity and intensity of these wet and dry spells changed?
- Have you noted longer term changes in rainfall and temperature?
- If rainfall and temperatures have changed, how have these affected the various aspects of people's livelihoods, including their land-based livelihood strategies (and practices)? *E.g. reduced yields (associated impacts on consumption and sale), increased cost of irrigation/inputs/labour, worse/unusual outbreaks of pests and diseases, increased livestock losses, etc.*
- What are the biggest climate-related risks faced by the community?
- Identify and described the three worst droughts and floods experienced in each community? Use the maps to ask people to identify those areas most affected by floods, droughts, etc.
- Has there been any change in the nature of climate hazards (e.g. more/less frequent, more/less intense etc.)?
- Do these climate hazards significantly affect peoples' livelihoods? If yes, which disasters have the greatest impact?

- Participants should consider the impacts on the ecosystem more broadly. E.g. has there been increased bush encroachment, increased soil erosion and an alteration in the ecosystem that affects agriculture, livestock or NTFPs?
- Discuss other key trends and events identified in the time trend and historical profile exercises, focusing on those that may be related to climate variability and change.

NOTE: The seasonal calendar, time trend and historical profile exercises provide details on the communities' respective vulnerability contexts in terms of shocks, trends, and seasonality. Together with the participants, discuss this overall vulnerability context and identify those shocks, trends and seasonal changes that make the greatest contribution to increased vulnerability and hardship.

10:40 - Tea break

11:00 - Explanation of impacts and the impact chain exercise
Use an impact chain exercise to explore the impacts of droughts and floods. Impacts refer to the consequences of the hazards on natural and human systems and can include forest and/or crop damage, income losses and reduced soil fertility. Both direct and indirect impacts should be considered. Ask participants to consider how livelihood strategies, livelihood outcomes, assets, structures, and provisioning services are impacted, and which livelihood groups are affected. For example:

Drought → trees dying (direct impact) → soil degradation (indirect impact on ecosystem service) → income loss for farmers (indirect impact on livelihood group)

12:00 - Additional general questions and discussions
Use the remaining time to gather more contextual information on the respective sites. Ask participants the following:

- What are the general agro-ecological conditions/constraints (e.g. soil too shallow/rocky for crop agriculture etc.) and how do these influence the dominant livelihood activities?
- Is there sufficient land for grazing, agriculture and settlement or is there competition?
- Do people invest in their livestock in any way (e.g. with veterinary care, inputs, etc.)? If livestock get ill, how is it treated - with traditional or veterinary medicine?

- Where are the closest markets for agricultural inputs and outputs?
- Do people sell every season without fail, only when they have surplus, never, etc. Why don't people sell? No markets? Cannot produce surplus, etc.?
- What are the main crops cultivated in the fields/homegardens? Are there trees in people's fields/homegardens? Are indigenous trees planted/maintained?
- What factors influence the selection of crops/IVs/trees? *E.g. Taste/preference; available market; seed availability; drought/climate resistant; cost effective; production experience; grows well (quantity); Other (Explain)*
- What causes crop failure? *E.g. Insect/disease outbreaks; too much/not enough rain; too high/low temperature; animal raiding; hail/wind/fire; etc.*
- Is there a preference for small or large stock? Why?
- What factors, influence the selection of livestock types? *E.g. Available market; taste/preference; drought resistant; production experience; breeds successfully; savings; cost effective/cannot afford alternative; Other (Explain)*
- Why do households sell/not sell livestock? Do they sell regularly, only sell when money is needed, never sell?
- What causes livestock loss? *E.g. disease outbreaks, predators, theft, drought, etc.*
- Are any of the key NTFP species affected by changes in weather/climate, etc. Have any NTFPs been domesticated as an adaptation strategy?
- Is it easy/difficult to access the resources you want? Is there competition for resources?
- What are the existing tenure arrangements and how do these affect access to land, to provisioning services (i.e. fuel, medicines, food, fibre, and water), etc.?
- Is there sufficient land available?
- What is the leadership body in the village? Traditional (chief/headman) or municipal or both?
- Are there customary and/or government rules regulating the use of provisioning services in the village?
- Explore the components of food security, i.e. availability and accessibility, as well as the contribution provisioning services make towards this.

13:00 - Lunch and close

DAY 3

08:00 - Arrival

08:30 - Start

08:40 - Impact chain exercise

Focusing on floods and droughts, ask participants to consider how livelihood strategies, livelihood outcomes, assets, structures, and provisioning services are impacted. Consider both direct and indirect impacts.

Ask participants to consider the key impacts (e.g. reduced water availability) as well as the consequences of these (e.g. reduced crop productivity leading to lower revenue, less food for storage, malnutrition, food insecurity and migration).

Ask participants to consider how each impact might affect the physical and human environments and which groups are most vulnerable. Discuss the severity of impacts, which groups are most vulnerable to these impacts and how families are affected. Consider why some households are more affected than others (e.g. their house may not be as sturdy resulting in flood-damage). Which livelihood strategies and assets are most at risk during droughts and floods?

Changes/impacts in the following should be considered:

- The general landscape (e.g. soil erosion, overgrazing, etc.)
- Arable agriculture – crop productivity, crop failure/loss/damage, loss/damage of agricultural land (impacts on rainfed agriculture), changes in agricultural practices (e.g. timing of planting)
- Animal husbandry - livestock productivity, livestock loss/damage (e.g. disease)
- Provisioning services (e.g. NTFPs) – availability, use and sale of provisioning services. Consider fresh water sources, traditional medicines, wild foods, fibre, building materials, fuelwood, etc.
- Water sources (for drinking, washing irrigation and livestock) – source dries up/washes away/water becomes undrinkable, etc. (i.e. problems with quality and quantity of water). Possible conflict between users, etc.

- Human health and well-being - e.g. water-borne and insect-borne diseases (e.g. cholera and malaria) cause sicknesses/death, people are injured or killed, overall productivity is affected, etc.
- Available infrastructure - e.g. loss of or damage to houses, roads, etc. Effects on market access, etc.
- Pests and diseases (e.g. become more prevalent, virulent, etc.)
- Fires (e.g. become more frequent, intense, etc.)
- Food security, nutritional status, food stores destroyed, etc.

10:10 - Tea break

10:30 - Presentation and discussion of impact chains

Participants should present their impact chains. Discuss the impacts (both direct and indirect) of droughts and floods. Having discussed the various impacts, ask participants to consider the threat of droughts and floods to their livelihoods, relative to other stressors experienced. Ask participants which assets are at greatest risk and are the worst to lose given their contribution to livelihood sustainability (including their role in helping households cope).

Briefly discuss the impacts associated with other climate-related shocks (e.g. wind, extreme storms, excessive heat, etc.) and how these compare to those associated with droughts and floods.

12:00 - Explanation of problem tree exercises

Describe the purpose of a problem tree exercise. While the above exercises identify specific hazards that impact on rural livelihoods, they do not consider why the communities are negatively affected by these hazards. The following exercise aims to address this using a problem tree (see example in Figure A2-1[19]).

The exercise will be conducted in groups. The group should take the impacts identified in the impact chain exercises and write each impact down on a card. Then, taking each card at a time, the participants should consider the causes of the impact – “why does it happen?” Each

[19] Turnbull, M. &Turvil, E. 2012. Participatory Capacity and Vulnerability Analysis: A Practitioner’s Guide. Oxfam International, Cowley. 43pp.

answer should be written on another card, and the question repeated. Repeat this step until the root causes of vulnerability and poverty have been identified. The causes and effects of a problem are likely to include factors such as “unsafe conditions, lack of institutions, global trends in urbanisation and migration, belief systems, structural inequities, climate variability, and climate change” (Turnbull & Turvil 2012[20]).

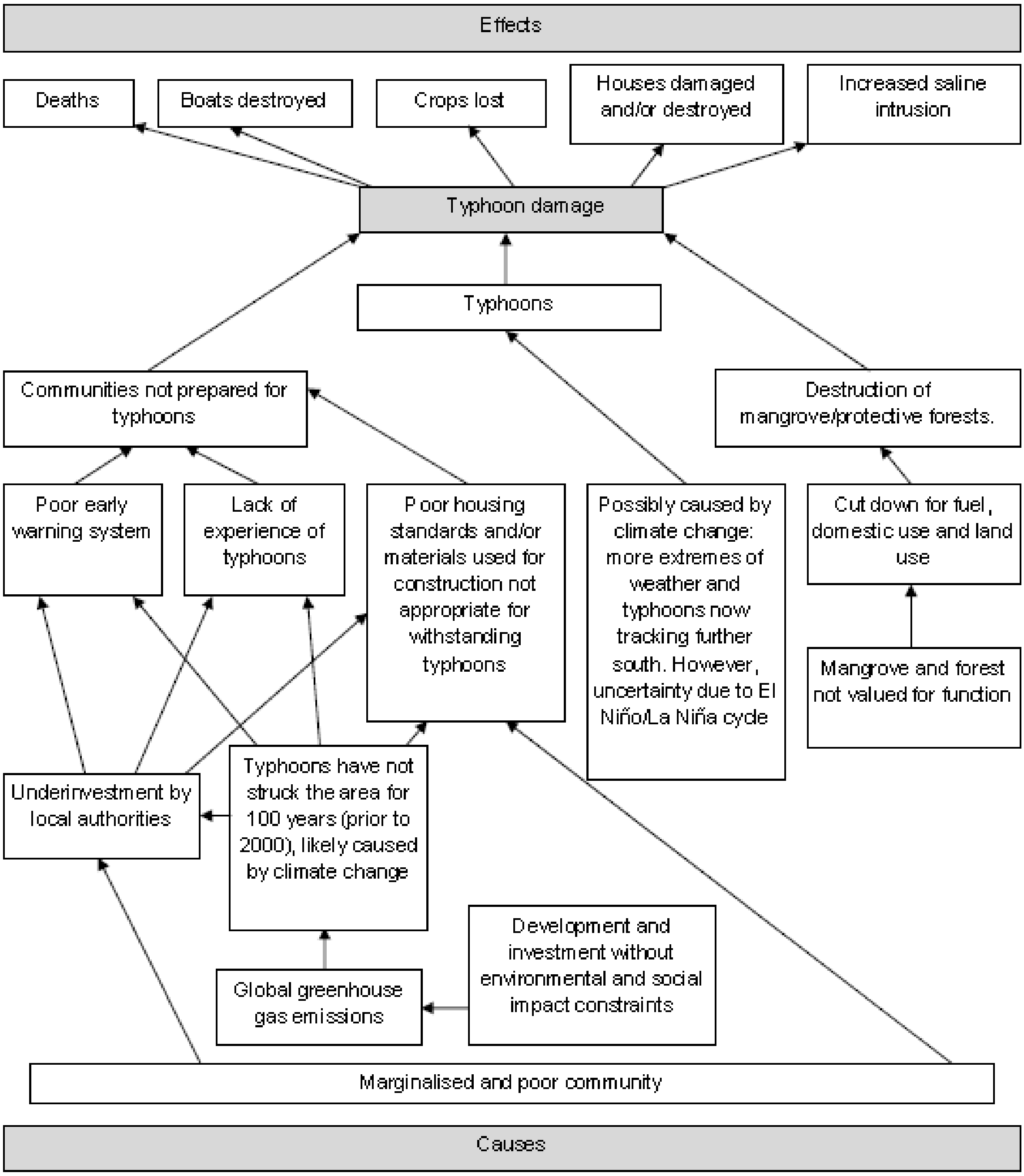

Fig. A2-1 Example of a problem tree (see Turnbull & Turvil 2012)

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[20] Turnbull, M. &Turvil, E. 2012. Participatory Capacity and Vulnerability Analysis: A Practitioner’s Guide. Oxfam International, Cowley. 43pp.

12:30 - Outstanding questions and discussions from the previous exercises

13:00 - Lunch and close

DAY 4

08:00 - Arrival

08:30 - Start

08:40 - Problem tree exercise

Ask participants to complete the problem tree exercise. Once the participants have completed all the cards, place the cards where the participants can see them. Draw a large tree on a flip chart and ask participants to arrange the cards with problems at the top, then causes to the roots.

09:40 - Presentation of, and discussions on, the problem trees

Ask the different groups to present their completed problem trees. As a group, discuss these problem trees and the various causes of vulnerability identified.

10:10 - Tea break

10:40 - Continue discussions on the problem trees

11:10 - Discussion on coping and adaptation

Explain the difference between coping and adaptation. Consider both coping and adaptation but start with coping. Consider that past and present coping and adaptation may help better understand future adaptation options to climate variability and change. Refer to Table A2-3 which details some common, informal, household-level coping strategies.

Discuss these different means of coping and ask the participants to identify any other coping options. Having discussed coping more generally, focus on the impacts of droughts and floods identified during the preceding exercises and ask the respondents to consider how they have coped with these in the past. Have they adapted in response to these impacts?

Table A2-3 Examples of common, informal, household-level coping strategies (Paumgarten 2007)[21]

1. Rely on kinship and community-support networks and the reciprocity of money, goods, land, and labour.
2. Sell assets (including livestock, land, etc).
3. Use and/or sell NTFPs
4. Migrate in search of work. Rely on remittances of those who have already migrated.
5. Diversify household livelihood strategies
6. Redistribute/reallocate labour, remove of children from school (to save on fees and provide labour), relocate dependents to extended family (adoption), provide casual labour (including in the community for food reciprocity). Find local waged labour.
7. Rely on saving schemes, stokvels (credit groups), buying on credit, etc. Withdraw from stokvels to avoid payments. Borrow against future earnings or loan money from a lender/credit association/bank/stokvel/loan shark.
8. Practice agricultural diversification (e.g. make changes in agricultural practices, in crop type, etc.). Harvest more/premature crops. Store food. Change animal husbandry practices.
9. Change household's spending and food consumption (e.g. make changes to both the quantity and quality of meals consumed). Reduced household spending on food. Sell food (e.g. stored crops, NTFPs, etc.) that would otherwise be used for household consumption.
10. Sell food, goods, and services (including prostitution). Start a new business.
11. Rely on assistance from NGOs, community/religious organizations, government, extension workers, etc.
12. Rent out land
13. Do nothing in particular

Take the identified impacts and for each impact ask participants to consider:

- What do households/the community do to reduce the risk on peoples' homes, livelihoods, etc.?
- Have you made any changes to your livelihoods in response to the droughts and floods detailed above to protect your household in the future and make you more resilient?
- What changes have you made? If you did not make changes, why not?

[21] Paumgarten, F. 2007. The Significance of the Safety-Net Role of NTFPs in Rural Livelihoods, South Africa. M.Sc Thesis. Rhodes University, Grahamstown. 256pp.

- If temperature and rainfall changes have impacted on your farming practices, what measures have you taken in response? Examples include:
    - Changed agricultural practices (e.g. the type and diversity of crops planted)
    - Changed the planting and/or harvesting time
    - Changed frequency and amount of irrigation
    - Stopped farming
    - Changed the types of livestock raised (e.g. small vs. large)
    - Changed animal husbandry practices
    - Stopped keeping livestock
    - Increased reliance on NTFPs (use/sale)
    - Replaced crops/livestock with NTFPs
    - Relocated in village (e.g. away from flood line) or migrated
    - Harvested water and/or stored food
    - Diversified off-farms (e.g. sought wage labour, started a business, etc.)

Ask participants to consider, and discuss, what drives their choice of coping strategies (and potential adaptation strategies)? What are the strengths and weaknesses of the respective strategies? The coping and adaptation strategies should be considered in terms of, i) their effectiveness for reducing vulnerability, ii) their efficiency in terms of costs and, iii) the feedback on assets (i.e. while some strategies may be efficient initially, they may result in maladaptation in the long term, e.g. through forest degradation).

13:00 - Lunch and close

DAY 5

08:00 - Arrival

08:30 - Start

08:40 - Discussion on NTFPs, droughts and floods

Discuss the role of NTFPs in coping in general. Ask participants to give some examples. Discuss whether NTFPs have helped households cope with droughts or floods in the past. Consider how droughts and floods affect NTFPs, using the list of NTFPs compiled on Day 1.

Consider the following questions on wild foods?

- How many meals in week include forest foods (NTFPs)?
    - When food is plentiful (i.e. after the harvest)
    - When food is scarce (i.e. during low production months)
    - During a famine (i.e. when crops fail – drought, etc.)
- Compared to agriculture, how much do these resources contribute towards food security?
    - More than [ ] The same [ ] Less than [ ]
- Are these resources available during drought years?
- How important are forest foods for surviving famine?
    - Very important [ ] Important [ ] Somewhat important [ ] Not important [ ]
- Are there foods that your household only eats during famine months/years? Explain.
- If participants noted changes in the average rainy season temperatures and rainfall and, the nature of the rainfall, have these changes affected their use of NTFPs? How?

10:40 - Tea break

11:00 - Coping and adapting to impacts

Continue with the discussions on coping and adaptation.

- Have you ever received prior warning about droughts and floods?
- Are there disaster/risk management and early warning systems in place?
- Do households have access to information on hazards, etc.?
    - If yes, did this allow you to make changes to reduce the impacts of drought/flood? Explain.
    - If no, would adequate warning have allowed you to protect your assets? Explain.
- Did you receive any assistance from outside stakeholders (e.g. government, NGOs) in response to past droughts/floods? Explain.
- Are there any NGOs working in the area? What are they working on?
- What would help to reduce the impact of future droughts/floods?
    - Extension services – to increase drought/flood resilience in agriculture and livestock
    - Climate information – to adjust livelihood strategies accordingly

- Improved early warning
- Capacity building – e.g. business skills development to support livelihood diversification
- Public health care and welfare
- Credit facilities
- Infrastructure developments – e.g. improved roads, water harvesting facilities, flood walls, etc.
- Improved market access (to input and output markets)
- New technology, farm assets, etc.
- Policies

- What are the current roles of government, NGOs, private markets, farmers, and other stakeholders in supporting subsistence farmers in coping with adverse outcomes from natural disasters?
- Who should be responsible for reducing vulnerability to natural disasters?
    - Government
    - NGOs
    - Insurance companies
    - Households themselves (the community)
- What role could these different groups play in reducing vulnerability and impacts?
- Are there any institutions in the area working directly on climate-related crises (e.g. floods, droughts) and climate change?

Taking the respective coping and adaptation strategies into consideration, ask the participants should consider the following:

- What are the strengths and weaknesses of these different strategies? (E.g. for provisioning services, issues of access to, quantities of, knowledge of and use of resources).
- Are certain strategies more effective and cost efficient than others?
- Are certain strategies more sustainable than others?
- Are these strategies short-term, long-term, reactive, or proactive?
- Are these strategies used irrespective of the crisis in question or are certain strategies only used in response to certain crises? Why do people respond as they do?
- What drives people’s choice of strategies? What are the barriers to existing strategies?

- Are these strategies available to all members of the community, particularly the most vulnerable households?
- Are strategies used in the past, still relevant and will people continue to use them? If not, why not? (e.g. issues of sustainability/availability of provisioning services)
- Are there particular resources (including provisioning services) that are key for coping/adapting?
- Do people respond to shocks, trends, and seasonal changes proactively or reactively?

13:00 - Lunch and close

APPENDIX 3: Community maps completed during the community workshops for Bennde Mutale and Vondo

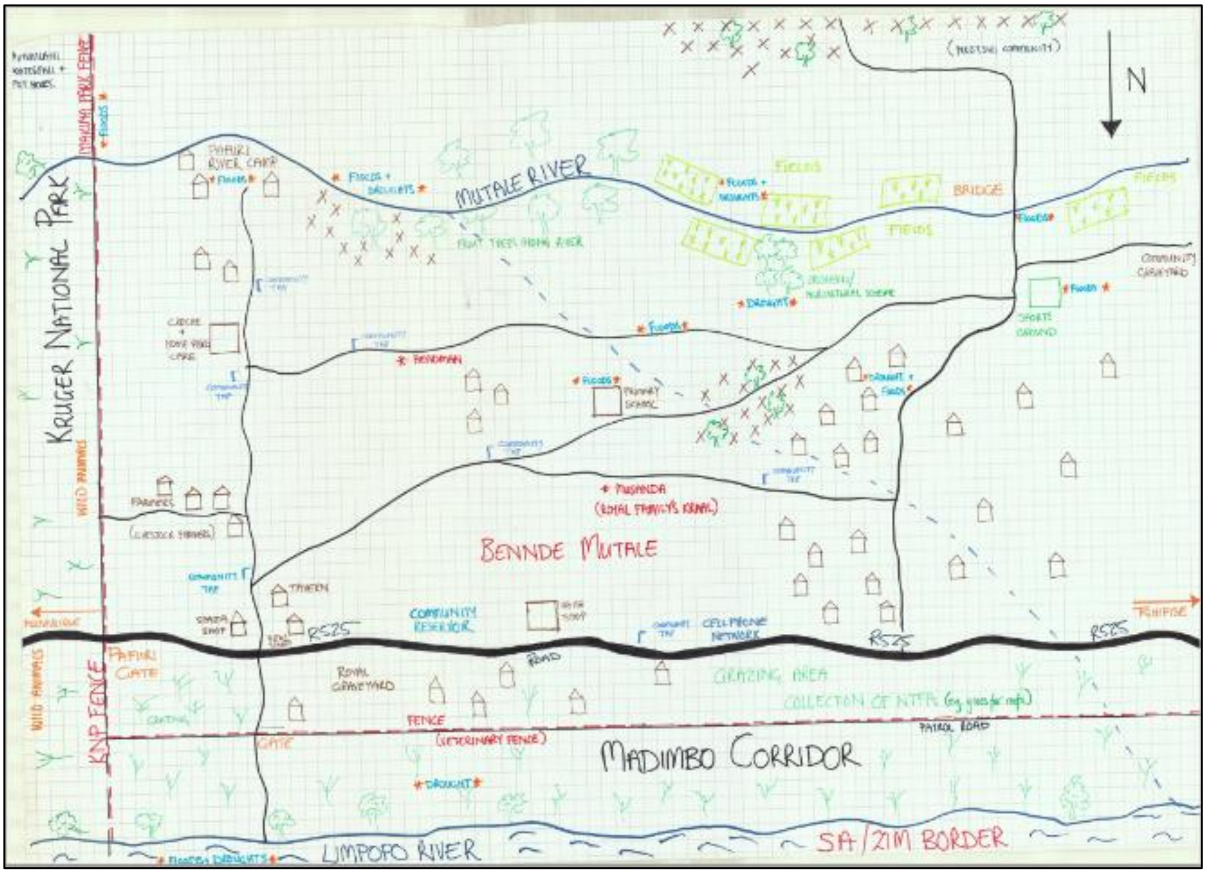


Fig. A3-1 Community map for Bennde Mutale

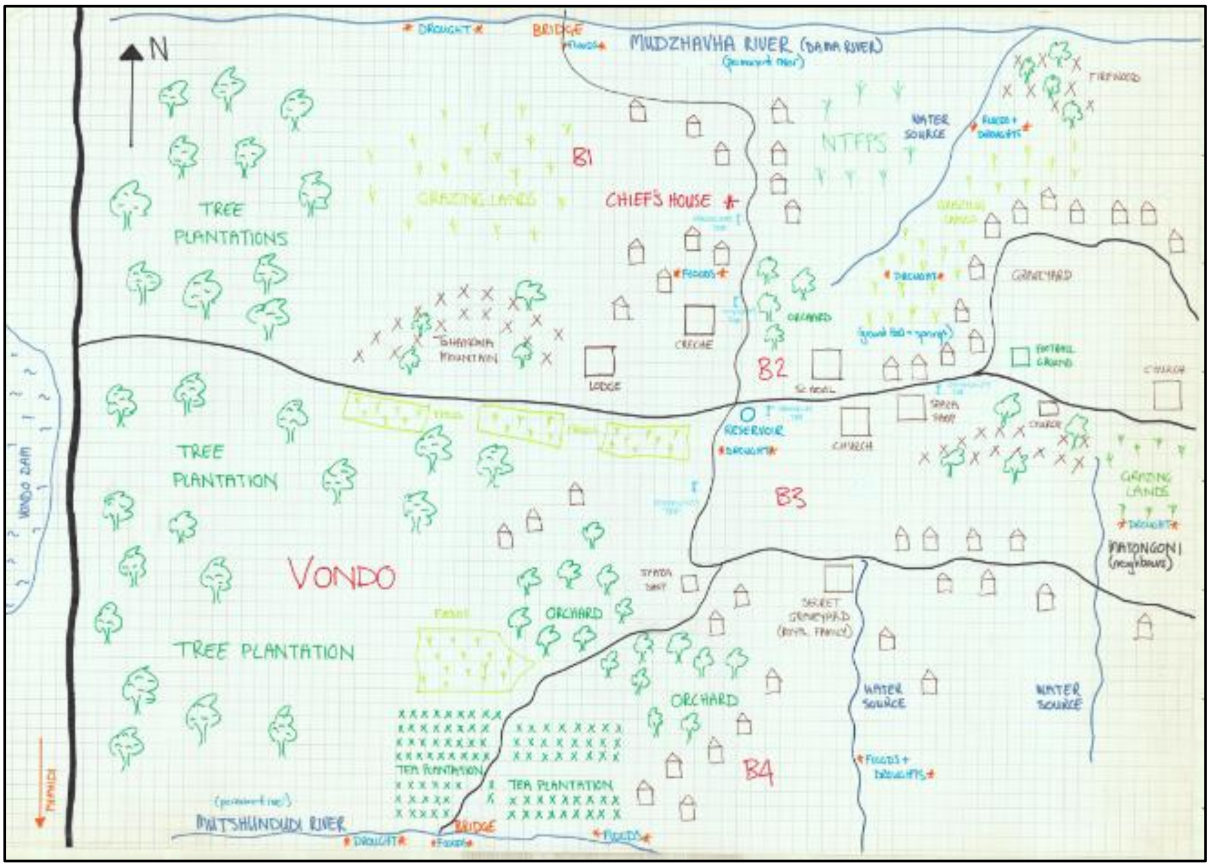


Fig. A3-2 Community map for Vondo

APPENDIX 4: Seasonal calendars completed during the community workshops for Bennde Mutale and Vondo

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall		**********	***									***	*****
Temperature		**********	******	****	****	***	*		****	*****	********	********	*********
Plant fields			**********									******	**********
Plant gardens						********	**********	*****					
Harvest fields				**********			**********						
Harvest gardens							*****	**********	**				
Crop pests					**********		**********						**********
Sell crops				**********				******					
Livestock disease										******	**********		
Grazing		***	******	**********	*******	****	**						
Sell livestock				***			**********						**********
Hunger season									**********	**********	********	********	
Human disease				*****			********	**********					
High expenditure		**********										**********	**********
Use wild foods		**********	**********	**********	**********		**********	**********					****
Sell wild foods					****	********	******						
Use firewood			*	*	****	*	**********	****	*	*	*	*	********
Sell firewood			*	*	**********	*	**********	*	*	*	*	*	**********

Fig. A4-1 Seasonal calendar for Bennde Mutale

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall		*********	*****	**********	*					*	********	**	***
Temperature		***	**	*	****	*	*	*	*	********	******	**********	*****
Plant fields											**********	********	****
Plant gardens				**********		********	****	**	******				
Harvest fields					**	*****	**********						
Harvest gardens						********	**********	*****	****	*			
Crop pests													
Sell crops		*******	*******										
Livestock disease													
Grazing		********	*******	***	**	*						****	**********
Sell livestock		*******											
Hunger season									**********	*******		*********	
Human disease							********	*******	**********	*****			
High expenditure		*********	**	*******		*	*****	*	*	*	****	***	**********
Use wild foods		*******	*****			***	**				******	*******	**********
Sell wild foods		******	*****			***	**				******	*******	**********
Use firewood		***	***	******	*	******	**********	*******	**	*	**	*	********
Sell firewood		***	***	*****	*	******	**********	********	**	*	**	*	********

Fig. A4-2 Seasonal calendar for Vondo

APPENDIX 5: Historical profiles completed during the community workshops for Bennde Mutale and Vondo

Table A5-1 Historical profile for Bennde Mutale

Year	Details
1969	• The village was relocated to its current position to allow for the creation of the (*check if it was the Park or the Madimbo Corridor*). • Big floods forced people to move from lower to higher ground.
1970	• The first school was built – a wooden structure with a zinc roof. • Because there was no fence with the Park, wild animals were a problem (lions in particular).
1976	• The tar road between Pafuri and Tshipise was built. Some households were moved to make way for the road.
1980	• Outbreak of a disease called “lekker krap” (Scabies?)
1982	• Bad drought
1983	• Bad drought.
1984	• Bad drought. • Makuya Park fence was erected reducing the amount of land available for grazing. • Possible bilharzia outbreak.
1992	• Bad drought. Livestock killed by lions.
1993	• Bad drought. Livestock killed by lions.
1994	• New South Africa
1996	• The veterinary fence was moved, again reducing the amount of grazing land available
2000	• Bad floods. Some discussion as to whether other floods had been worse. Trees, houses, and roads washed away. Old lady argued that the 1969 floods were worse, but others argued that the river was bigger in 2000.
2001	• Eclipse
2002	• Pafuri Gate was moved near the village
2005	• Tornado damaged several buildings in the area including the old school. • A small flood. Cattle washed away including those of Lufuno’s mother. Their legs got stuck in tree branches.
2006	• New school was built • Wood availability was really bad
2013	• Bad floods

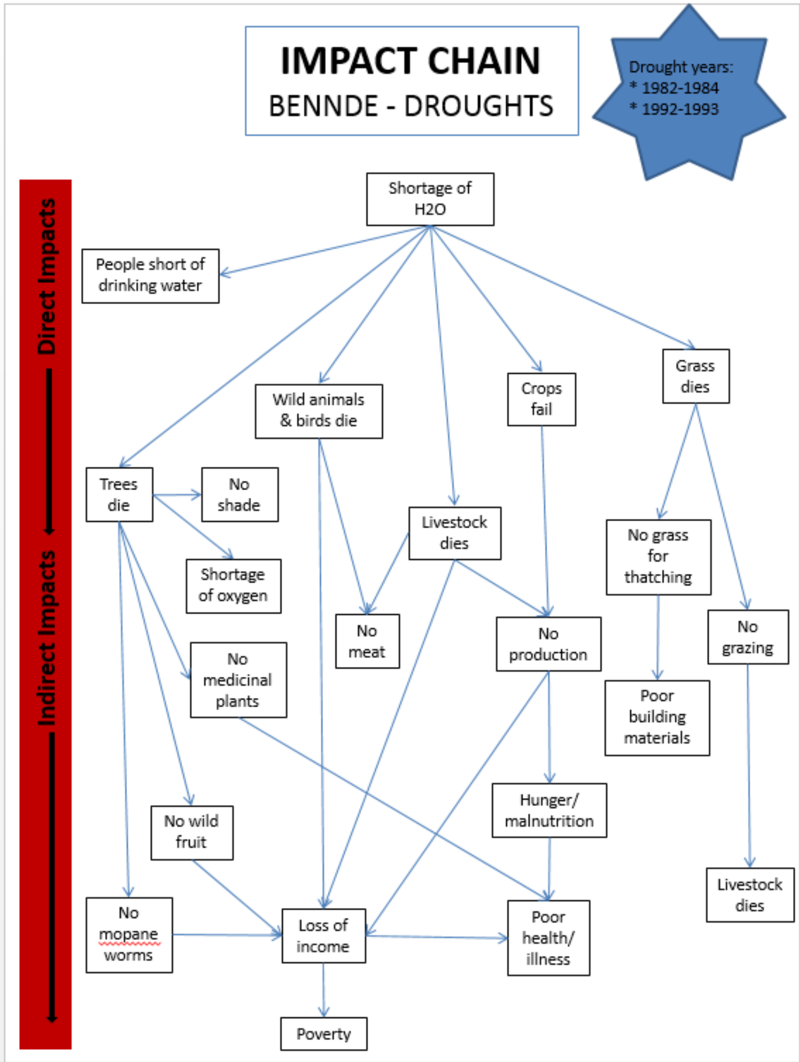
Table A5-2 Historical profile for Vondo

Year	Details
1901	• White men arrived in the area
1902	• Conflict between Chief Ramaramisa Chibasa and the Nevondo family which resulted in the Nevondo separating from the Chief. (Still not sure I understand this).
1902/03	• Venda people handed in their guns to the Whites. People were paid £1.10 per gun. The guns were destroyed (burnt) on top of the mountain. A few old guns were noted in people's households. Apparently after the guns were destroyed, nothing grew in the area because of the chemicals in the soil.
1908	• The white people left the area and moved to Sibasa. Accessibility issues and malaria made them leave. There was no bridge across the river and people had to bring food and other supplies in with donkeys, etc. But when there were bad floods the livestock was washed away, people starved as a result and therefore moved.
1910	• Union of South Africa. Forced tax of £1.10 was introduced.
1914	• A plague of locusts destroyed all the crops
1915	• Cattle dipping was started
1924	• Another plague of locusts. According to respondents there were so many locusts that people could not see the sun. The locusts roosted on a tree at the Chief's Kraal, causing branches to break.
1945	• Smallpox outbreak as well as Lekker Krap (Scabies?)
1948	• Drought and bad hunger
1952/53	• Plantations started with associated forced removals
1954	• Floods
1958	• Bad hail • Worms destroyed crops
1962	• Drought and bad hunger
1964/65	• Household stands were established/started (need to find out how people lived before this)
1975	• Tea plantation was established
1976	• Black power strike (i.e. Soweto riots)
1977	• Floods
1979	• Venda gained independence
1983	• Drought
1992/93	• Worms ate crops
1994	• Democratic elections
1995	• Water pipe was installed
1997	• School started as a wooden shack
1999	• School rebuilt with blocks
2000	• Floods

2002	• Electricity installed
2003	• Eclipse • Crèche established
2007	• Earthquake
2010	• Eclipse
2013	• Heavy rains

APPENDIX 6: Drought and flood impact chains completed during the community workshops for Bennde Mutale and Vondo

a.



b.

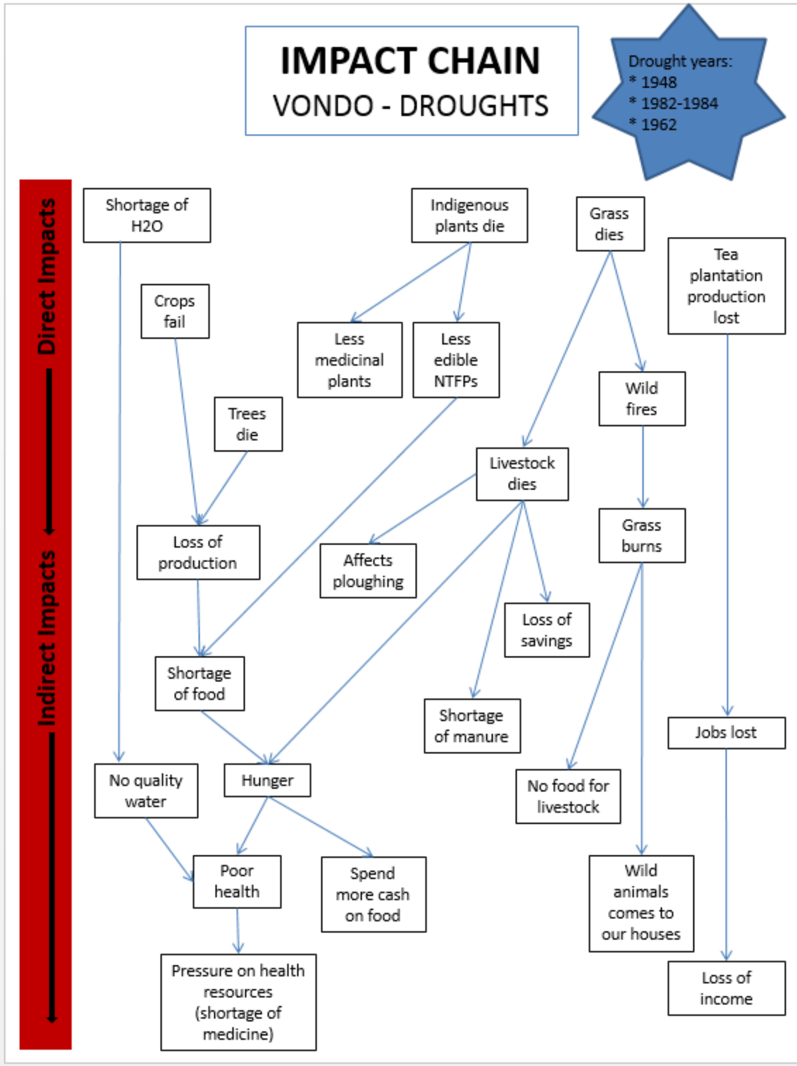


Fig. A6-1a & b Drought impact chains for Bennde Mutale (a) and Vondo (b)

a. b.

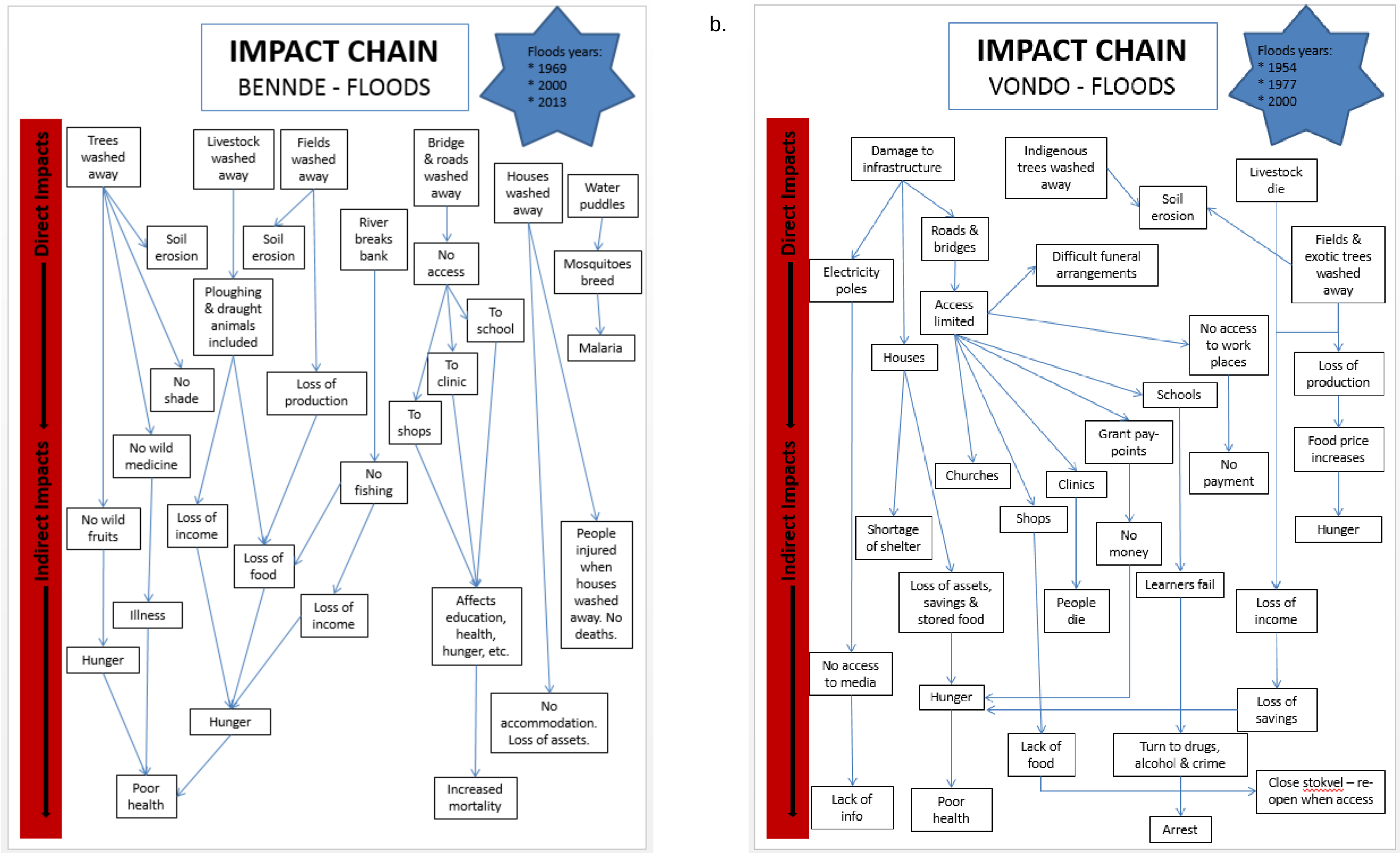


Fig. A6-2a & b Flood impact chains for Bennde Mutale (a) and Vondo (b)

APPENDIX 7: Drought and flood problem trees completed during the community workshops for Bennde Mutale and Vondo

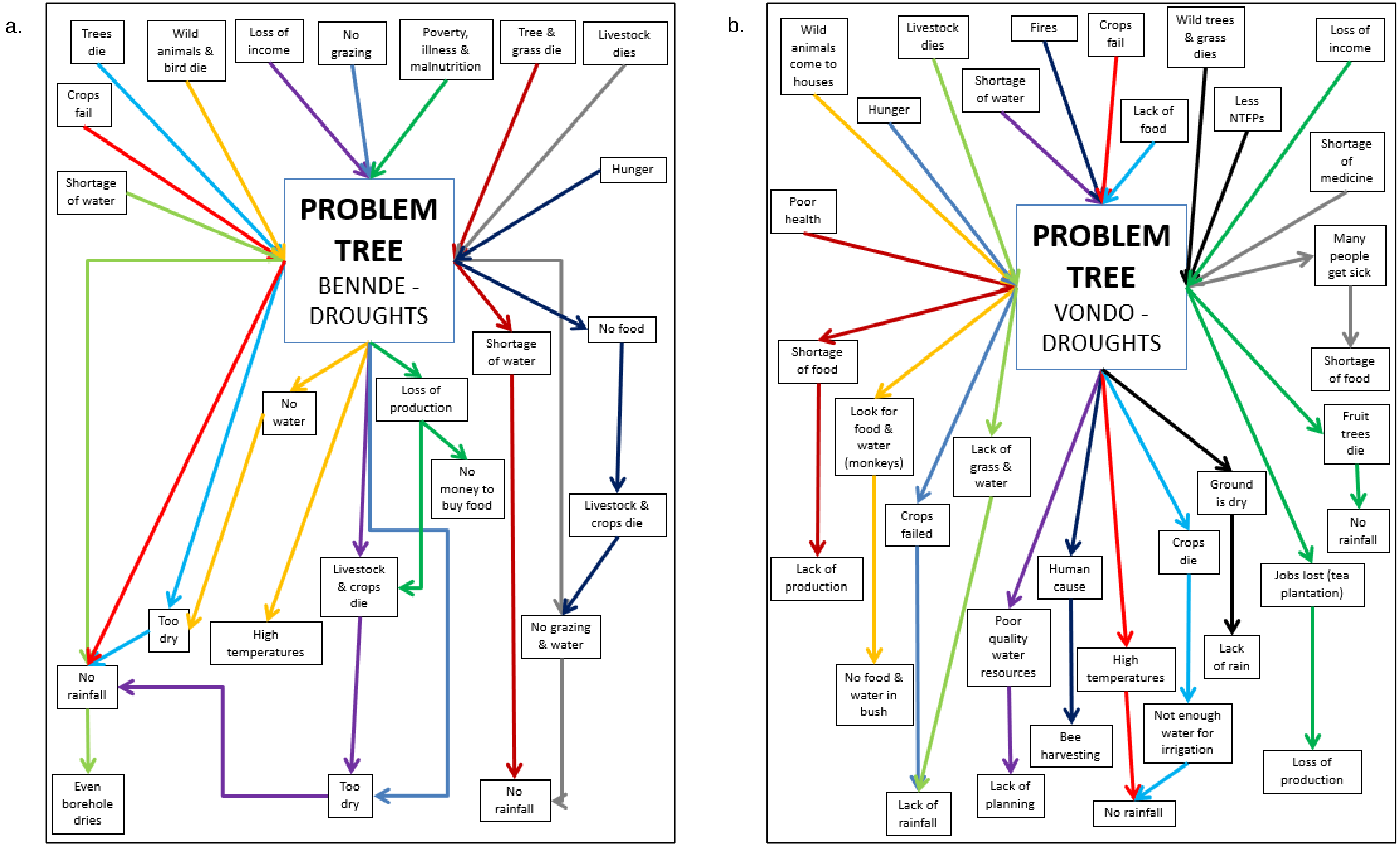


Fig. A7-1a & b Drought problem trees for Bennde Mutale (a) and Vondo (b)

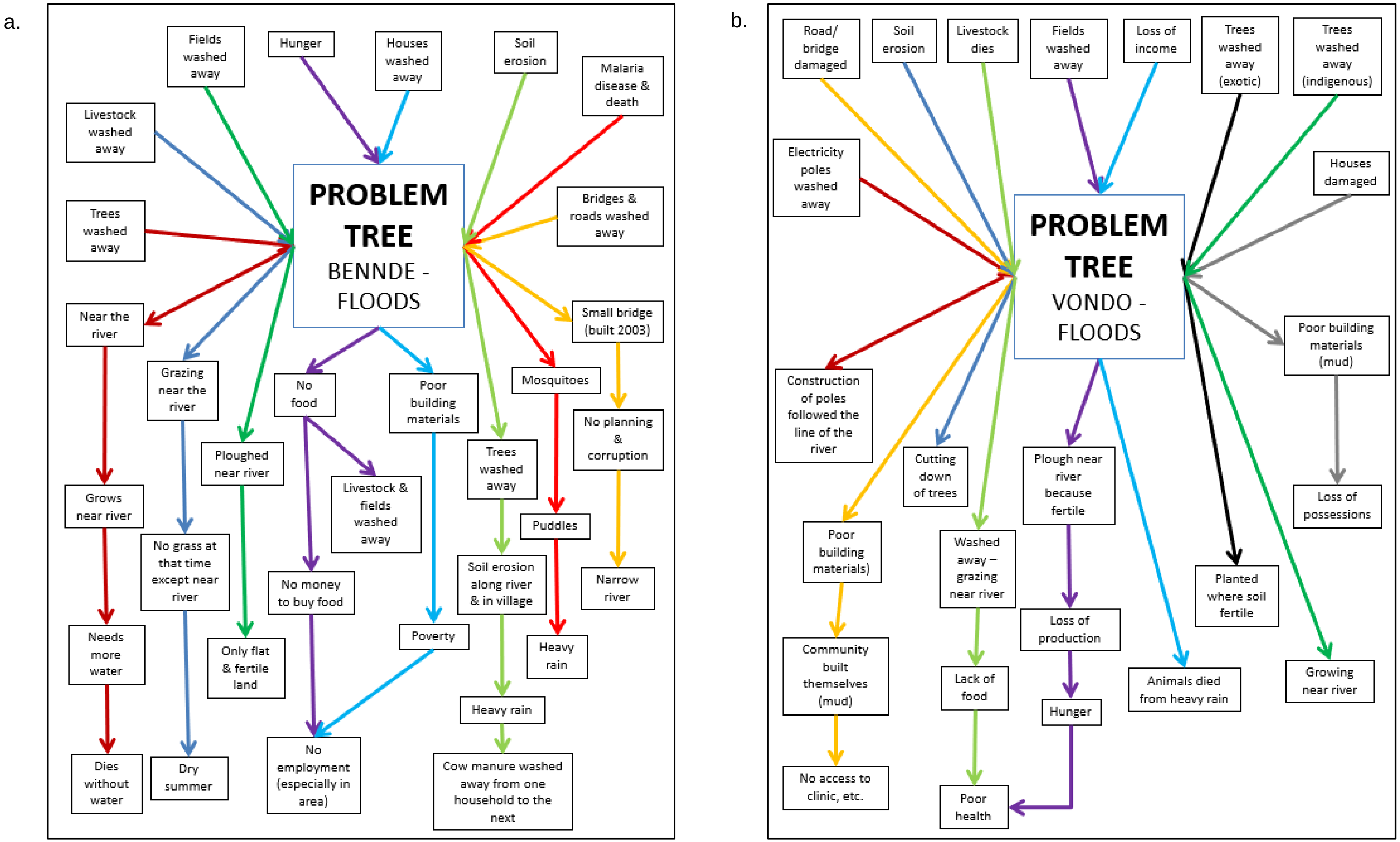


Fig. A7-2a & b Flood problem trees for Bennde Mutale (a) and Vondo (b)

APPENDIX 8: Interview schedule for the semi-structured household survey for both Bennde Mutale and Vondo

Household Questionnaire 1

Participant Information Sheet:

Good day.

My name is Fiona Paumgarten and I am a researcher with the University of the Witwatersrand (Wits) in Johannesburg. This interview is being conducted with the assistance of:

_______________________________ (translator to write their name)

Introduction
You are invited to participate in a research project conducted by myself and my team from the University of the Witwatersrand. This project aims to explore the impact of weather and climate change on the livelihoods of members of your community. The research will also be conducted in another village in South Africa.

In this research we will explore factors that increase household vulnerability, focusing on climate-related factors (e.g. droughts, floods). The research will then consider how households have coped with these events focusing particularly on how the surrounding bush helps households to cope. For example, when crops fail, do households find food in the surrounding bush? Or if households need extra money to replace these crops with purchased vegetables, do they sell firewood?

By exploring how households in this area cope with periods of vulnerability in general and with climate related events in particular, we can begin to understand how these households might cope with future climate change and what measures may be needed to ensure that these shifts don’t result in increasing vulnerability.

How do I participate in the research?

You are invited to participate in this research. The interview will be conducted in your homestead. A translator will be present throughout the interview. We will be selecting households randomly, so your household has not been selected for any particular reason.

Does participation in the interview cost me anything?

Participation in the interview will not cost you anything other than the time taken to answer the questions. At the same time, there is no payment or remuneration for participating. Participating is completely voluntary.

If I decide not to participate or to withdraw, will I be penalized in any way?

Participation in this interview is voluntary and refusal to participate or withdrawal during the interview will not involve any penalty or loss of benefits.

Do I have to answer all the questions?

No, you do not have to answer all the questions. Only answer the questions that you want to answer. You will not be penalized if you do not answer all the questions.

Is the information I give during the interview confidential?

The information you give during the interview will be confidential. Your name will not appear on any of the resulting questionnaires or reports.

Why is this research proposed?

It is hoped that the research will contribute to an improved understanding of how future climate change may affect households and what measures may be needed to ensure that these households do not become more vulnerable.

How will this benefit me?

A better understanding of how households have coped with past climate related vulnerability, will help to design recommendations on how households can be cushioned against/supported through future climate vulnerability and change.

How long will this research take?

Interviews are being conducted in 2013 and possibly into 2014. Final results and presentation of the data will aim to take place towards the end of 2014. The general results of this research will be reported back to your community in a feedback meeting.

Who can be contacted?

Fiona Paumgarten from the School of Animal, Plant and Environmental Sciences, University of Witwatersrand is doing this research. She lives in Johannesburg and can be contacted at:

Cell: 083 600 6399

Email: fi.paumgarten@gmail.com

P.O. Box 2105, Johannesburg, 2000

You can also contact any of translators assisting me:

1. Edward: 082 731 5853
2. Lufuno: 071 414 3174
3. Prince: 078 605 0154
4. Christopher: 076 302 9383

How do I indicate my consent?

If you decide to participate in the study, you can sign a consent form which will confirm that you understand the study and have agreed to participate.

Participant Signature ____

Interviewers Signature ____

Witness Signature ____

Confidential Contact Details Form:

Interviewers name: ____

Date of interview: ____

Place (Village name): ____

Time of interview: ____

Contact details of interviewee: ______________________________________

Interviewees Code X________

Interviewees Name ______________________________________

Cell number ______________________________________

Address ______________________________________

Household Questionnaire 1

(Please note: If there are any questions below that you do not understand, please rather leave them blank and we can go back to the household later.)

1. General Information

a. When was this household started: ____

2. Socio-democratic Information

a. Gender of respondent: Male [ ] Female [ ]

b. Is the respondent the household head (de jure)? Yes [ ] No [ ]

c. What is the tribe in the household?

Venda [ ]

Shangaan [ ]

Zimbabwean [ ]

Other [ ]

d. How many people belong to this household (i.e. full-time residents sharing the kitchen, not people just visiting)? *(PLEASE COMPLETE TABLE A8-1 - use the following codes*)

Codes:

** **Relation to household head**: 1 = Husband/Wife; 2 = Son/Daughter; 3 = Grandchild; 4 = Stepchild/Foster Child/Orphan; 5 = Mother/Father; 6 = Brother/Sister; 7 = Other Family; 8 = Not related*

*** **Main occupation**: 1 = Formally employed; 2 = Informally employed; 3 = Unemployed; 4 = Self-employed (e.g. retailer, artisan, etc.); 5 = Farmer (crops and/or livestock); 6 = Pensioner; 7 = At School; 8 = Under 6 year; 9 = Other*

**** **Government grants**: OAP = Old age pension; CCG = Child-care grant; DG = Disability grant*

e. Are there any children less than 18 years old from other families living in your house because one or both of their parents has died? Yes [ ] No [ ]

f. How many family/household members have left the village to work elsewhere (i.e. migrant labourers)? ____

g. Do any of these migrants still send money, food, or household items home?

Yes [ ] No [ ]

Table A8-1 Information on Household Members (Full-time Residents)

	Gender M/F	**Age or date of birth**	**HH head** *(de jure & de facto)*	**Relation to the de jure HH head** *	**Education/ training** *(Specify if std/grade or tertiary)*	**Main occupation** *(job type)* **	**Receives a government grant** ***	**Contributes money to the HH** (Y/N)
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								

h. If the household has migrants, why did this person/these people leave the village?

____

____

i. What do the migrants contribute:

Money [ ]

Food [ ]

Household items [ ]

All of the above [ ]

j. How often do the migrants contribute money/food/household items/etc.?

Weekly [ ]

Monthly [ ]

Every 6 months [ ]

Once/year [ ]

Only when asked (e.g. emergencies) [ ]

Never [ ]

Other [ ]

3. Social Capital (Kinship)

a. Do you have family in the village? Yes [ ] No [ ]

b. Are you a part of any of the following?

Local church [ ]

Burial Society [ ]

Savings Group [ ]

Agricultural co-operative [ ]

User group (Forest or other) [ ]

Other? [ ]

c. If you have family in the village, can rely on your family to help you during difficult times (i.e. provide food, money, labour)?

Yes [ ] Sometimes [ ] No [ ]

d. If you cannot rely on your family for help, can you rely on members of these groups or others in the village for help during difficult times (i.e. provide food, money, labour)?

Yes [ ] Sometimes [ ] No [ ]

4. Assets and Savings

a. Does this household have any savings in banks/burial societies/stokvels/savings or credit groups/insurance? Yes [ ] No [ ]

b. If yes, *PLEASE COMPLETE TABLE A8-2 BELOW*

Table A8-2 Household Savings

	Savings	**Y/N**
1	Burial societies	
2	Stokvels/Savings Club (rotating & accumulating schemes)	
3	Bank/post office accounts	
4	Crop/weather insurance	
5	Other (e.g. insurance); Please explain	

c. Does your household have electricity? Yes [ ] No [ ]

d. Does your household have piped water on the household stand (i.e. not a communal tap)? Yes [ ] No [ ]

e. Implements and other large household items:
(PLEASE COMPLETE TABLE A8-3 BELOW)

f. Type of house –
(PLEASE COMPLETE TABLE A8-4 BELOW - use the codes below. If people have more than one building, record for all.)

Codes:

** **Wall material**: 1 = Mud/soil & sticks; 2 = Bricks made from mud; 3 = Bricks/concrete bought from outside; 4 = Wood (majority of wall not just poles); 5 = Iron (or other metal) sheets; 6 = Reeds/thatch /grass; 7 = Other*

*** **Roofing material**: 1 = Reeds/thatch/grass; 2 = Wood (majority of roof not just poles); 3 = Iron (or other metal sheets); 4 = Tiles; 5 = Other*

Table A8-3 Assets Owned by the Household

	Asset	**Owned Y/N**
1	Stove for cooking (gas/paraffin/electric)	
2	Fridge/Freezer	
3	Radio/Hi-fi/Cassette/CD player	
4	Cellphone	
5	TV	
6	Car	
7	Bicycle	
8	Tractor	
9	Wheelbarrow/wooden cart	
10	Plough	
11	Chainsaw	
12	Water pump	
13	Solar panel	

Table A8-4 Type of House

1	What type of material are (most of) the walls made of? *	
2	What type of material is (most of) the roof made of? **	

5. Water and Firewood

a. Please complete the questions below regarding access to water:

i. Where do you get water for drinking and washing?

River: [ ]

Communal tap: [ ]

Household tap: [ ]

Spring: [ ]

Other: [ ]

ii. Do you have access to a regular supply of water (or are there times it is difficult to find water)?

Yes, I have access to a regular supply [ ]

No, the supply is not always regular [ ]

iii. If you answered "No" to the question above, why is it difficult to access water regularly?

____

____

____

iv. Are there any problems with the water you use for yourself, you r agriculture and your livestock (e.g. the quality is not good, there is not enough for everyone, etc.)? Please explain:

____

____

____

iv. How long does it take you to travel to where you get water and back home?

____

v. How many times per week do you collect water? ________________________

vi. Do you spend more time collecting water now than 5 years ago? (i.e. has it got harder to find water?) Yes [ ] No [ ]

vii. Do you store water for either household consumption or agriculture? (e.g. in buckets, rainwater tanks, etc.) Yes [ ] No [ ]

viii. If you store water, why, when, and how? (e.g. I store water for my garden, I only store water in winter, I store water in 10l buckets)?

____

____

____

b. Please complete the questions below regarding access to firewood:

i. Do you use firewood? Yes [ ] No [ ]

ii. If yes, do you collect or buy the firewood?

Collect [ ] Buy [ ] Both [ ]

iii. Is there enough firewood for everyone in the village?

Yes [ ] No [ ]

iv. If you collect firewood, how long does it take you to travel to where you collect it and back home ____

v. How many times per week do you collect firewood? ______________________

vi. If you collect firewood, do you spend more time collecting wood now than 5 years ago? (i.e. has it got harder to find firewood?

Yes [ ] No [ ]

6. Arable Agriculture and Agroforestry

(Please note that gardens are the small gardens on people's stands. These are different to fields.)

a. Does your household have a garden? Yes [ ] No [ ]

b. Does your household have any fields? Yes [ ] No [ ]

c. If your household does not cultivate at all, why not?

____

____

____

IF THE HOUSEHOLD DOESN'T HAVE A GARDEN OR FIELD, PLEASE MOVE ONTO SECTION 7. IF THE HOUSEHOLD DOES HAVE A GARDEN OR FIELD, PLEASE CONTINUE WITH THE QUESTIONS BELOW.

d. Do you cultivate all your land every year or is some left fallow? __________________

e. If some is fallow, why and for how long?

____

____

____

f. Do you store crops from your harvest to eat during other times of the year?

Yes [ ] No [ ]

g. Do you store seed to grow the next year? Yes [ ] No [ ]

7. Animal Husbandry

a. Does your household own any livestock? Yes [ ] No [ ]

b. If your household does not own livestock, why not?

____

____

IF THE HOUSEHOLD DOESN'T HAVE ANY LIVESTOCK, PLEASE MOVE ONTO SECTION 8. IF THE HOUSEHOLD DOES HAVE LIVESTOCK, PLEASE CONTINUE WITH THE QUESTIONS BELOW.

c. *PLEASE COMPLETE TABLE A8-5 BELOW:*

Table A8-5 Livestock Ownership

Animal	**Y/N**	**Number**	**Animal**	**Y/N**	**Number**
Cattle			Sheep		
Donkey			Pigs		
Goats			Chickens		
Ducks			Other		

d. What are the top three most important livestock types and why?

____

____

____

8. Non-timber Forest Products (NTFPS)

(Please note that NTFPs means products people collect from the bush, fields, gardens, stands but does not include cultivated crops)

a. Does your household use NTFPs? Yes [ ] No [ ]

b. Does your household store NTFPs? Yes [ ] No [ ]

IF YOUR HOUSEHOLD USES NTFPS, PLEASE COMPLETE TABLE A8-6 BELOW.

Table A8-6 Household use and procurement of NTFPs (Please use the codes below the table to complete it)

	Resource	**Collect Y/N**	**Buy Y/N**	**Sell Y/N**	**Collected by whom ***	**Sold by whom ****	**Frequency collected *****	**Frequency sold ******	**Rank**
1	Wild fruits								
2	Wild herbs/spinach								
3	Medicinal plants								
4	Grass for thatching, hand sweepers, etc.								
5	Twigs for hand sweepers								
6	Indigenous poles for construction/fencing								
7	Reeds: weaving/ construction								
8	Wood for household items †								
9	Fuelwood								
10	Bushmeat (incl. insects & fish)								

Codes:

** "**Collected by whom**": 1 = Adult female household members; 2 = Both adult males and adult females participate about equally; 3 = Adult male household members; 4 = Girls (< 15 years); 5 = Boys (< 15 years); 6 = Children, and boys and girls participate about equally.*

*** "**Sold by whom**": 1 = Adult female household members; 2 = Both adult males and adult females participate about equally; 3 = Adult male household members; 4 = Girls (< 15 years); 5 = Boys (< 15 years); 6 = Children, and boys and girls participate about equally.*

**** "**Frequency collected**": 1 = At least once a week (throughout the year); 2 = At least once a month (throughout the year); 3 = At least once a week (season only); 4 = At least once a month (season only); 5 = Only when I feel like it; 6 = Only when we need; 7 = Other*

***** "**Frequency sold**": 1 = At least once a week (throughout the year); 2 = At least once a month (throughout the year); 3 = At least once a week (season only); 4 = At least once a month (season only); 5 = Only when I can find a market; 6 = Only when I need extra cash; 7 = Other*

† Examples of wood items: stirring/cooking spoons, plates/bowls, pestle & mortar, hoe/pick/axe handles, walking/fighting sticks, yokes, pipes, carvings (art), furniture

9. Diet and Food Security

a. Where does your household get most of its food from?

The shops/store [ ]

Our field [ ]

Our garden [ ]

Our livestock [ ]

From the bush [ ]

As gifts from friends/family/community [ ]

Government/NGO food parcels [ ]

Other [ ]

If other, please explain:

____

____

b. Are there times during the year when your family does not have enough food?

Yes [ ] No [ ]

c. Has the household ever been the recipient of food aid? Yes [ ]

No [ ]

d. Is it harder to find food for your household now compared to 5 years ago? Yes [ ] No [ ]

10. Household Vulnerability - Multiple Stressors

a. Do you pay school fees? Yes [ ] No [ ]

b. If you have a garden or field, do you have months during the year when you have nothing growing in either the garden or the field (i.e. seasonal crop shortfalls)?

Yes, there are months I have no crops [ ]

No, I grow and harvest crops the whole year [ ]

c. Are Christmas and Easter expensive times for your household?

Yes [ ] No [ ]

d. Do you spend money every year on fertilizers, pesticides, buying seed, buying medicine and food for livestock? Yes [ ] No [ ]

e. Do you think the price of living has increased over the last 5 years (e.g. cost of food, cost of fuel, agricultural inputs, etc. has increased)?

Yes [ ] No [ ]

f. Do you have any household members who are chronically sick and need medicine on a regular basis? Yes [ ] No [ ]

PLEASE COMPLETE TABLE A8-7 below on unexpected problems/difficulties your household has experienced over the last 5 years and how severe the problems/difficulties were.

Table A8-7 Shocks experienced by households

Problem/Difficulty	**Y/N**
Serious crop failure	
Serious crop disease/pests (requiring pesticides, etc.)	
Major livestock loss (theft, drought, eaten by wildlife, etc.)	
Major livestock disease (requiring treatment)	
Infrastructure or major assets destroyed/lost (e.g. house, road, agricultural implements, etc.) (includes theft)	
Land loss (e.g. damaged by erosion (e.g. flood washed it away, expropriated, etc.)	
Death of productive age-group adult	
Death of a government grant recipient	
Death of breadwinner	
Increase in number of dependents (children under 18 years and adults over 60 years)	
Loss of remittances	
Loss of wage employment (e.g. retrenchment)	
Failure of own business	
Serious illness/injury in family (productive adult unable to work for >1 month during past year, due to illness, or to take care of ill person; or high medical costs)	
Wedding or other costly social events (irregular events)	
Natural disasters (e.g. floods, droughts, fire, hail, strong winds)	
Other. Specify:	

Household Questionnaire 2

1. General Information

a. Translator name: ______________________________

b. Village: ______________________________

c. Name of household head: ______________________________

d. Stand number: ______________________________

e. Cell number: ______________________________

f. Date of interview: ______________________________

g. Date household established: ______________________________

2. Questions for Select Households

a. Migrants and remittances (*Questions for households who have migrant workers)*

i. If you needed help at home (with money, food, labour, household items, etc.) would you ask this migrant to help? Yes [ ] No [ ]

ii. If no, why not: ______________________________

____

____

iii. If yes, can you give an example from the last 2 years when you have asked the migrant for help?

____

____

b. Household Savings *(Questions for households for savings)*

i. Have there been any problems in the last 2 years when you have had to draw money from your savings? Yes [ ] No [ ]

ii. If yes, please explain what the problem was?

____

____

c. Fields and gardens *(Questions for households with fields/gardens)*

i. How many years have you been farming? ______________________________

ii. Do you have any fruit trees in your field or garden? Yes [ ] No [ ]

iii. If yes, are they indigenous (wild) or exotic fruit trees?

Indigenous (e.g. baobab, marula) [ ]

Exotic (e.g. orange, avocado) [ ]

iv. Do you grow crops/fruit trees for?

Home consumption [ ]

Sale [ ]

Both [ ]

v. If you sell crops/fruit, do you:

Sell after every harvest [ ]

Sell sometimes [ ]

vi. Do you fertilize crops/trees? Yes [ ] No [ ]

vii. What is your usual form of irrigation?

(*PLEASE COMPLETE TABLE A8-8 BELOW, use the codes below)*

Table A8-8 Methods of irrigation

	Type of irrigation	**Y/N**	**Source of water** *
1	Rainfed		N/A
2	Bucket		
3	Drip irrigation		
4	Sprinkler irrigation		
5	Other?		

Codes:

** **Source of water**: 1 = River/stream; 2 = Dam/lake/watering hole; 3 = Community well/pump/standpipe; 4 = Rainwater tank/bucket; 5 = Other*

viii. When do you farm?

Summer only [ ]

Winter only [ ]

Throughout the year [ ]

ix. What proportion of your household's diet comes from your field/garden?

All [ ]

Most [ ]

Half [ ]

Less than half [ ]

Just a small part [ ]

x. What changes do you make to your diet if your crops fail dies?

____

____

____

xi. What challenges do you face to growing (and selling) crops/fruit trees?

PLEASE COMPLETE TABLE A8-9 BELOW

Table A8-9 Key challenges to agricultural production

Challenge	**Y/N**
Not enough land	
Not enough labour to help/labour too expensive	
Livestock or wild animals/birds eat the crops/fruit	
No fencing materials or fencing materials expensive	
Poor soil (e.g. stony)	
Fertilizer, seeds, pesticide too expensive (expensive inputs)	
Not enough money	
Pests and diseases (e.g. locusts, etc.)	
No plough (either with tractor or donkey/cattle); no money to pay someone to plough → need to plough by hand	
No market for crops/fruit (hard to sell)	
Low market price	
No irrigation → rely on rainfall	
Climatic reasons (rain/temperature/hail/wind)	
Other	

xii. If you mentioned "climatic reasons" above, how does the climate (rain, temperature, hail, wind, etc.) make farming difficult?

____

____

____

xiii. Has the climate always been a problem or is it changing? If it is changing, how is it changing?

____

____

____

d. Livestock ***(****Questions for households with livestock)*

i. How many years have you had livestock? ____________________

ii. Why do you keep livestock:

Home consumption [ ]

Sale [ ]

Savings (e.g. "cattle are my bank") [ ]

Lobola/other cultural practices [ ]

Draught power (ploughing) [ ]

Transport (e.g. donkey cart) [ ]

Hides/skin/wool [ ]

Manure [ ]

Other [ ]

iii. If you sell livestock, do you:

Sell regularly [ ]

Sell only sometimes [ ]

iv. Have you sold livestock in the last 2 years?

Yes [ ] No [ ]

v. Why did you sell livestock?

____

____

vi. What proportion of your household's diet comes from your livestock?

All [ ]

Most [ ]

Half [ ]

Less than half [ ]

Just a small part [ ]

vii. What changes do you make to your diet if your livestock dies?

____

viii. What challenges do you face in raising (and selling) livestock (Table A8-10)?

Table A8-10 Key challenges to animal husbandry

Challenge	**Y/N**
Not enough land/grazing	
Not enough labour to help/labour too expensive	
Wild animals attack livestock	
No fencing materials or fencing materials expensive (for kraals, etc.)	
Medicine, dips, veterinary services too expensive (expensive inputs)	
Not enough money	
Pests and diseases	
No market for livestock (hard to sell)	
Low market price	
Not enough water for livestock to drink	
Buying fodder too expensive	
Climatic reasons (rain/temperature/hail/wind)	
Theft	
Food and mouth red fence	
Other	

ix. If you mentioned "climatic reasons" above, how does the climate (rain, temperature, hail, wind, etc.) make raising livestock difficult?

x. Has the climate always been a problem or is it changing? If it is changing, how is it changing?

e. **Non-timber Forest Products (NTFPS)** ***(****Questions for households using/selling NTFPs)*

i. How much time (e.g. hours) do you spend per week collecting products from the bush (e.g. firewood, morogo, wild fruit, mopane worms, etc.)? ______________________

ii. How many meals in week include food from the bush (e.g. wild fruits, morogo, bushmeat including animals, fish, birds, and insects) (NTFPs)?

When food is plentiful (i.e. after the harvest): ___________________________

When food is scarce (i.e. during low production months): _____________________

During hungry times (i.e. when crops fail – drought, etc.): _____________________

iii. How important are forest foods for surviving hungry times?

Very important [ ]

Important [ ]

Somewhat important [ ]

Not important [ ]

iv. Taking NTFPs into account, what proportion of your household's diet comes from the bush?

All [ ]

Most [ ]

Half [ ]

Less than half [ ]

Just a small part [ ]

v. If household sells NTFPs, when and why did they start selling?

____

____

____

vi. Have there been times in the last 2 years when you have used or sold NTFPs more than usual?

Yes [ ] No [ ]

If yes, please explain why and detail which NTFPs you used/sold more of?

____

____

f. **Assets** ***(****Questions for households with listed assets)*

i. Have there been any problems in the last 2 years when you have had to sell household assets? Yes [ ] No [ ]

ii. If yes, please explain what the problem was?

____

____

g. Coping with Multiple Stressors ***(****Questions for households that experienced problems/difficulties)*

i. *PLEASE COMPLETE TABLE A8-11 BELOW, use the codes below:*

Table A8-11 Household coping strategies

Problem/Difficulty	How did you cope? *		
	Cope1	Cope2	Cope3
Serious crop failure			
Serious crop disease/pests (requiring pesticides, etc.)			
Land loss (e.g. damaged by erosion, expropriated, etc.)			
Major livestock loss (theft, drought, etc.)			
Major livestock disease (requiring treatment)			
Infrastructure or major assets destroyed/lost (e.g. house, road, agricultural implements, etc.) (includes theft)			
Death of productive age-group adult			
Death of a government grant recipient			
Death of breadwinner			
Increase in number of dependents			
Loss of remittances			
Loss of wage employment (e.g. retrenchment)			
Failure of own business			
Serious illness/injury in family (productive adult unable to work for >1 month during past year, due to illness, or to take care of ill person; or high medical costs)			
Wedding or other costly social events (irregular events)			
Other, specify:			

Codes:

** 1 = Spent cash savings; 2 = Got a loan from money lender/bank/stokvel/employer; 3 = Received assistance from friends/relatives (kinship); 4 = Received assistance from NGO, community/religious* *organization or similar; 5 = Received assistance from government, extension workers, etc.; 6 = Sold assets (land, household items, etc.); 7 = Sold livestock; 8 = Did extra casual labour work (including in the community for food – reciprocity); 9 = Searched/migrated for work; 10 = Reduced household spending; 11 = Reduced quantity/quality of meals taken; 12 = Increased reliance on NTFPs (use or sale);13 = Did nothing in particular; 14 = Other*

ii. If you used other means of coping, please provide details:

____

____

____

iii. If there are times when you household does not have enough food, what changes do you make to your diet during these times? (e.g. we rely more on food from the bush or we get food from relatives; we manage with less meals per day):

____

____

____

3. Questions for All Households

a. Kinship

i. In the past 2 years, did relatives/friends help your household with food, money, labour, household items, etc.? Yes [ ] No [ ]

ii. In the past 2 years, did your household help relatives/friends with food, money, labour, household items, etc.? Yes [ ] No [ ]

b. Livelihood Ranking

i. *PLEASE COMPLETE TABLE A8-12 BELOW. Rank these activities in terms of which activity makes the most important contribution to your household. Use the codes below.*

Table A8-12 Rank of contributing livelihood strategies

Rank	**Activity***
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

Codes:

1 = Employment (full or part-time); 2 = Self-employment (e.g. retailing); 3 = Migrant remittances; 4 = Government grants; 5 = Animal husbandry; 6 = Arable agriculture; 7 = NTFPs; 8 = Kinship; 9 = Other

c. Weather and Climate

i. Do you have access to weather forecasts (on the radio/TV/cell phone/ through extension services)? Yes [ ] No [ ]

ii. Over the last 10 years (or if the house has been there for less than 10 years, ask for information since they lived there):

- Have average temperatures during the rainy season (summer):
  Increased [ ] Decreased [ ] Not changed [ ]
- Have the average temperatures during the dry season (winter):
  Increased [ ] Decreased [ ] Not changed [ ]
- Has average rainfall during the rainy season:
  Increased [ ] Decreased [ ] Not changed [ ]

iii. Does the rainy season:

Start earlier than it did 10 years ago [ ]
Start later than it did 10 years ago [ ]
Start at the same time as it did 10 years ago [ ]
Start at a different time every year (more erratic) [ ]

iv. Does the rainy season:

End earlier than it did 10 years ago [ ]

End later than it did 10 years ago [ ]

End at the same time as it did 10 years ago [ ]

End at a different time every year (more erratic) [ ]

v. When during the year do rainfall and no rainfall cause problems? Please explain:

____

____

____

vi. When during the year do high and low temperatures cause problems? Please explain:

____

____

____

vii. Are there other weather/climate events (e.g. wind, hail, etc.) which cause problems? Please explain which?

____

____

____

viii. Has your household experienced a drought? Yes [ ] No [ ]

ix. If yes, what year was the worst drought you remember? ____________________

x. What other years have you experienced droughts? ____________________

xi. Has your household experienced floods? Yes [ ] No [ ]

xii. If yes, what year was the worst flood you remember? ____________________

xiii. What other years have your experienced floods? ____________________

xiv. Which is worse? Droughts [ ] Floods [ ]