



Leveraging Improved Seed Technology, Migration and Climate
Information for Building the Adaptive Capacity and Resilience
to Climate Risks in Semi-Arid Regions

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Declaration

I **Zachary M. Gitonga** declare that this dissertation is my own work, except where acknowledged in the text. I further declare that this thesis has not been submitted for a degree in this or any other university.

Signature

Signed by candidate

Monday, February 3, 2020

Abstract

Droughts induced by climate change will most likely push dryland ecosystems beyond their biophysical thresholds and lead to long-term decline in agricultural productivity. Subsistence farming in developing countries where agricultural productivity is low will become less viable for many families already ravaged by food insecurity and poverty. This dissertation examines three ways of reducing vulnerability to the adverse effects of climate variability and building resilience in the farming communities residing in semi-arid lands. These include the use of adaptive seed technology, migration as a livelihood diversification and adaptive strategy, and the use of climate information in farm decision-making.

The second chapter evaluates the impact of improved adaptive seed technology on market participation and food security, using data from a representative sample of 1344 households selected across six agro-ecological zones in Kenya. The study employed two estimation procedures for impact evaluation: a control function regression using OLS and IV regression estimated by Heckman bivariate sample selection model and 2SLS regression. The study used percentile shares approach to describe distributional inequalities in improved seed adoption across households. Kenya has a well-developed seed system, through which adaptive maize seed has been introduced for various agro-ecological zones. Despite its success with improved maize breeding programs, Kenya is still grappling with food insecurity.

The marketed share of household's maize produce, among adopters, was on average 12 percentage points higher than for the control group. This increased with adoption intensity, albeit at a decreasing rate. The top 20% of households accounted for 63% of the quantity and 65% of the area planted with improved maize. The bottom 40% only accounted for 6% of the quantity purchased and 5% of the area planted with improved maize. Adopting households were less vulnerable to food insecurity and stored maize for longer than non-adopters. Larger families participated less in the market and were more food insecure. Wealth and education are other key determinants of food security and market participation. The results of the study indicate a need for a strategic policy on food security in Kenya that considers the concentrated nature of the maize farming sector, to address the problem of food insecurity. Such a policy could aim at food self-sufficiency for small farms and promote commercial production by large-scale producers for national strategic reserves. There is also a need for post-harvest policies that promote safe on-farm grain storage for small and medium scale producers.

The third chapter focuses on migration, because of the growing interest among scholars in understanding the relationship between migration and adaptation to climate change. Past studies have looked at climate change as a trigger for migration, but the focus has now shifted to looking at migration as an enabler of climate-change adaptation and a livelihood diversification strategy. However, those most vulnerable to climate variability are the poor who are less able to afford mobility and entry costs. This study adds to the literature by evaluating, in chapter 3, the impact of migration on household consumption expenditure, relative food expenditure share, dietary diversity, spending on agricultural inputs and adaptive capacity. The study used survey data collected from a representative sample of 653 households across three arid regions of Northern Namibia. The study employed a novel identification strategy in migration studies by combining the standard exogenous instruments and Lewbel's constructed instruments using heteroscedastic errors. The study found two-thirds of the sampled households to be migrant-sending households. Poverty and the lack of economic opportunities in the rural villages were the main push factors driving migration to towns and cities. Although tertiary education and technical training of the

migrants are key determinants of remittances received by migrant-sending households, over three quarters of the migrants were unskilled and very few having tertiary level training. Migrant-sending households had lower consumption spending and higher food budget share, suggesting relative deprivation. Although consumption spending increased with number of migrants, quality of human capital had greater impact on well-being. Migration had a positive impact on household's adaptive capacity but an inverse relationship between number of migrants and adaptation suggests failure of local adaptive strategies. The study finds households with migrants to have a significantly higher spending on agricultural inputs than those without migrants, with tractor-hire services for land preparation being a major component. The effect of family labour loss is somehow, through remittances, countervailed and compensated by mechanization. In conclusion, migration can potentially play a bigger role as an adaptive and risk-mitigation strategy in the face of climate variability, but poverty, lack of post-school skills training, and low transition to tertiary-level training are key barriers. Developing markets for credit, inputs and farm output, and preparing migrants for participation in labour markets and self-employment through training can further enhance the impact of migration and build resilience to climate shocks. Due to self-reinforcing poverty traps in poor households, the study recommends targeted public programs that support higher education and technical training.

Lastly, chapter 4 examined the role of climate information and early warning in decision-making among farming communities in rural Namibia. Improved climate forecasting has been heralded as an important risk management and mitigation tool in climate-sensitive economic sectors such as agriculture. However, Africa has not reaped the benefits of improved climate forecasting and empirical studies about its impact are scanty. Chapter 4 first discusses access to and utilization of climate information in farm decision-making, and then evaluates its impact on dietary diversity, food spending and adaptive capacity of the households using propensity score matching, with a sensitivity analysis for hidden bias.

Only half of the farmers had access to climate information and most of them relied primarily on traditional knowledge to make decisions on crop and livestock production. Many of the households without access to climate information also had little knowledge of alternative adaptive strategies. The likelihood of receiving climate information increased with the number of migrants per household, household size, social networks, trust and participation in community decision-making processes, but declined with age. Although male heads were more likely to receive climate information, females headed most of the households. The main sources of information for farmers were radios and peer learning. Respondents expressed a low level of trust in information from available channels and most of them rated the information received as insufficient for decision-making. Although 95% of households owned mobile phones, only 5% received information through them, indicating untapped opportunity of using an ICT platform to share information with farmers. Households with climate information had more diversified diets and significantly higher food spending. These households also engaged in more adaptive strategies, but the scale of adoption was small. Community empowerment through enhanced access to extension services, information on alternative adaptive choices, and the development of markets, rural communication and transport infrastructure are prerequisites to access to and effective utilization of improved climate forecast information for successful adaptation.

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I will start by drawing from the wisdom of our ancestors in this adage from Kikuyu land, “You never walk alone when you have a choice for a good company”. Indeed, I had great company of friends in this journey without whom this work would not have materialized. First, I am deeply indebted to my doctoral advisor Professor Martine Visser for her tireless guidance, support and great patience during the entire process of planning and executing the field research and the writing of this dissertation. I will forever be grateful for her encouragement, emotional and financial support when things got tough.

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I am grateful to Dr. Hugo De Groot for his encouragement and for giving me a space to work from during my vacations in Kenya and letting me use CIMMYT data to write one of the chapters.

Dedication

I dedicate this work to my mother Agnes, my wife Caroline and my children Janice and Vince

&

In loving memory of my late grandpa Elesban Kihuba

List of acronyms

ACDI:	African Climate Development Initiative
ADB:	African Development Bank
ASSAR	Adaptation at Scale in Semi-Arid Regions
ATE:	Average Treatment Effect
ATENT	Average Treatment Effect on the Non-treated
ATT:	Average Treatment Effect on the Treated
CCAFS	Climate Change, Agriculture and Food Security
CIMMYT	International Maize and Wheat Improvement Center
DMC:	Drought Monitoring Center
FAO:	The Food and Agriculture Organization of the United Nations
FAOSTAT	Database of the Food and Agricultural Organization of the United Nations
GHACOF:	Great Horn of Africa Climate Outlook Forum
GIS:	Geographic Information System
IOM:	International Organization for Migration
IPCC	Intergovernmental Panel on Climate Change
NAD:	Namibian Dollar
NCPB:	National Cereals and Produce Board
NMS:	National Meteorological Services
PPS:	Probability Proportionate to Size Sampling
PRESSAO:	PRÉvisions Saisonnières en Afrique de l'Ouest
PSU:	Primary Sampling Unit
RCOF:	Regional Climate Outlook Forums
SADC:	Southern African Development Community
UNEP:	The United Nations Environment Programme
WMO:	The World Meteorological Organization

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Chapter 1: Introduction, Motivation, Objectives and Data Sources

"We do not inherit the earth from our ancestors; we borrow it from our children." Anonymous

1.1 Background to the Research Problem and Motivation

Since the publication of the Intergovernmental Panel on Climate Change (IPCC) report by the Working Group II (WGII) on *Impacts, Adaptation, and Vulnerability* ([J. J. McCarthy et al., 2001](#)), it is now widely accepted that poor countries with the least capacity to adapt will bear the brunt of climate change impacts. Adaptive capacity with respect to climate risks is the ability of an individual, community or government to make adjustments or take actions that protect them from suffering losses or harm from the adverse effects of climate change ([Grothmann & Patt, 2005](#)). [Gallopín \(2006\)](#) extends this definition to include taking advantage of opportunities that might arise in the process of change. Effective adaptation, or what [Grothmann and Patt \(2005\)](#) refer to as *objective adaptive capacity*, depends on resource endowment, knowledge of adaptive technology options, existing regimes of property rights, and institutional and social support ([Adger et al., 2005](#)). [Gallopín \(2006\)](#) defines vulnerability as the susceptibility of a socio-ecological system to specific external disturbances. This dissertation operationalizes the term vulnerability to refer to the degree of exposure and sensitivity of the local communities' main livelihood activities to negative effects of climate variability and extreme events like droughts and floods. [Adger \(2000\)](#) gives a social definition of resilience as the ability of groups or communities to cope with exogenous shocks like political, social or environmental change. Resilience, in the context of this study, refers to the ability of a household or community to sustain or maintain their livelihoods following social, economic or climate shocks. Comprehensive definitions of and the linkages between vulnerability, resilience and adaptive capacity are discussed in detail in [Gallopín \(2006\)](#). This study defines adaptive capacity as the number of adaptation strategies used by a household to cope with effects of climate variability and extreme events like droughts. These were grouped in to five categories to include those related to crops, livestock, land management, water management and other off-farm strategies like starting small businesses or employment in non-farm sector.

Arid and semi-arid lands are home to slightly more than a third of the world's population and comprise over 40% of the earth's land surface ([Fraser et al., 2011](#)). One of the key features of semi-arid climates is rainfall variability and this variability is bound to increase with climate change, on both seasonal and decadal timescales. Droughts induced by climate change are likely to push the dryland ecosystems beyond their biophysical thresholds and lead to a long-term decline in agricultural productivity, ([Fraser et al., 2011](#)). We can expect climate change to increase vulnerability to socioeconomic and environmentally-related risks for societies dependent on natural resources that are sensitive to

climate variability ([Adger et al., 2003](#); [J. Barnett & Adger, 2007](#); [Conway & Schipper, 2011](#); [Davis, 2011](#); [McSweeney et al., 2010](#)).

Subsistence farming in developing countries where agricultural productivity is low would, in such a situation, become even more precarious a livelihood for many households already ravaged by food insecurity and poverty. Making options for adaptive technology more accessible to communities could increase their resilience and reduce their vulnerability to climate shocks. This dissertation explores three ways in which communities vulnerable to adverse climate-change impacts can improve their resilience and enhance their adaptive capacity. These include the use of improved adaptive seed technologies, migration and the effective use of climate information and early warning.

Chapter 2 evaluates how adoption of improved maize technology can reduce vulnerability and increase the resilience of rural communities to climatic and socioeconomic shocks through market participation and improved food security. [Olwande et al. \(2015\)](#) found low market participation among maize producers in Kenya and suggest that the use of production-enhancing inputs such as improved seed could increase marketed surplus. This chapter uses data from CIMMYT collected from all of Kenya's six agro-ecological zones. Past empirical work found that improved maize adoption had a positive impact on welfare outcomes, such as income, poverty and inequality reduction, and yields ([Kassie et al., 2014](#); [Mathenge et al., 2014](#); [Mwabu et al., 2007](#); [Nyangena & Juma, 2014](#); [Suri, 2011](#)). The present study will extend this evaluation to look at the effect of the intensification of maize production on market participation and food security across different agro ecological zones in Kenya.

The contribution of this chapter includes the empirical application of the Cerulli's ([2015](#)) dose-response model specification for continuous treatment to impact evaluation of improved agricultural technology adoption. The model developed by [Cerulli \(2016\)](#), unlike generalized propensity score matching proposed by [Keisuke. Hirano and Imbens \(2004\)](#), allows us to account for cases where subjects may react heterogeneously to observable confounders, treatment level is zero for many subjects in which case the normality assumption is violated and selection into treatment is endogenous. As maize is the main food staple in Kenya, I use detailed maize storage inventory from a previous complete production cycle to measure months of adequate food provisioning. This differs from previous approaches that used a subjective measure ([Kassie et al., 2014](#)). Based on the reviewed literature, this is the first time such a detailed storage inventory data is used to measure market participation and food security. The other important contribution in this chapter is illustrating the skewed nature of the improved seed adoption intensity by computing percentile shares of the quantity and area under improved seed. Such information is useful in planning resource allocation and formulating policy on food security. Thirdly, I evaluate the impact of improved maize adoption on market participation across six agro-ecological zones.

In addition to adaptive technologies, migration has been recognized as one of the strategies rural households can use to diversify their livelihoods in response to inherent agricultural risks occasioned by climate variability ([Barrios et al., 2006](#); [Boano & Morris, 2008](#); [Mendola, 2008](#)). Migration could be a survival strategy and in some cases the best pathway out of poverty for the rural poor population ([Awumbila & Ardayfio-Schandorf, 2008](#); [Hatlebakk, 2016](#)). Recent scholarly work has looked at migration, not only as a coping mechanism in response to climate and socioeconomic shocks, but also as a rural livelihood strategy for adapting to climate change ([Alem et al., 2016](#); [J. R. Barnett & Webber, 2010](#); [Karanja Ng'ang'a et al., 2016](#); [R. McLeman & Smit, 2006](#); [Tacoli, 2009](#); [Zeza et al., 2011](#)). Migration can also be a long-term diversification strategy in anticipation of future climate shocks ([Boano & Morris, 2008](#)).

Many studies consistently show that international migration through remittances has a positive impact of improving the wellbeing of the migrant-sending households left behind ([Richard H. Adams & Cuecuecha, 2013](#); [Gupta et al., 2009](#); [Mendola, 2008](#)). However, high mobility and entry cost could exclude poor vulnerable households from this type of migration ([R. Adams et al., 2008](#); [Mendola, 2008](#); [Wouterse, 2012](#)). The internal rural-urban low-return type migration has relatively low entry costs, but might not have a meaningful impact on the wellbeing of poor households ([Mendola, 2008](#); [Möllers & Meyer, 2014](#)).

The few empirical studies on the relationship between migration, welfare and climate change adaptation provide mixed findings. Although recent scholarly research has documented some positive impact of migration on the uptake of costly adaptive technologies ([Karanja Ng'ang'a et al., 2016](#)), and welfare ([Azzarri & Zeza, 2011](#); [Carletto et al., 2011](#); [De Brauw, 2011](#); [Mergo, 2016](#)), poor migrant households are likely to spend much of the remittance income on consumption smoothing. It is not immediately clear how migrants can support such costly investments given that many are themselves poor and usually live in informal settlements of urban areas ([Pendleton et al., 2014](#); [Dian Spear et al., 2015](#)). This conundrum points to a research gap that must be bridged if migration is to be a central focus of public policy.

Chapter 3 contributes to the existing literature on migration and climate change adaptation, in the context of Namibia, one of the driest countries in Sub-Saharan Africa. This chapter characterizes the migrants and the migration process and evaluates the impact of migration on wellbeing outcomes and the adaptive capacity of rural communities living in semiarid regions of central Northern Namibia. There are very few studies on migration in Namibia ([Mufune, 2011](#)). The first contribution of this study is the data on rural-urban migration spanning three administrative regions. Empirical survey data on migration is scanty and almost non-existent, with most studies on the subject using the qualitative case study approach. This is the first empirical study that evaluates the impact of migration on

wellbeing and the adaptive capacity of rural families in arid Namibia. Its other contribution is the use of an analytical approach through the application of the Lewbel's model of constructed instruments using heteroscedastic errors in addition to the standard exogenous instruments. The study will deepen current understanding of the role of migration as an adaptive and livelihood-diversification strategy among households most vulnerable to climate change.

Chapter 4 draws the reader's attention to the role of climate information as a tool for effective risk mitigation and improved resilience in communities dependent on agriculture. Many small-scale producers in developing countries still rely on out-of-date sources of information to make decisions ([Camacho & Conover, 2019](#)). It is now recognized that reliable and relevant climate information can be a useful tool for climate risk mitigation and planning in agriculture and other climate-sensitive sectors of the economy ([Fraisie et al., 2006](#); [Roudier et al., 2014](#); [Singh et al., 2018](#)). Recent scholarly work in sub-Saharan Africa shows that farmers in the continent can use climate information to reduce their vulnerability to droughts or take advantage of good weather expectation ([A. Patt et al., 2005](#); [Phillips et al., 2001](#); [Roncoli et al., 2008](#); [Roudier et al., 2014](#)). Climate forecasting and early warnings are very important for humanitarian and development organizations involved in disaster-risk reduction ([A. G. Patt et al., 2007](#)).

Following the first climate outlook forum in 1997 ([A. G. Patt et al., 2007](#)), climate forecasting has improved remarkably ([Tall et al., 2018](#)), but Africa has not been able to benefit from improved provision of climate services. Climate forecast information remains underutilized as a tool for climate-risk management and enhancing food security in southern Africa ([Vogel & O'Brien, 2006](#)). Many farmers in Africa do not even have access to this kind of climate information ([Luseno et al., 2003](#); [O'Brien et al., 2000](#)). The existing literature provides little insight on the level of access and use of climate information in Namibia despite its inhabitants' vulnerability to negative impacts of climate variability. Empirical data on the subject is also difficult to find. This chapter will look into access to climate information and its use for decision-making by farm families living in semi-arid regions of Northern Namibia. The chapter also presents evaluation results for the impact of climate information on food security and the adaptive capacity of these families.

1.2 Objectives

The overriding goal of this dissertation is to examine how to leverage improved seed technology, migration and climate information to increase the resilience and adaptive capacity of rural communities that are vulnerable to the negative effects of climate variability. There are three broad objectives, each of which is addressed in a standalone chapter.

The first objective is to evaluate the impact of improved maize seed technology on households' participation in the grain market and on food security across the agro-ecological zones of Kenya. Kenya has the most developed seed breeding programme and seed market in the region, with well adapted seeds for different agro-ecological zones ([H De Groote et al., 2015](#)). In spite of development of improved maize seed, maize yields have stagnated below 2t/ha ([Cairns et al., 2013](#)). Kenya is still grappling with food insecurity despite the relatively high adoption rate of improved maize seeds. This chapter also examines the distribution of adoption patterns by analyzing percentile shares of the quantities and areas planted with improved maize across households.

The second objective is to examine the role of migration as a livelihood diversification and adaptive strategy among rural families in the context of the dry lands of semi-arid North-central Namibia. Existing studies reveal rapid urbanization and growing urban poverty in Namibia, with most migrants living in sprawling informal settlements ([Tvedten, 2004](#)). Therefore, the ability of such migrants to finance adaptation back in their rural homes becomes an interesting conundrum. The communities in the study regions are vulnerable, owing to high rates of unemployment, the high percentage of the elderly in the population, and a high dependence on agriculture ([M. N. Angula & Kaundjua, 2016](#)). This gives rise to the second research question of whether such vulnerable households can trade-off long-term investments in adaptive strategies for short-term survival needs. This chapter will evaluate the impact of migration on consumption expenditure, relative food expenditure shares, dietary diversity, spending on agricultural inputs and adaptive capacity of rural households in context of semi-arid regions of Namibia.

The third objective evaluates access, use and impact of climate information among farm families in Namibia. Climate information has become a key climate risk mitigation and planning tool for farmers as well as humanitarian and development organization in disaster risk management. Despite the improvements in seasonal climate forecasting, access and integration of such information in farm production decisions remains low in many African countries. This study will specifically examine the degree of access and utilization of climate information in farm production decisions by farming families in Namibia. To understand fully the potential utilization of climate information in farming decisions, the study will assess the perceived importance, the need and possible use of such information in crop and livestock production decisions by households that have no access.

1.3 Data sources

To reach the first objective, the study uses cross-sectional data collected from a representative sample of 1344 households across six agro-ecological zones in Kenya. The survey was conducted in 2013 by CIMMYT with sub-location, the smallest administrative unit, as the primary sampling unit. The required number of PSUs per agro-ecological zone was selected with probability proportionate to size sampling. The data include detailed information on the types of maize varieties grown, areas allocated for both improved and local varieties, production and marketing. The data also contains a detailed maize storage and consumption inventory from the month the family put maize in storage up to the time when they took out the last batch. Chapter 2 presents a detailed description and summary statistics of the dependent, independent and outcome variables used in the analysis.

For objectives two and three, the study used survey data collected from a representative sample of 653 rural households in arid regions of Northern Namibia. A multistage sampling procedure was used to generate a self-weighted probabilistic sample with the village as the primary sampling unit. The survey was conducted between July and September 2017 and covered three regions of North Namibia namely Omusati, Oshana and Oshikoto. Chapters 3 and 4 will further describe and summarize the key variables used in the analysis.

1.4 Organization of the dissertation

The remainder of this dissertation is organized into three chapters drawn from the above three objectives. Chapter 2 evaluates the impact of improved maize seed technology on rural households' wellbeing through market participation and food security across the major agro ecological zones in Kenya. Chapter 3 evaluates the impact of migration on household wellbeing and adaptive capacity. Chapter 4 gives insights into the level of access, utilization and impact of climate information among the farm families in Namibia. Chapter 5 synthesizes the results, offers policy implications, and suggests areas for further research.

Chapter 2: Impact of Improved Adaptive Maize Technology on Market Participation and Food Security

Abstract

This chapter used a representative sample of 1344 farm households selected across the six agro-ecological zones in Kenya to evaluate the impact of improved maize varieties on food security and market participation. A control function approach with multilevel dose-response model specification was used. Results show high adoption of improved seed even though most households produced for subsistence. The top quintile of households accounted for 63% of the quantity of improved seed purchased, and 65% of the area planted with it. The bottom two quintiles only accounted for six percent of the quantity purchased and five percent of the area planted with improved seed. The marketed share of total maize produce was about twelve percentage points higher for the adopters than for the non-adopters. This increased with the level of adoption, though at a decreasing rate. Adopting households were less vulnerable to food insecurity and stored maize for three months longer than non-adopters. Households store for consumption smoothing and temporal price arbitrage. Larger families participated less in the market, stored maize for shorter duration and were less food secure. Wealth and education are other key determinants of food security and market participation. To address the food insecurity problem in Kenya, results indicate a need for a paradigm shift in policy. The state could promote food self-sufficiency or high value crop cultivation for small farms and enhance largescale production by main producers for national strategic reserves. There is also a need for postharvest policies that promote safe on-farm grain handling and storage.

Key words: Food security, improved maize, market participation, Kenya, dose-response

2.1 Background

The goal of eradicating hunger and reducing the global nutritional and food insecurity by half was set three decades ago during the FAO World Food Summit in 1996 ([Shetty, 2006](#)). Food insecurity, however, remains a global challenge with over 795 million people undernourished, most of them in developing countries ([FAO et al., 2015](#)). While many developing regions such as Central Asia, Eastern Asia, Latin America and Northern Africa have made considerable progress in addressing food insecurity, Southern Asia and Sub Saharan Africa remain problem areas. East Africa suffers from chronic food insecurity and it is one of the most food insecure regions with 62 million people aged 15 years and above facing extreme food shortages and malnutrition ([Coughlan de Perez et al., 2019](#); [FAO, 2017a](#); [UNEP, 2011](#)). Africa has clearly missed the 1996 World Food Summit goal of eradicating hunger and reducing the number of undernourished people to half by 2015 ([FAO et al., 2015](#); [Sasson, 2012](#)).

Some of the past main challenges to hunger reduction include higher food and energy prices, increasing climate variability and frequency of extreme weather events, rising unemployment and the 1997-99 and 2008 economic recessions ([Dawe et al., 2015](#)). Gains made towards reducing hunger and malnutrition in Sub Saharan Africa have often been reversed by adverse climatic conditions, especially those related to the El Niño phenomenon ([FAO, 2017b](#); [Wheeler & von Braun, 2013](#)). Rural families in arid and semi-arid regions will find it difficult to meet their own food needs as subsistence farming become increasingly less viable livelihood option due to increasing frequencies and intensity of dry conditions. To achieve global food security amidst the challenges of climate change, [Reynolds et al. \(2016\)](#) recommend the development of stress tolerant cultivars that have high genetic¹ yield potential by exploiting existing genetic variability through breeding.

Wheat, rice, maize, pearl millet, and sorghum contribute over half of the food calories consumed in least developed countries and 45% globally ([FAO, 2016](#); [Reynolds et al., 2016](#)). These cereals constitute important food staples and have obvious food security implications in many developing countries. With increasing populations, competition for land, water and energy and rising food demand, meeting the food needs without adversely affecting the production systems and ecosystem services will be a great challenge ([Godfray et al., 2010](#); [P. Smith, 2013](#)). [P. Smith \(2013\)](#), notes that sustainable intensification through increasing production per unit of available land and reducing food wastage can be one way of managing food demand. Effective use of improved modern grain storage technologies reduce food waste, reduce food insecurity, smooth consumption and increase market

¹ [Evans and Fischer \(1999\)](#) define genetic yield potential as the yield of a cultivar when grown in the environment to which it is well adapted with adequate nutrients and water while controlling stress factors like pests, weeds and diseases.

participation by small producers while taking advantage of temporal price arbitrage ([Gitonga et al., 2013a](#)).

Maize breeding programs in Kenya are considered a major success story in the region ([Mathenge et al., 2014](#); [Olwande & Smale, 2012](#)). The programs resulted in many popular improved maize varieties, mostly hybrids, released specifically for different zones over the years. This however, has not been matched by an increase in maize yields ([Faostat, 2016](#)). Even though production has increased over time, yields have stagnated below two tons per hectare indicating an expansion of area cultivated rather than an increase in productivity (Figure 2-1).

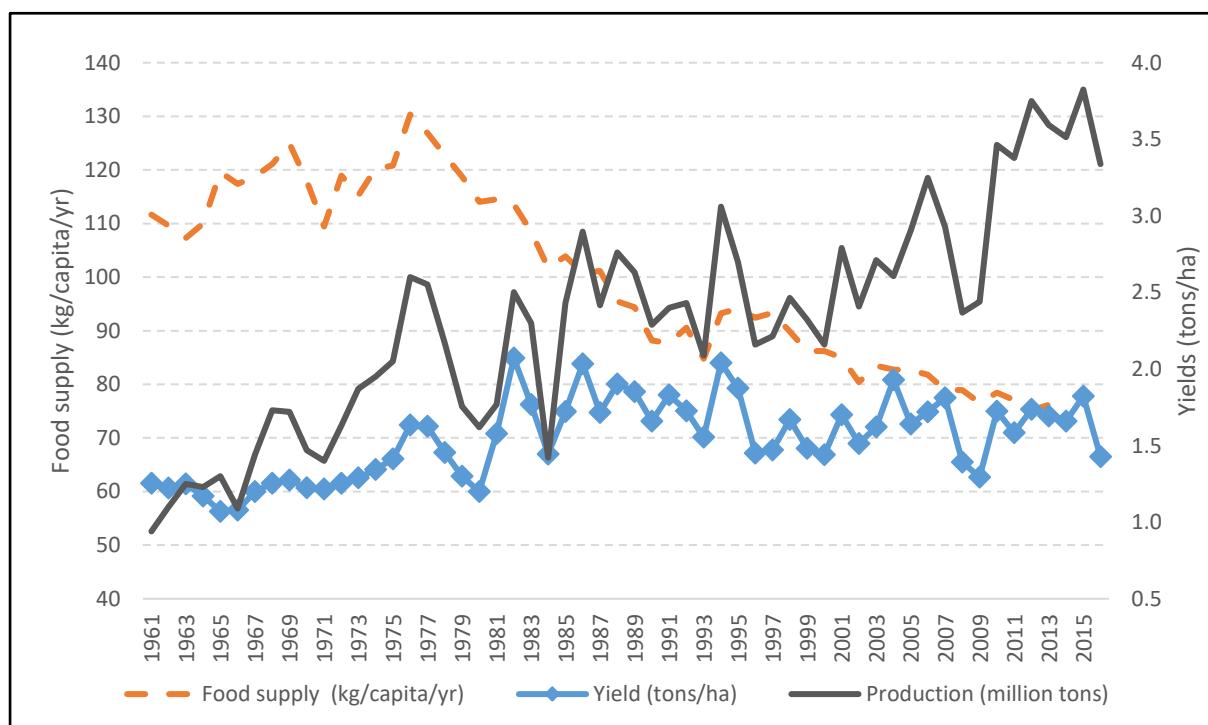


Figure 2-1: Kenya's Maize yields (t/ha) and Food Supply Quantity (kg/capita/yr) (Source: by author using FAOSTAT 2018 data).

With an ever-increasing population and yield stagnation, consumption is outpacing food production, resulting in declining consumption per capita from 130kg/person/year three decades ago to only 76 kg/capita/year in 2013. As a result, Kenya has been a net importer of maize since 1991 (Figure 2-2).

Kenya's average annual maize production over the last decade has been about 2.9 million tons but maize consumption is much higher at 3.9 million tons ([Faostat, 2016](#)). The need to find solutions to these food insecurity problems makes understanding the adoption patterns of improved maize seed technology and its impact on livelihoods of rural households more compelling. Previous studies in Kenya found a positive impact of adoption of maize hybrids on welfare outcomes such as income, poverty, and inequality ([Becerril & Abdulai, 2009](#); [Khonje et al., 2015](#); [Mathenge et al., 2014](#); [Mwabu](#)

[et al., 2007](#)). While [Suri \(2011\)](#) evaluated the relationship between hybrid maize adoption and yields in Kenya; [Nyangena and Juma \(2014\)](#) looked at the impact of joint adoption of improved maize seed and fertilizer on yields. As expected, both studies found a positive impact of improved seeds on yield. In Tanzania, [Kassie et al. \(2014\)](#) found a positive impact of improved maize varieties on farm household's own subjective evaluation of food security. In this chapter, the study focusses on the effect of intensified maize production through improved seed on market participation and food security in Kenya.

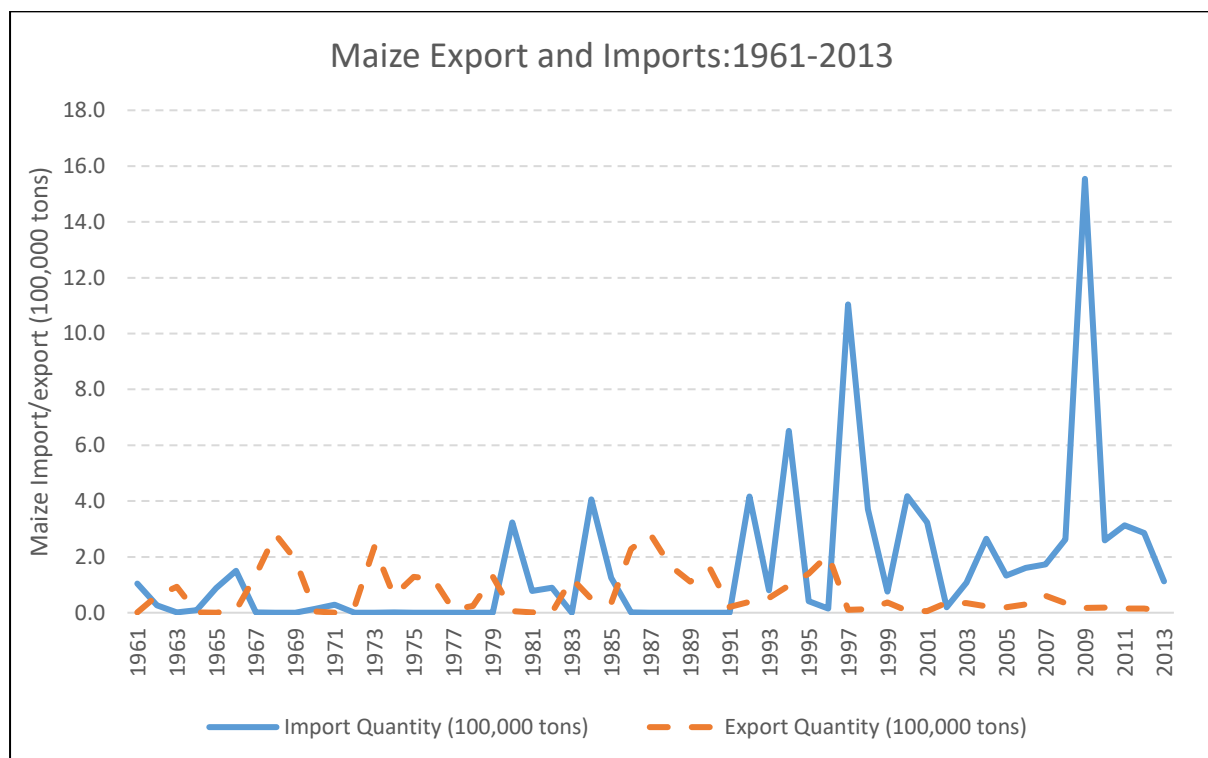


Figure 2-2: Kenya's maize import/export: 1961-2013 (Source: by author using FAOSTAT 2018 data)

The first contribution of this chapter is the use of detailed month-by-month maize storage inventory to measure market participation and food security. The study uses a detailed inventory of the previous completed maize storage cycle to measure months of adequate food provisioning. Maize is the main food staple in Kenya, and households consider themselves food insecure if they do not have access to it. This is the first study to use such detailed storage inventory data to measure consumption and sales as a food security proxy. The second contribution is the empirical application of the Cerulli's (2015) dose-response model specification for continuous treatment under treatment endogeneity to impact evaluation of improved agricultural technology adoption. The model, unlike generalized propensity score matching proposed by [Keisuke, Hirano and Imbens \(2004\)](#), allows for both control function estimation by OLS for an exogenous treatment and an IV specification when the treatment is endogenous. This chapter also highlights the uneven adoption of improved seed across households

and discuss its importance in planning resource allocation and formulating policy on food security. Finally, the impact of improved maize on market participation across six agro-ecological zones is evaluated.

2.2 Literature review on technology adoption and impact evaluation

2.2.1 Overview

The definition of farm level technology adoption by [Feder et al. \(1985\)](#) presupposes the existence of a long-run equilibrium when farmers have learnt about the technology and have full information about it and its potential. However, even technologies with ambiguous returns can diffuse rapidly, due to 'bandwagon pressure' where entities take up innovations to keep up with the rest or not to miss out on perceived future benefits ([Abrahamson & Rosenkopf, 1993](#); [Sneddon et al., 2011](#)). Returns to investment in technology are dynamic because of changes in market prices as more people adopt the technology, and therefore it is difficult to know its full potential beforehand. The other reason why it is difficult to predict perfectly the full potential of a given agricultural technology is the inherent uncertainty and risky nature of agriculture under the rain-fed conditions that prevail in most African countries. The long-run equilibrium envisaged by [Feder et al. \(1985\)](#) is not tenable because potential adopters rarely have the necessary level of awareness and information about its full impacts when making an adoption decision ([Dimara & Skuras, 2003](#)).

Adoption of agricultural technology in developing countries has, since the seminal work of [Griliches \(1957\)](#) attracted a lot of attention among agricultural and development economists. [Besley and Case \(1993\)](#) suggest that this is because technology adoption and diffusion has often been viewed as a viable pathway out of poverty for many rural families. Given the ever-increasing demands of the global population, adaptation to climate change, and man's inherent drive to innovate, changes in agricultural technology and their impacts are likely to continue drawing attention.

Earlier studies on the subject focused on identifying drivers and barriers to the rapid uptake and diffusion of new innovations, whilst subsequent interventions aimed at addressing these constraints, often with only partial success ([Doss, 2006](#); [Feder et al., 1985](#)). [Dimara and Skuras \(2003\)](#) noted that many earlier economic studies on adoption of agricultural technologies had modelled the adoption decision as single-stage binary dummy, categorizing subjects into adopters and non-adopters, ignoring the fact that adoption is often a multistage process. Analysis has evolved over time from simple descriptive statistics on technology uptake and diffusion to more complex issues about the multistage process of adoption and technology impact on welfare outcomes and environment ([Doss, 2006](#)). More recently there has been a shift towards field experiments to establish how risk behaviour and time

preference among farmers affect attitudes towards insurance, credit market and technology uptake ([Beaman et al., 2018](#); [Brick & Visser, 2015](#); [Cole et al., 2013](#); [Duflo et al., 2008, 2011](#); [Giné & Yang, 2009](#); [Liu, 2012](#); [Visser et al., 2019](#)).

2.2.2 Past approaches to impact evaluation studies of agricultural technologies

Most evaluations of new agricultural technologies fall into one of two broad categories: randomized social experiments and non-experimental observational studies. A detailed discussion of the non-experimental approaches has been provided in [Blundell and Costa Dias \(2000\)](#).

Amongst experimental approaches, RCTs are considered ‘the gold standard’ because of their ability to deal with self-selection and identification problems through a good randomization design. However, experiments can be very expensive and often present ethical and external validity concerns ([de Janvry et al., 2011](#)). Experimental studies risk the Hawthorn effect - subjects behaving differently when they know they are being watched ([McCarney et al., 2007](#)). On the other hand, non-experimental approaches applied to observational data suffer from the missing data problem. This is because individuals can only assume one treatment assignment status at a time. Following the potential outcomes framework by [Rubin \(1974\)](#), the treatment effect, TE , can be defined as

$$TE = Y_{it}(t = 1) - Y_{ic}(t = 0) \quad (1)$$

Where t (treatment status) equals one if the individual is treated and zero otherwise. Y_{it} is the outcome of an individual when assigned to treatment and Y_{ic} represents the potential outcome of the same individual when assigned to the control group. The problem is that we can only observe one potential outcome ([Duflo et al., 2007](#)), what [Holland \(1986\)](#) refers to as the *fundamental problem of causal inference*. One way to overcome this problem is to randomly assign subjects to each experimental group. The distribution of impacts over subjects in the two groups can then be used to estimate average treatment effect (ATE), in the population ([J. J. Heckman & Smith, 1995](#)).

$$ATE = E(Y_{it} - Y_{ic}|t = 1) + E \left\{ \underbrace{(Y_{ic}|t = 1) - (Y_{ic}|t = 0)}_{\text{selection bias}} \right\} \quad (2)$$

$(Y_{ic}|t = 1)$ represents the unobserved potential outcome the untreated subject would have realized had he or she been treated. Random assignment of treatment would eliminate selection bias by ensuring that there are no systematic differences between the treated and control groups. Unfortunately, this cannot always be achieved in applied empirical work. In most cases, the decision to adopt a technology or to participate in an intervention is voluntary and individual. The resulting selection bias means that a naïve *before-and-after analysis*, which compares the same group over time, or a *with-and-without analysis*, that compares two groups at the same time, cannot be presumed to give reliable estimates of the treatment effect.

A *before-after* approach assumes that the outcomes are insensitive to any external shocks and time trends in the economy during the program implementation, while the *with-without* method assumes that potential outcomes are independent of the study subjects' treatment assignment status ([ADB, 2011](#); [Guido W Imbens & Wooldridge, 2009](#)). The last three decades has seen an upsurge of work on developing impact evaluation techniques that establish proper counterfactual groups and reduce selection bias. Since the seminal work of [LaLonde \(1986\)](#) that compared performance of non-experimental impact evaluation methods against the randomized experiment design, there has been remarkable improvement and development of estimation techniques for non-experimental data in socioeconomic research. These include double difference for longitudinal data, regression discontinuity, instrumental variables, Heckman selection models, endogenous switching regressions, and matching models. The quality and quantity of household data has improved significantly as has the application of these methods as analytical tools in development economics ([de Janvry et al., 2011](#); [Guido W Imbens & Wooldridge, 2009](#)). [White and Raitzer \(2017\)](#) give a good description of the necessary preparations and steps to obtain high quality data for impact evaluation. [Heckman and Smith \(1995\)](#) make the point that Holland's 1986 critique of non-experimental methods was more of a data quality issue than the weakness of the methodologies per se. [J. Heckman et al. \(1998\)](#) show that with good quality data and the right evaluation technique, one can create a counterfactual with outcomes very close to those of a control group in experimental settings. For example, [D. S. Lee \(2008\)](#) demonstrate that causal-inference from regression discontinuity can be as credible as a randomized experiment. These methodologies have been extended to accommodate cases where the treatment variable takes continuous form ([Bia & Mattei, 2008](#); [Egger & Von Ehrlich, 2013](#); [Keisuke. Hirano & Imbens, 2004](#); [Guido W. Imbens, 2000](#)) and categorical or endogenous form ([Guido W. Imbens, 2000](#); [Joffe & Rosenbaum, 1999](#)). Recently [Cerulli \(2016\)](#) proposed a model for cases where the treatment assignment depends on random shocks and when the treatment effect is heterogeneous across treated subjects. The following section gives a brief overview of how econometric techniques for impact evaluation has evolved to accommodate wide range of treatment variables including endogenous treatment variables.

2.2.3 Modelling causal effects in cross sectional data with continuous treatment

The current study uses cross sectional data with a continuous treatment variable for impact evaluation. The propensity score method developed by [P. R. Rosenbaum and D. B. Rubin \(1983\)](#) has long been used to estimate causal inference in cross-sectional studies, as it reduces the self-selection bias that arises from non-random treatment assignment. An extension of the propensity score matching for categorical treatment variables was proposed by [Guido W. Imbens \(2000\)](#) while [Joffe](#)

[and Rosenbaum \(1999\)](#) developed an extension of the impact technique for an ordinal treatment variable.

The dose-response approach for a continuous treatment variable proposed by [Imai and Van Dyk \(2004\)](#) and [Keisuke. Hirano and Imbens \(2004\)](#) assume in the first stage that the treatment (T) is distributed as normal conditional on covariates. This assumption may not hold in cases where there are many subjects with zero treatment (t=0), like the non-adopters in this case. Area under improved seed is a common measure of adoption level ([Bezu et al., 2014](#); [Kassie et al., 2014](#); [Shiferaw et al., 2014](#); [Verkaart et al., 2017](#)). Other studies used kilograms of improved seed rather than the area to measure adoption intensity ([Mathenge et al., 2014](#); [Smale & Mason, 2014](#)). In this chapter, the quantities of improved seed and the area planted are both used to proxy the intensity of adoption. It is argued that, a priori, the coefficients of both adoption intensity proxies in the outcome equation should not be very different unless there are major measurement errors.

Following [Cerulli \(2015\)](#), this study uses a model that allows for two dose-response estimation procedures: using a control function regression that is estimated by OLS and an IV estimation by Heckman bivariate selection model and 2SLS to account for treatment endogeneity. This model, unlike other dose-response models like the generalized propensity score proposed by [Keisuke. Hirano and Imbens \(2004\)](#), does not require the treatment variable to be normally distributed for a given vector of covariates i.e. $(T_i|X_i) \sim N(\beta_i X_i, \sigma^2)$. The dose response function is estimated by a third-degree polynomial approximation. If the conditional mean independence assumption holds, OLS can consistently estimate the average treatment effect (ATE) and dose response function. This means that the both the treatment assignment and treatment level are exogenous in ATE estimation equation as in [Cerulli \(2015\)](#). For the endogenous treatment estimation, an instrument variable approach is implemented in two stages. In the first stage, we use a Heckman bivariate selection model of the binary treatment assignment and level of treatment variables. Stage 2 involves use of a 2SLS estimation for the outcome equation. This chapter presents results from both the OLS and IV estimations for robustness check.

2.3 Conceptual framework and empirical model

2.3.1 Conceptual framework

A household's decision to adopt improved maize is a two-stage process where in the first stage the household decides whether to adopt the technology, often referred to as the participation decision in impact evaluation literature. If the household decides to adopt, the second hurdle is determining the adoption intensity (amount of improved seed to purchase or amount of land to allocate to improved seed). The adoption decision can be modelled using random utility theory ([Adesina & Zinnah, 1993](#)). Let U_a denote the expected utility the household derives from adopting an improved variety and U_{Na} be its expected utility before adoption or opportunity cost of adopting, and $w_i \in (0,1)$ be a binary treatment assignment indicator variable taking a value of one if a household adopts improved maize and zero otherwise. w_i^* is an unobservable latent random variable indicating net benefit of adoption. The household adopts the improved maize if $w_i^* = U_a - U_{Na} > 0$ in which case the dummy variable w_i is observed.

$$w_i = \begin{cases} 1 & \text{if } w_i^* > 0 \\ 0 & \text{if } w_i^* \leq 0 \end{cases} \quad (3)$$

Since U_a and U_{Na} are unobserved, the latent model (see eq. 4) can be expressed as a function of a vector of observable covariates \mathbf{X}_{wi} that influence the adoption decision for household i . These include the individual-specific, farm-level, household and institutional characteristics discussed in detail in section 2.5. The random error term ε_{wi} is assumed to be distributed normally and equation 4 is estimated using a probit model.

$$w_i^* = \mathbf{X}_{wi}\beta + \varepsilon_{wi} \quad (4)$$

The second hurdle for household i is deciding the quantity of improved seed t_i to purchase. This component is also partially observed due to self-selection

$$t_i = \begin{cases} t_i^* & \text{if } w_i = 1 \\ 0 & \text{if } w_i = 0 \end{cases} \quad (5)$$

t_i^* is fully observed only when $w_i = 1$ and its reduced form is given as

$$t_i^* = \mathbf{X}_{ti}\beta + \varepsilon_{ti} \quad (6)$$

where \mathbf{X}_{ti} represents a vector of explanatory variables that affect the decision about the intensity of adoption.

2.3.2 Econometric approach

To reiterate, the analytical framework presented in this section is an adapted real data application of the model proposed by [Cerulli \(2016\)](#). Consider two potential outcomes: $y_1 = outcome$ when the subject is in the treated state and $y_0 = outcome$ when the same subject is not treated; \mathbf{X} = vector of exogenous covariates and w is a binary variable showing treatment assignment status (1=treated, 0=control), t is the continuous non-negative treatment level variable, then:

$$\begin{cases} w = 1 \text{ if treatment } t > 0 \\ w = 0 \text{ if treatment } t = 0 \end{cases} \quad (7)$$

Taking the treatment intensity as either the quantity of improved seed adopted, or the area allocated to improved maize, equation 8 shows the parametric model estimation for each of the two-treatment status.

$$\begin{cases} w = 1 \Rightarrow y_1 = \alpha_1 + \mathbf{X}\boldsymbol{\beta}_1 + h(t) + e_1 \\ w = 0 \Rightarrow y_0 = \alpha_0 + \mathbf{X}\boldsymbol{\beta}_0 + e_0 \end{cases} \quad (8)$$

Where $h(t)$ represents a response function to treatment level t . α_0 , α_1 and $\boldsymbol{\beta}$ are parameters to be estimated; e_1 and e_0 are random errors assumed to be homoscedastic with a mean of zero. The population average treatment effect (ATE) conditional on confounders \mathbf{X} and treatment level t becomes:

$$ATE(\mathbf{X}; t) = E[Y_1 - Y_0 | \mathbf{X}, t] = \begin{cases} (\alpha_1 - \alpha_0) + \mathbf{X}(\boldsymbol{\beta}_1 - \boldsymbol{\beta}_0) + h(t) & \text{if } t > 0 \\ (\alpha_1 - \alpha_0) + \mathbf{X}(\boldsymbol{\beta}_1 - \boldsymbol{\beta}_0) & \text{if } t = 0 \end{cases} \quad (9)$$

By letting $(\alpha_1 - \alpha_0) = \alpha$ and $(\boldsymbol{\beta}_1 - \boldsymbol{\beta}_0) = \boldsymbol{\beta}$, the conditional average treatment effect can be given as

$$ATE(\mathbf{X}; w, t) = w[\alpha + \boldsymbol{\beta}\mathbf{X}_t + h(t)] + (1 - w)[\alpha + \boldsymbol{\beta}\mathbf{X}_0] \quad (10)$$

\mathbf{X}_t here denotes \mathbf{X} values for $t > 0$ and \mathbf{X}_0 for $t = 0$

By the law of iterated expectation, the unconditional $ATE = E_{(x,t)}\{ATE(\mathbf{X}; w, t)\}$ and hence taking expectation of eq.10 over \mathbf{X} and t yields:

$$ATE = P(w = 1) \underbrace{[\alpha + \boldsymbol{\beta}\bar{\mathbf{X}}_t + \bar{h}]}_{ATT} + P(w = 0) \underbrace{[\alpha + \boldsymbol{\beta}\bar{\mathbf{X}}_0]}_{ATE_{NT}} \quad (11)$$

where $P(\cdot)$ denotes the probability of treatment assignment and $\bar{h}(t)$ the average of the response function taken over the positive values of treatment level t . ATT is the average treatment effect on

the treated while ATE_{NT} is the effect the treatment would have had on the non-adopters of improved seed had they adopted. By algebraic manipulation² of equation 10:

$$ATE(\mathbf{X}; w, t) = w[\alpha + \beta\bar{X} + \bar{h} + \beta(\mathbf{X} - \bar{X}) + (h(t) - \bar{h})] + (1 - w)[\alpha + \beta\bar{X} + \beta(\mathbf{X} - \bar{X})] \quad (12)$$

By using the law of iterated expectation, the dose response can be defined by averaging equation [12] over \mathbf{X}

$$ATE(\mathbf{X}; w, t) = w[ATT + (h(t) - \bar{h})] + (1 - w)[ATE_{NT}] \quad (13)$$

ATT is presented in our regression as the coefficient on the dummy of the treatment assignment while the dose response which in this case is a function of adoption intensity $(h(t) - \bar{h})$, is given by coefficient on t_{1w}, t_{2w}, t_{3w} , where

$$t_{1w} = (h(t) - E(t)), \quad t_{2w} = (h(t) - E(t^2)) \text{ and } t_{3w} = (h(t) - E(t^3))$$

2.3.3 Empirical framework

2.3.3.1 Estimation under exogenous treatment assumption and conditional mean assumption

Following [Rubin \(2005\)](#), the potential outcome framework of estimating causal inference, $y_i = y_{0i} + (y_{1i} - y_{0i})$, the regression equation can be specified using a random coefficient model as follows:

$$(y_i | \mathbf{X}_i; w_i, t_i) = \alpha_0 + \mathbf{X}_i \boldsymbol{\beta}_0 + w_i (\alpha + \beta\bar{X} + \bar{h} + \beta(\mathbf{X}_i - \bar{X}) + (h(t_i) - \bar{h})) + \eta_i \quad (14)$$

Where $\eta_i = e_{0i} + w(e_{1i} - e_{0i})$. Under the conditional mean independence assumption, that is;

$$E(y_{ij} | \mathbf{X}_i; w_i, t_i) = E(y_{ij} | \mathbf{X}_i) \text{ with } j = \{0, 1\} \text{ and exogeneity assumption of } w \text{ and } t, \text{ i.e.}$$

$$E(\eta_i | \mathbf{X}_i; w_i, t_i) = E(e_{0i} + w(e_{1i} - e_{0i}) | \mathbf{X}_i; w_i, t_i) = 0;$$

parameters $\alpha_0, \alpha_1, \boldsymbol{\beta}_0, \boldsymbol{\beta}_1$ and ATEs can consistently be estimated using control function regression estimated by ordinary least squares.

$$E(y_i | \mathbf{X}_i; w_i, t_i) = \alpha_0 + \mathbf{X}_i \boldsymbol{\beta}_0 + w_i ATE + w_i \beta(\mathbf{X}_i - \bar{X}) + \gamma_1 t_{1w_i} + \gamma_2 t_{2w_i} + \gamma_3 t_{3w_i} \quad (15)$$

The dose response function (additional benefit from adopting an extra unit of improved seed or allocation of an additional acre of land to improved maize seed cultivation) is estimated using the consistent parameters from eq. (15), as

$$\widehat{ATE}(t) = w \left[\widehat{ATT} + \hat{\gamma}_1 (t_i - E(t)) + \hat{\gamma}_2 (t_i^2 - E(t^2)) + \hat{\gamma}_3 (t_i^3 - E(t^3)) \right] \quad (16)$$

² Adding and subtracting $\beta\bar{X}_t + \bar{h}$ and $\beta\bar{X}_0$ on the first and second expressions respectively on the RHS of [10] and then rearranging.

2.3.3.2 Estimation with endogenous treatment

Under the assumption that the adoption decision and hence the treatment level variables are endogenous in the outcome estimation equation,

$E(\eta_i | \mathbf{X}_i; w_i, t_i) = E(e_{0i} + w(e_{1i} - e_{0i}) | \mathbf{X}_i; w_i, t_i) \neq 0$ and thus, the OLS estimates are biased and no longer consistent. When the error term in the outcome regression equation changes with change in the treatment assignment status or level of treatment, due to unobserved heterogeneity or measurement errors, it becomes difficult to attribute changes in outcome to the adoption decision.

$$y_i = \alpha_0 + \mathbf{X}_i \boldsymbol{\beta}_0 + w_i ATE + w_i \boldsymbol{\beta} (\mathbf{X}_i - \bar{\mathbf{X}}) + \gamma_1 t_{1w_i} + \gamma_2 t_{2w_i} + \gamma_3 t_{3w_i} + \eta_i \quad (17)$$

$$w^* = \mathbf{X}_w \boldsymbol{\delta} + \varepsilon_w \quad (18)$$

$$t^* = \mathbf{X}_t \boldsymbol{\delta} + \varepsilon_t \quad (19)$$

Note that $\mathbf{X}_w = [\mathbf{X}, \mathbf{Z}_w]$ and $\mathbf{X}_t = [\mathbf{X}, \mathbf{Z}_t]$. \mathbf{Z}_w and \mathbf{Z}_t are vectors of instruments for w^* (adoption decision) and t^* (treatment level) variables. The instruments are directly strongly correlated with adoption decision and the adoption intensity, but directly uncorrelated with either food security or market participation (outcomes). t^* is the treatment intensity measured as quantity (kg) of improved seed planted and the area allocation to improved seed cultivation.

The errors in equations [18] and [19] are assumed to have a joint normality with mean zero and a constant variance (homoscedastic).

$$\begin{pmatrix} \varepsilon_w \\ \varepsilon_t \end{pmatrix} \sim N \left[\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \sigma_w^2 & \sigma_{w,t} \\ \sigma_{w,t} & \sigma_t^2 \end{pmatrix} \right] \quad (20)$$

The analysis begins by jointly estimating equations (18) and (19) using a type-II tobit model to get the predicted values of w and t i.e. \hat{w}_p and \hat{t}_p . The predicted values are then used to estimate (21) using 2SLS to give consistent estimators of $\alpha_0, ATE, \boldsymbol{\beta}_0, \boldsymbol{\beta}, \gamma_1, \gamma_2$ and γ_3

$$(y | \mathbf{X}; w, t) = \alpha_0 + \mathbf{X} \boldsymbol{\beta}_0 + \hat{w}_p ATE + \hat{w}_p \boldsymbol{\beta} (\mathbf{X} - \bar{\mathbf{X}}) + \gamma_1 \hat{t}_{1pw} + \gamma_2 \hat{t}_{2pw} + \gamma_3 \hat{t}_{3pw} + \eta \quad (21)$$

This analysis used past exposure to climate shocks as instruments, for the decision to adopt improved maize and level of adoption. Farmers who have experienced such shocks in the past are likely to make adjustments including taking up adaptive technologies like improved seeds to minimize future risks from similar shocks. Past shocks are unlikely to affect the current outcomes directly except through such adjustments as adopting improved seeds. However, persistent shocks such as recurrent droughts, might indeed affect current outcomes such as food security, but this was not the case for

this study. The 2011 drought that affected the entire East African region was followed by good rains in 2012, which improved the harvest.

2.3.3.3 Test for endogeneity of treatment

Following [Davidson and MacKinnon \(1993\)](#) a Durbin-Wu-Hausman augmented regression is used to test for endogeneity (see Table 5-1 appendix 1). This involves first obtaining the residuals of the adoption decision indicator, w , as a function of the other exogenous explanatory variables

$$w = X_1\beta + \varepsilon_w \quad (22)$$

these residuals are then included in the regression of the outcome equation

$$y = \beta_0 + \beta_1w + \beta_2X + \beta_3w_{residuals} + \varepsilon \quad (23)$$

The adoption decision is endogenous if the coefficient β_3 is significant, in which case an IV specification is used. In the current case, the coefficient β_3 was not significant and therefore there is no evidence of endogeneity. The issue of self-selection is not a big issue in improved maize seed adoption due to good network of agro-dealers across the country, flexible seed packaging and the evolution of mobile money services that allows for easy transfer of cash for those working in distant towns to their rural families for improved seed purchases. The platform also allows family members living in urban areas to make payments directly to agro-dealers, who stock agricultural inputs. Farmers can also access several mobile phone-based credit facilities if they wanted to.

Furthermore, if we take X_{hro} to be some exogenous variables contained in X vector that are interacted with the treatment indicator w (i.e. heterogenous response) and ensuring that $X_{hro} \in X$, this restriction identifies the model parameters without the need for any additional instruments. This restriction is captured as the heterogeneous response to confounders ($w(X - \bar{X})\beta$) in estimation of equation [15] ([Baum & Cerulli, 2016](#)). However, the model would be less efficient than the IV model with standard excluded instruments.

2.4 Sampling design and data collection

A household survey, designed to cover all major maize growing zones in Kenya, was conducted in the 2012/2013 season (Figure 2-3). The survey used the same stratified two-stage sampling design as a previous household survey conducted in 2010 ([H. De Groote et al., 2016](#)) with maize production zones as strata. The sampling frame of sub-locations and their number of households was based on the 2009 census and was obtained from the Kenya National Bureau of Statistics ([KNBS, 2010](#)). This was followed by grouping of sub-locations into their respective maize production zones. The number of primary sampling units (PSUs) selected in each zone was set using probability proportionate to size sampling,

such that a fixed number of households per sub-location would provide a self-weighted sample. The resulting number of PSUs per zone varied from 15 at the coast to 30 in the moist transitional zones. A list of all households in each of the selected PSUs was established from which 12 households were randomly selected. For budgetary reasons, only six households were selected per sub-location in the lowlands, where maize is a less important crop. In total, the survey covered 1,344 households. The data were collected from October 2012 to February 2013 by 18 enumerators in three teams, each with a supervisor for quality control.

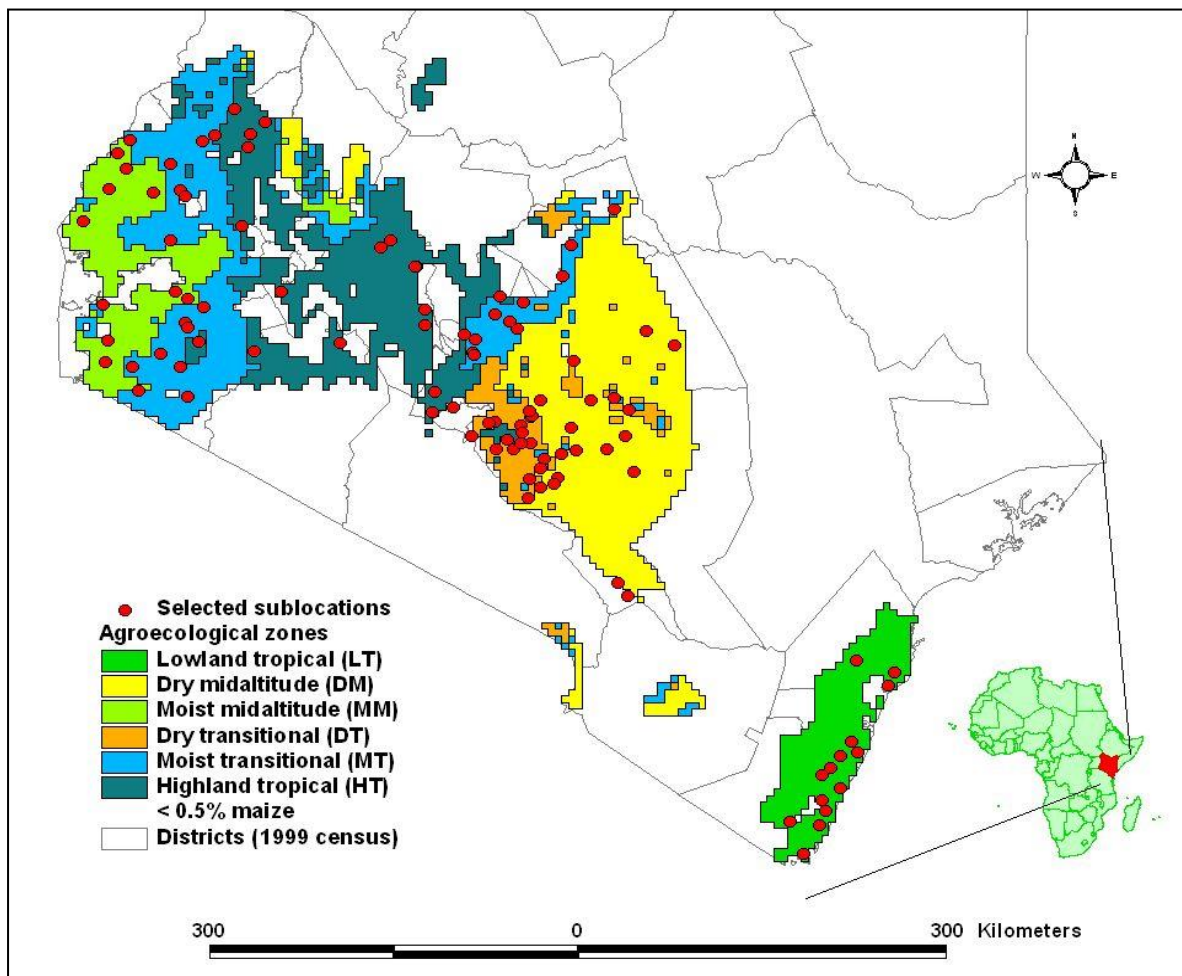


Figure 2-3: Sampled sub-locations in the six agro-ecological zones covered during the survey in Kenya (source:([Gitonga et al., 2013b](#)))

2.5 Data Description

This section discusses how the explanatory variables used in the quantitative analysis were measured and presents summary statistics comparing the households that adopted improved maize seed (treatment group) and those that did not (the control group). It also describes the measurement of the outcome variables and gives a comparison of summary statistics between the two groups. Table 2-3 provides a descriptive analysis of these variables.

2.5.1 Improved maize adoption and market participation by agro-ecological zones

Table 2-1 shows that the average area under improved maize was 2.5 acres and average amount of improved seed planted was 19 kg. High potential zones that include dry transitional, moist transitional and high tropics had the highest adoption rates at 85%, 92% and 94% respectively. Despite the relatively high adoption rates of improved maize seed across zones, less than half of the households participated in the grain market. This could be attributed to the small-scale farm operations due to land fragmentation as indicated by area allocations to improved maize. High tropics zone had the highest proportion of farmers participating in market. Most of the big farms that grow maize commercially in the North Rift are found in high

tropics although there are also many smallholder producers in densely populated areas of central highlands. Very few non-adopters participated in the grain market with coastal region having the lowest at 4.4%. The marketed share of the households' total maize harvest was 21% with highlands zones reporting the highest (34%) and coastal zones the lowest (10%). Adopters reported higher marketed share (23.5%) of own maize produce than non-adopters (8.1%). Non-adopting households in Coastal lowlands on average sold less than a percentage of their maize produce. In general, market participation was lower in coastal and drier zone

Table 2-1: Improved maize adoption and market participation by agro-ecological zones (Source: Authors calculations)

Agro ecological zones	Improved maize adoption			Did you sell (%)			What proportion of produce did you sell (%)				
	Adopting households (%)	Average quantity purchased (kgs)	Average area (acres)	Adopters	Control	All	Adopters		Control		All
			Mean				mean	Std. Dev.	mean	Std. Dev.	
low tropics (n=90)	62	16.92	2.52	29.85	4.4	23.33	13.7	24.9	0.6	3.0	10
Dry mid altitude (n=216)	72	18.74	3.93	27.67	12.3	23.61	13.4	24.9	4.9	19.4	11
Dry Transitional (n=204)	85	14.87	2.70	36.57	6.9	32.35	19.1	33.6	5.3	19.9	17
Moist Transitional (n=354)	94	21.31	2.26	48.97	30.8	48.31	25.7	35.7	16.1	26.2	25
High Tropics (n=240)	92	24.68	2.33	61.61	18.8	58.75	34.8	47.3	11.9	25.5	33
Moist mid altitudes(n=240)	65	14.91	1.8	52.87	28.8	46.25	22.2	27.8	13.5	24.1	20
all (n=1344)	82	19.08	2.5	46.05	17.7	41.74	23.5	35.8	8.1	20.6	21

2.5.2 Measurement and description of treatment intensity

The two measures of adoption or treatment intensity used are the area allocated to improved maize by a household, and the quantity of improved maize seed that it purchased. Figure 2-4 shows the skewed distribution of these two indicators of treatment intensity. Few of the households sampled allocated more than five acres to improved maize cultivation. We also see that most households planted less than 20kg of improved seed. A small number of large-scale producers, especially in the North Rift, accounted for much of the adopted improved seed. From Table 2-2, we can see that the top quintile of households in our sample accounted for 63.2% of the amount of improved seed purchased and 65.7% of the area planted. The bottom two quintiles accounted for 6% of the quantities purchased and 5% of the area planted with improved maize seed. The middle 20% accounted for 10.9% of the quantity purchased and 10% of the area planted with improved maize.

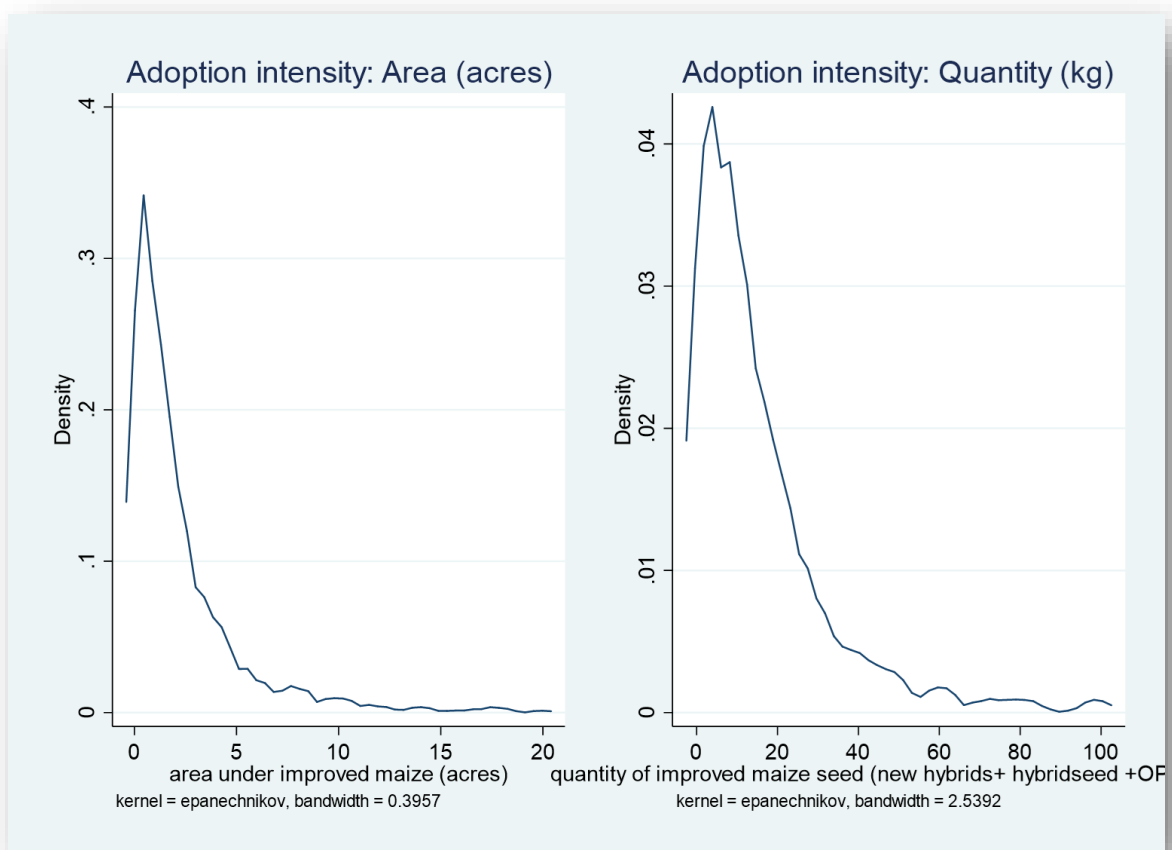


Figure 2-4: Distribution of adoption intensity of improved maize (Source: Author).

Table 2-2. Percentile³ shares of improved seed by quantities purchased and area planted (Source: Author)

Percentiles	Quantity of improved maize seed				Area planted with improved maize seed			
	Coef.	Std. Err.	[95% Conf. Interval]		Coef.	Std. Err.	[95% Conf. Interval]	
0-20	0.0044	0.0015	0.0015	0.0074	0.0034	0.0009	0.0015	0.0053
20-40	0.0565	0.0034	0.0498	0.0632	0.0464	0.0035	0.0395	0.0532
40-60	0.1092	0.0052	0.0990	0.1193	0.0995	0.0051	0.0895	0.1095
60-80	0.1983	0.0084	0.1818	0.2147	0.1936	0.0087	0.1767	0.2106
80-100	0.6316	0.0161	0.6000	0.6633	0.6571	0.0159	0.6259	0.6883
Observations	1344				1344			

2.5.3 Measurement and description of independent variables

Age: The average of household head was 54 years (Table 2-3). Adopters of improved maize seed were slightly younger (53.5 years) than non-adopters (56years).

Gender of the household head is a binary dummy taking a value one if male and zero otherwise. The strong relationship between gender, livelihood and poverty is well-documented and women in general are poorer than men because of the existing gender inequalities ([M. Angula, 2010](#); [Demetriades & Esplen, 2010](#); [Meenakshi & Ray, 2002](#); [Wamukonya & Rukato, 2001](#)). Males head 80% of households in the current sample.

Education was measured as years of schooling completed. In an earlier Kenyan study, [Ogada, et al. \(2014\)](#) showed that adoption of hybrid maize increased with education. This study has found that, while household-heads on average had eight years of completed formal schooling, heads from adopting households had two more years of schooling compare to those from non-adopting households. The average household size was seven members for both adopters and non-adopters.

Household size: [Widyanti et al. \(2009\)](#) suggest that in general, larger families are more likely than not to be poor, partly because such families allocate high shares of family budget to consumptive rival goods ([Lanjouw & Ravallion, 1995](#)). Family size could also indicate the availability of family labour as well as economies of scale in household purchases ([Lanjouw & Ravallion, 1995](#); [Smale & Mason, 2014](#)). However, [Meenakshi and Ray \(2002\)](#) observe that while consumption economies will affect poverty estimates, it would not affect the state of poverty ranking. It is expected that family size will affect not just household's decision to adopt improved varieties but also the quantities to purchase. The average household size in the sample was seven persons with no significant difference between adopters and non-adopters.

³ Percentile shares is an approach of describing and presenting distributional inequalities using varying percentages as thresholds e.g. top 20% or bottom 10%.

Total farm size (ha) was one of the wealth indicators (Table 2-3). Households with bigger land parcels are likely to purchase larger quantities of improved seed, and plant larger areas with it. The average farm size was 5.56 acres, with no significant difference between adopters and non-adopters.

Wealth: [Hamazakaza et al. \(2013\)](#) argued that the adoption of agricultural technologies, like improved hybrids, is an increasing function of wealth and income. Two measures of household wealth were used. The first was *Tropical livestock units (tlu)* which were computed following [Chilonda and Otte \(2006\)](#) whose conversion factors are: cattle = 0.7, camels=0.7, donkeys=0.3, sheep = 0.1, goats = 0.1, pigs = 0.2, chicken = 0.01. The average household had 2.76 TLUs although adopters of improved seed had more (2.88) than non-adopters (2.08).

The second measure wealth was the household's *Asset index*. This indicator was constructed following Langyintuo's (2008) guidelines for the computation of wealth indices using principal component analysis. Once again, the results supported the initial view: farmers adopting improved seed had a wealth index of seven whilst non-adopters had an index of five.

Total maize area (acres): this is the total area allocated to maize, whether improved or local varieties. The average area under maize was 3.8 acres with adopters of improved maize having more (3.85 acres) than non-adopters (3.4 acres).

Fertilizer use: most of the surveyed farmers (60%) used commercial fertilizer, most of whom (68.5%) were adopters of improved maize. Only a quarter of non-adopting farmers used commercial fertilizers.

Fertilizer rate was measured as the quantity of commercial fertilizers used per acre (kg/acre). Farmers were on average applying fertilizers at the rate of 20kg/ acre. Adopters however applied more fertilizer at 23.48 kg/acre than non-adopters who on average applied 5.13 kg/acre.

Distance to the main market (km): The average distance to the main market was 7km. It was 6.52km for adopters and 7.41km for non-adopters.

Credit (Institutional factors): Credit was measured as a binary dummy variable, indicating whether those farmers who sought credit got it. On average, only 20% of households had access to credit. However, access was significantly higher among adopters (22%) than for non-adopters (13%).

The study used agro-ecological zones as defined by [Hassan \(1998\)](#) in his work on maize technology development and the transfer and application of GIS for research planning. The adoption rate of improved varieties was high in the moist transitional (94%), high tropic zones (92%) and dry transitional zones (85%). Coastal low lands and dry mid altitudes had adoption rates of 69% and 72% respectively, while moist mid altitudes had the lowest adoption rates at 65%.

Table 2-3: Variable definition and mean comparison between adopters and non-adopters of improved maize seed (Source: Author)

	Variable	Combined (n= 1344)		Adopters (n= 1,097)		Non-adopters (n=247)		t-test
		Mean	Std. Error	Mean	Std. Error	Mean	Std. Error	Mean Difference
Individual	Age of the household head (years)	53.97	0.38	53.47	0.41	56.21	0.93	2.74***
	Male headed household (%)	81.03	1.07	82.86	1.14	72.87	2.829	10.00***
	Household head education (years)	7.73	0.12	8.14	0.14	5.88	0.24	2.26***
Household	Household size (number of members)	6.46	0.07	6.47	0.08	6.4	0.18	0.01
	Household size (Adult equivalent)	5.54	0.06	5.56	0.07	5.45	0.15	0.09
	Hosting big social events	0.20	0.01	0.20	0.01	0.22	0.03	0.02
Wealth	Farm size (acres)	5.56	0.25	5.75	0.30	4.74	0.33	1.01
	Livestock assets (tlu)	2.63	0.10	2.75	0.11	2.13	0.15	0.62***
	Physical asset index	6.80	0.11	7.14	0.13	5.31	0.20	1.84***
Productivity	Total maize area (acres)	3.768	0.151	3.854	0.175	3.387	0.265	0.47
	Fertilizer use intensity (kg/acre)	20.11	0.99	23.48	1.18	5.13	0.913	18.35***
	Use of commercial fertilizer (%)	60.42	1.33	68.46	1.40	24.70	2.74	43.76***
	Distance to main market (km)	6.69	8.36	6.52	8.00	7.41	9.78	0.89
	Access to credit	20.31	1.10	21.88	1.25	13.36	2.16	8.52***
Outcome variables	% maize sold	21.19	0.94	23.53	1.06	8.12	1.45	15.42***
	Months of maize storage	5.34	0.10	5.64	0.11	3.68	0.21	1.96***
	HFIAS	6.63	0.18	6.03	0.19	9.31	0.48	3.28***
AEZ	Coastal Low land (% of n=90)			69		31		
	Dry mid altitude (% of n=216)			72		28		
	Dry transitional (% of n=204)			85		15		
	Moist transitional (% of n=354)			94		7		
	High tropics (% of n=240)			92		8		
	Moist mid altitude (% of n=240)			65		35		

*** p<0.01, ** p<0.05, * p<0.1

2.5.4 Measurement and description of outcomes variables

Market participation index: This was measured as a continuum of the share of the total maize production of a previous completed production cycle that the household sold: zero indicates pure subsistence, while 100% indicates a fully commercialized household. [Carletto et al. \(2017\)](#) used a similar approach to measure the extent of agricultural commercialization but used the value of produce sold rather than the quantity. The disadvantage of using value is that of households selling their produce at different times within the season, and as a result receiving different prices. Imperfect recollection is also a problem; poorly recalled information on prices and the value of sales amplifies the measurement errors caused when households sell at different times within season. This approach helps to reveal households' selling behaviour ([Carletto et al., 2017](#)). For this study, there was a detailed maize inventory module capturing the amount of maize harvested, quantities consumed and sold. On average, families sold 21.2% of the harvested maize from the previous season but the proportion sold by adopters (23.53%) was three times that sold by non-adopters (8.11%) (Table 2-3).

Duration maize storage: This was the duration in months, computed from a detailed maize storage inventory that tracked how households used their maize produce from the month it was first put in storage until the time it was depleted. The food crisis occasioned by maize shortage in 2017 highlights the importance of maize as an indicator of food security status in Kenya. The average duration maize lasted in storage was five months, but adopters stored for longer duration (5.6 months) than non-adopters did (3.7 months). In addition to smoothing consumption during the lean periods, farmers do also store maize for temporal price arbitrage ([Gitonga et al., 2013b](#)).

Household Food Insecurity Access Scale (HFIAS): To estimate the HFIAS, respondents answered nine sequential questions on the occurrence of events indicating increasing levels of household food insecurity from anxiety about not having enough food to feed the family to severe food insufficiency. Subsequently, respondents were asked how often the event or condition occurred during the past four weeks, with responses ranging from never (=0), rarely (=1), sometimes (=2), and often (=3). The questions were asked to the person in the household mostly responsible for preparing meals, usually the female spouse to the household head ([Coates et al., 2007](#)). Each household was scored on a scale of 0-27 with a higher score indicating increasing severity of food insecurity. Non-adopters had significantly higher score (9.31) than adopters (6.03).

2.6 Empirical Estimation Results

This section presents the control-function regression estimated by ordinary least squares. It evaluates the impact of improved maize on market participation, duration of maize storage and an index on food insecurity severity. An IV regression using a Heckman bivariate selection model is also estimated, with robustness checked using 2SLS. Results of Heckman bivariate selection model are presented in Table 5-2 in appendix 2.

2.6.1 Dose-response function of improved seed adoption on market participation

This subsection presents the estimation results of equation [15] - the impact of the decision to adopt improved maize, and the intensity of that adoption, on market participation by rural farm households. Columns 1 and 5 of Table 2-4 show the OLS estimates of the impacts results of adoption intensity as measured by the quantities of improved seed and the area allocated to it. Column 3 presents instrumental variables (2SLS) regression results.

Results show that adoption of improved maize has significant impact on the level of market participation⁴ by rural families. The share of household's marketed maize produce was between 11.67 and 13.12 percentage points higher for adopters than it was for the non-adopting households. The impact on market participation increase with adoption intensity but at a decreasing rate (*also see figure 6*⁵). The turning point was at 100kg at which point the consumption share of total maize production becomes negligible. These are commercial farmers with over five hectares of land under maize. The results of IV regression estimated by Heckman bivariate selection model and 2SLS are close to those obtained using the Control-function regression estimated by OLS.

Market participation declined with the age of the household head and family size but increased with years of farming experience. Every additional family member was associated with a 1.5-percentage point reduction in the share of maize output being marketed. This shows that large families use much of the produced maize for subsistence. Households that used commercial fertilizer sold more of their maize. A shift to using commercial fertilizer was associated with a six-percentage point increase in the share of the marketed maize produce. Previous work by [Duflo et al. \(2008\)](#) showed correlation between use of commercial fertilizer and yields although the marginal productivity could differ significantly depending on local soil conditions in different agro-ecological zones ([Theriault et al.](#),

⁴ Some households are semi-subsistence where they sell part of their produce soon after harvest, not because they have surplus to run them throughout the season, but to meet immediate cash needs. Such households usually buy later in the season from the market at higher prices.

⁵ Standardized quantity at the turning point in Figure 6 (or calculated from Table 2-3 using delta method) is 15.17, which translates to 100.4kg when converted to actual quantities (15.175563×6.62). 25kg of improved seed goes into one hectare.

2018). The coefficient on the interaction term between fertilizer and improved seed was statistically insignificant. Farmers sometime purchase improved seeds first, plant using organic fertilizer (manure or compost), and later buy topdressing fertilizers.

Table 2-4: Impact of improved seed adoption on market participation (Source: Author)

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
	OLS-Quantity (kgs)		IV-Quantity (kgs)		OLS-Area (ha)	
	Coef.	se	Coef.	se	Coef.	se
Adoption status (1=Yes, 0=No)	11.746***	3.632	11.818*	6.373	12.354***	3.486
Tw_1	0.515	0.621	6.273*	3.283	3.214***	0.645
Tw_2	-0.020	0.015	-0.192	0.158	-0.152***	0.027
Tw_3 ⁶	0.000	0.000	0.001	0.001	0.001***	0.000
Male head	3.162	2.405	2.863	2.391	2.717	2.367
Household head age (years)	-0.778	0.477	-0.745	0.483	-0.893*	0.471
Quadratic age	0.006	0.004	0.005	0.004	0.007	0.004
Farming experience	0.462*	0.267	0.564**	0.268	0.454*	0.263
Quadratic experience	-0.009**	0.005	-0.011**	0.005	-0.009*	0.005
Household head education (years)	0.297	0.238	0.202	0.237	0.260	0.235
Household size (Adult equivalent)	-1.357***	0.425	-2.281***	0.509	-1.759***	0.423
Group membership	-0.992	2.741	-0.505	2.735	-0.862	2.708
Tropical Livestock Units (tlu)	0.683**	0.280	0.324	0.294	0.620**	0.278
Credit	-0.162	2.254	0.609	2.400	-0.954	2.227
Asset index	0.592**	0.278	0.263	0.492	0.682**	0.280
Log income	1.073	0.779	0.834	0.787	0.780	0.769
Fertilizer rate (kg/acre)	0.036	0.028	0.013	0.030	0.039	0.027
Use commercial fertilizer	6.776***	2.299	5.728**	2.494	6.645***	2.264
Hosting big social events	-4.688**	2.259	-4.467*	2.324	-4.790**	2.221
Total area under maize (ha)	2.078***	0.455	0.510	0.957	2.625***	0.780
Engaged in charcoal and timber	3.610	2.764	4.206	3.146	4.709*	2.730
Engaged in carpentry	15.290**	7.102	18.097**	7.120	14.857**	6.992
Distance to main market (km)	0.255**	0.108	0.201*	0.108	0.222**	0.106
Low tropics	-10.801**	4.912	-10.578*	5.624	-13.143***	4.849
Dry mid altitude	-14.557***	3.898	-15.041***	5.307	-18.639***	3.853
Dry transitional	-8.057**	3.671	-6.141	5.397	-10.839***	3.601
Moist transitional	-3.288	2.867	-1.959	3.632	-3.167	2.824
Moist mid altitude	-3.335	3.647	-2.220	4.757	-3.746	3.577
long rain season (baseline category)						
Short rain season	-6.924*	4.051	-7.517*	4.199	-6.841*	3.994
Both long and short seasons	-6.433***	2.425	-6.730**	2.997	-7.377***	2.382
_ws_x ⁷						
_ws_headedu (head education)	0.092	0.648			0.143	0.654
_ws_experience (head experience)	-0.198	0.167			-0.206	0.168
Constant	15.243	14.760	26.676*	15.055	24.795*	14.670
Observations	1,344		1,342		1,344	
R-squared	0.150		0.170		0.174	

*** p<0.01, ** p<0.05, * p<0.1

Distance to the main market was positively associated with higher share of the marketed maize produce. Although this seem counterintuitive, as distance to the market increases, only households

⁶ Represents $\gamma_1 t_{1w} + \gamma_2 t_{2w} + \gamma_3 t_{3w}$ (dose-response) part of equation 15.

⁷ Subset of \mathbf{X} vector interacted with treatment indicator w. Represents $\mathbf{w}(\mathbf{X} - \bar{\mathbf{X}})\delta$ part of equation [15].

with substantial surplus to sell would take their grain to the main market. Those with less than a certain minimum volume required to cover their transaction costs would rather sell at the farm-gate to neighbours or local assemblers.

Results show that market participation rates differ significantly by agro-ecological zone. The share of households' total maize produce marketed was at least ten percentage points lower in the low tropics than in the high tropics. Similarly, that share was 14.9 and 8.06 percentage points lower in dry mid altitude and dry transitional zones when compared to high tropics. Households in the moist transitional zones and the high tropics marketed almost the same proportion of the maize they produced.

Compared to households that planted maize only in the long-rain season, the share of the marketed maize produce was seven percentage points lower for households who only planted maize in the short season. Those that planted in both long-rain and short-rain seasons did not perform any better. Kenya has two types of seasons namely unimodal with only one growing season in high altitude areas and bimodal with two seasons where the farmers can grow two maize crops per year. Farmers in high altitude areas grow one maize crop per year but have higher yields due to more precipitation, better soils, as well as improved seed and mechanization in areas where farms are larger.

2.6.2 Analysis of impact on market participation by agro-ecological zones

Looking at the average treatment effect on the treated (ATET) by zones, the impact on market participation was highest for adopting households in drier zones showing great potential for improved varieties in improving livelihoods in these zones (Table 2-5). The average impacts of improved maize adoption on market participation for the adopters in DMA and DT zones were 21.13 and 14.35 respectively. This is higher than the 14 percent for adopters in the high potential zones (HT and MT). The distribution of the average treatment effect on the treated (ATET) by zones is presented in Figure 2-5.

Table 2-5: ATT by zones conditional on both the covariates (x) and dose (t) (Source: Author)

VARIABLES	(1)		(2)		(3)		(4)	
	Quantity (kg) planted		Area Planted with improved seed		Quantity (kg) planted		Area Planted with improved seed	
	ATET_x_t	se	ATET_x_t	se	ATET_x_t	se	ATET_x_t	se
Coastal Lowland (LT)	16.939***	1.046	19.298***	0.921	16.939***	1.046	19.298***	0.921
Dry mid altitude (DMA)	17.776***	0.672	20.830***	0.719	17.776***	0.672	20.830***	0.719
Dry Transitional (DT)	14.683***	0.505	17.779***	0.561	14.683***	0.505	17.779***	0.561
Moist Transitional (MT)	14.959***	0.441	15.262***	0.345	14.959***	0.441	15.262***	0.345
Highland Tropics (HT)	16.550***	0.617	15.404***	0.485	16.550***	0.617	15.404***	0.485
Moist mid altitudes (MMA)	15.714***	0.580	15.930***	0.484	15.714***	0.580	15.930***	0.484
Observations	1,139		1,139		1,139		1,139	

*** p<0.01, ** p<0.05, * p<0.1

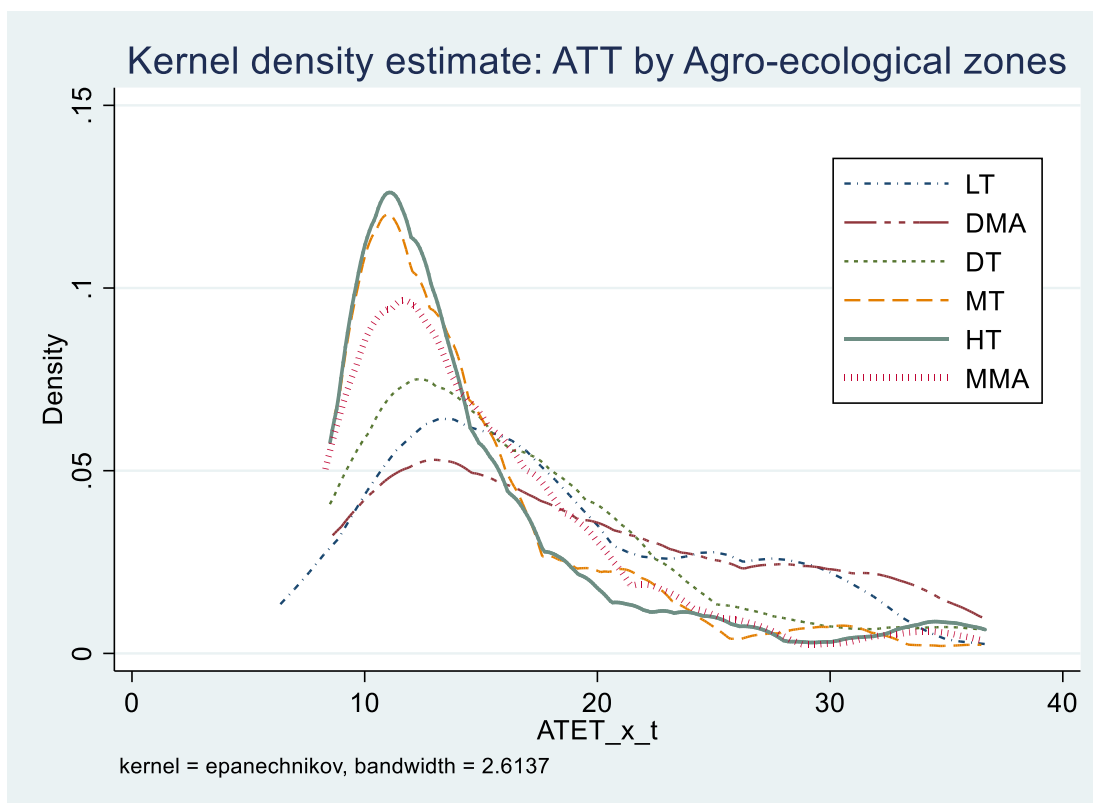


Figure 2-5: Distribution of ATT by agro-ecological zones (Source: Author)

2.6.3 Dose-response function of improved seed adoption on food security

2.6.3.1 Impact on duration of maize storage

Adoption of improved seed has an impact on duration of maize storage at the 5% level of significance (Table 2-6). The control function with OLS estimates show that adopters had maize in storage for at least two months more than non-adopters did (Figure 2-6). The results remain the same regardless of whether the adoption intensity is measure in quantities of improved seed adopted or area planted with improved seed. The IV 2SLS estimates were higher than OLS estimates. This duration Length of storage increased with treatment intensity (quantity of adopted seed and area allocation to improved maize production) but at a decreasing rate *ceteris paribus*. Using the delta method, the turning point was calculated to be 5.25ha. Large farmers usually sell their maize to national cereals and produce board (NCPB⁸) in bulk to get money for the next season and minimize on-farm storage costs. Using the quantity of improved seed as an indicator of treatment intensity, the turning point is 110 kg⁹, which

⁸ This is a state-owned national parastatal for strategic grain reserve. It has storage silos in various parts of the country where most commercial maize producers deliver their produce.

⁹ Computed from Table 2-6 using the delta method: $(-0.266 / (2 * -0.008)) * 6.62$

again points to large-scale maize production. Farmers operating at this scale would rather sell in bulk in NCPB than store due to storage costs.

Duration of maize storage increased with education of the household head, asset endowment and use of commercial fertilizers, but decreased with increasing family size. Families that engaged in charcoal production had shorter duration of maize storage. Charcoal production is common in dry altitude zones and households may well be trading-off time and effort between gathering wood for charcoal and farming.

The average duration of maize storage by households in high tropics was longer than in other zones. Drier zones had the shortest maize storage duration. The duration of maize storage was about a month less in MT and MMA zones, two months shorter in LT and DT zones and three months shorter in DMA than in HT zone. Other than droughts, the other main problem in the dry zones is postharvest losses due to storage pests and the prevalence of aflatoxins contamination ([Mahuku et al., 2019](#)). Outbreak of aflatoxin contamination in these dry zones happen when the seasonal rains come too early forcing the farmers to store their maize under dump condition ([Lewis et al., 2005](#)). [Mahuku et al. \(2019\)](#) found significant pre-harvest aflatoxin contamination in maize from those zones and lay emphasis on the need to intervene at this stage. Maize shortage in the country usually leads to spike in food prices making poor households more vulnerable ([Tefera, 2012](#)).

Households that only grew maize in the short-rain season stored maize for seven weeks (1.763 months) less than those that grew maize only in long-rain season. The duration of maize storage for families that grew maize in both cropping seasons was six weeks less than those that grew in main long-rain season.

2.6.3.2 Impact on household insecurity severity (HFIAS)

Adoption of improved maize led to a significant reduction in the food insecurity severity index. The IV estimates are almost double the results estimated by OLS (Table 2-7). The food insecurity index of households that adopted improved maize was on average three points lower than that of non-adopters. The food insecurity severity score declines at an increasing rate with level of adoption. The severity of food insecurity also decreases with education, asset endowment, earning nonfarm income and use of commercial fertilizers and area allocation to maize farming. Larger families and households that engaged in producing charcoal were food insecure.

Food security also varied by agro-ecological zones. Compared to high tropics, other agro-ecological zones were more food insecure. The severity of food insecurity was particularly higher in drier zones.

Table 2-6: Determinants of household maize storage period (months) (Source: Author)

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
	OLS-Quantity (kgs)		IV -Quantity (kgs)		OLS-Area (ha)	
	Coef.	se	Coef.	se	Coef.	se
Adoption status (1=Yes, 0=No)	2.326***	0.343	3.953***	0.635	2.422***	0.344
Tw_1	0.266***	0.053	0.915***	0.345	0.269***	0.057
Tw_2	-0.008***	0.002	-0.037**	0.017	-0.011***	0.003
Tw_3	0.000***	0.000	0.000**	0.000	0.000***	0.000
Male head	-0.099	0.232	-0.149	0.252	-0.110	0.234
Household head age (years)	-0.066	0.046	-0.054	0.051	-0.076	0.046
Quadratic age	0.001	0.000	0.000	0.000	0.001	0.000
Farming experience	0.018	0.029	0.001	0.028	0.013	0.029
Quadratic experience	-0.000	0.000	-0.000	0.000	-0.000	0.000
Household head education (years)	0.124**	0.061	0.038	0.025	0.123**	0.061
Household size (Adult equivalent)	-0.149*	0.085	-0.094*	0.053	-0.140*	0.085
Group membership	-0.148	0.263	-0.122	0.284	-0.166	0.264
Tropical Livestock Units (tlu)	0.050*	0.027	0.024	0.031	0.064**	0.027
Asset index	0.100***	0.027	0.033	0.050	0.113***	0.027
Log income	0.019	0.075	-0.002	0.083	0.013	0.076
Fertilizer rate (kg/acre)	0.005**	0.003	0.002	0.003	0.006**	0.003
Hosting big social events	0.335	0.218	0.476**	0.242	0.320	0.218
Total area under maize (ha)	0.033	0.051	-0.078	0.101		
Engaged in charcoal and timber	-0.573**	0.269	-0.622*	0.331	-0.563**	0.269
Engaged in carpentry	-0.247	0.685	-0.192	0.750	-0.379	0.688
Distance to main market (km)	-0.005	0.010	-0.007	0.011	-0.005	0.010
Low tropics	-2.055***	0.467	-2.808***	0.567	-2.269***	0.469
Dry mid altitude	-3.199***	0.363	-4.011***	0.521	-3.371***	0.361
Dry transitional	-2.424***	0.353	-2.985***	0.564	-2.641***	0.353
Moist transitional	-0.656**	0.277	-1.286***	0.387	-0.745***	0.278
Moist mid altitude	-1.157***	0.349	-1.789***	0.493	-1.261***	0.350
long rain season (baseline category)						
Short rain season	-1.763***	0.392	-1.681***	0.443	-1.734***	0.393
Both long and short seasons	-1.420***	0.233	-1.147***	0.313	-1.415***	0.233
_ws_headedu	-0.095	0.064			-0.091	0.064
_ws_experience	-0.010	0.016			-0.010	0.017
_ws_HHsize	0.126	0.082			0.142*	0.082
Constant	5.957***	1.575	5.939***	1.577	6.241***	1.586
Observations	1,344		1,344		1,344	
R-squared	0.268		0.149		0.261	

*** p<0.01, ** p<0.05, * p<0.1

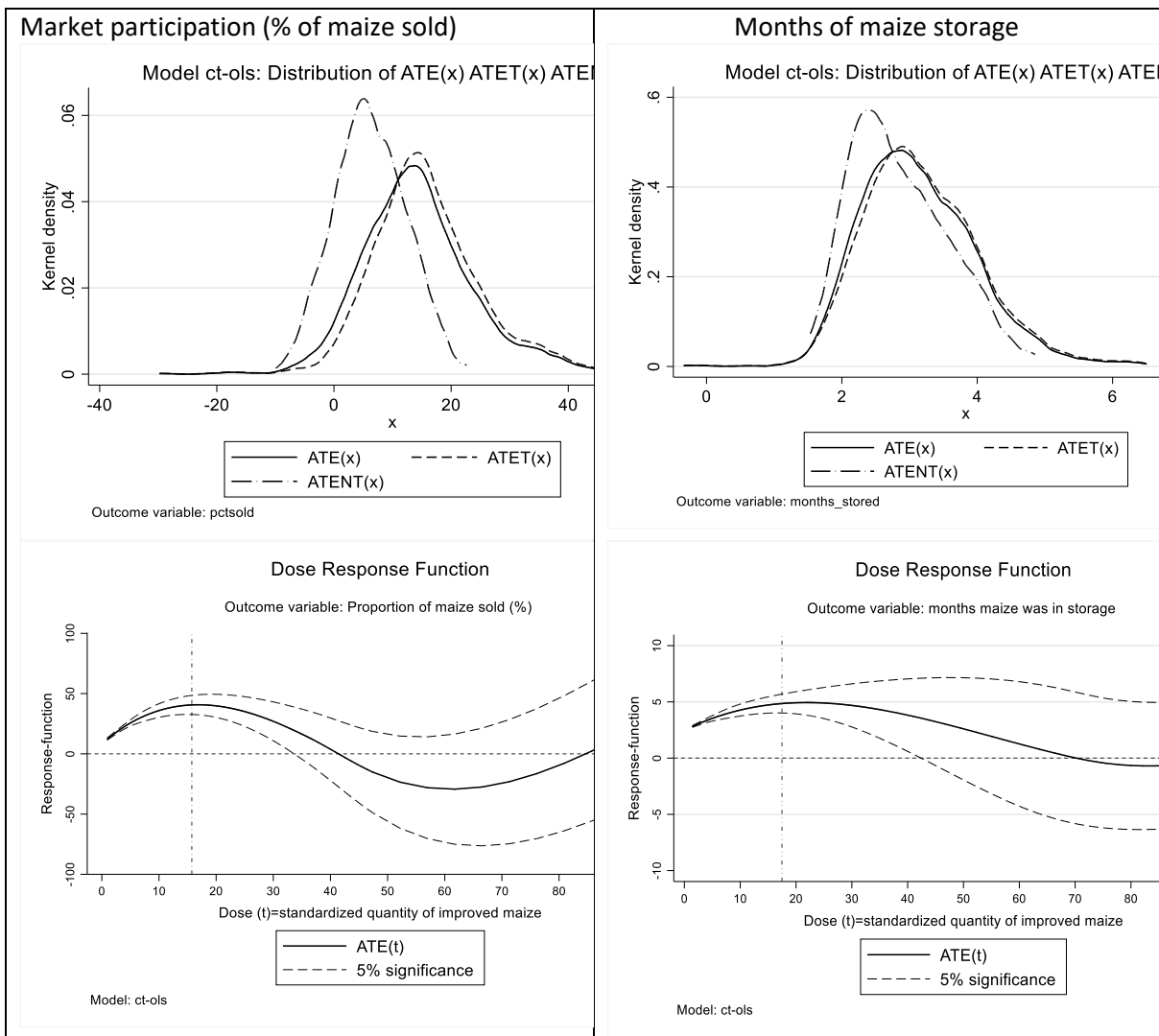


Figure 2-6: Distribution of conditional ATE, ATT and ATENT and dose-response Function (Source: Author)

Table 2-7: Impact on household food insecurity access scale (HFIAS) (Source: Author)

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
	OLS-Quantity (kgs)		IV-Quantity (kgs)		OLS-Area (ha)	
	Coef.	se	Coef.	se	Coef.	se
HFIAS
Adoption status (1=Yes, 0=No)	-2.674***	0.594	-5.530***	1.162	-2.688***	0.593
Tw_1	-0.163*	0.096	0.616	0.631	-0.495***	0.104
Tw_2	0.009**	0.004	-0.035	0.030	0.022***	0.005
Tw_3	-0.000	0.000	0.000	0.000	-0.000***	0.000
Male head	0.238	0.422	0.145	0.460	0.306	0.423
Household head age (years)	0.084	0.084	0.121	0.093	0.098	0.084
Quadratic age	-0.001	0.001	-0.001	0.001	-0.001	0.001
Farming experience	-0.010	0.047	0.003	0.052	-0.014	0.047
Quadratic experience	0.001	0.001	0.001	0.001	0.001	0.001
Household head education (yrs)	-0.163***	0.042	-0.156***	0.045	-0.163***	0.042
Household size (ADTEQV)	0.523***	0.076	0.475***	0.098	0.512***	0.075
Group membership	-0.409	0.479	-0.508	0.520	-0.431	0.479
Tropical Livestock Units (tlu)	-0.094*	0.050	-0.088	0.057	-0.099**	0.049
Asset index	-0.446***	0.050	-0.565***	0.092	-0.439***	0.050
Log of income	-0.614***	0.137	-0.513***	0.152	-0.603***	0.137
Fertilizer rate (kg/acre)	-0.015***	0.005	-0.014***	0.005	-0.014***	0.005
Hosting big events	-0.122	0.397	-0.005	0.443	-0.050	0.396
Total area under maize (ha)	-0.291***	0.094	-0.500***	0.185		
Engaged in charcoal and timber	1.029**	0.489	0.327	0.607	1.063**	0.487
Engaged in carpentry	-0.144	1.250	0.252	1.374	-0.124	1.249
Distance to main market (km)	0.015	0.019	0.023	0.021	0.015	0.019
Low tropics	1.929**	0.847	3.311***	1.038	2.164**	0.849
Dry mid altitude	3.893***	0.663	5.815***	0.953	3.803***	0.655
Dry transitional	2.743***	0.644	4.833***	1.032	2.784***	0.640
Moist transitional	0.835*	0.505	2.099***	0.709	0.902*	0.504
Moist mid altitude	0.730	0.635	2.413***	0.902	0.727	0.633
Short rain season	-0.012	0.713	-0.665	0.810	-0.063	0.713
Both long and short seasons	0.361	0.425	-0.622	0.573	0.291	0.422
Constant	14.056***	2.594	15.178***	2.888	13.267***	2.607
Observations	1,344		1,344		1,344	
R-squared	0.285		0.164		0.284	

*** p<0.01, ** p<0.05, * p<0.1

2.7 Conclusion

Compared to other countries in East Africa, Kenya has relatively well developed and vibrant maize seed sector, with more registered seed companies, more registered and released maize seed varieties, high turnover of certified seed sales and higher adoption rates ([Erenstein et al., 2011](#)). This success can in huge part be attributed to public investment in research and liberalization of the maize seed market ([Ariga & Jayne, 2009](#)). Despite these milestones, Kenya like other Horn of African countries remain vulnerable to food insecurity ([Coughlan de Perez et al., 2019](#)). According to FAO statistics, the average maize yields have stagnated at less than two tons per hectare. Maize remains a key component and determinant of food security for millions of families in SSA and the immediate impact of its shortage is hunger and food insecurity among the most vulnerable section of communities ([Shiferaw et al., 2011](#)). Additionally, maize being the main ingredient in animal feeds formulations, its shortage results in a significant increase in feed costs. Against this background, there is a need for better understanding of adoption patterns of improved maize varieties and their impact on household welfare outcomes.

In this chapter, percentile shares approach indicates a highly skewed improved maize adoption with the top quintile of the sample accounting for 63% of seed purchased and almost two-thirds of the area planted with it. The lower 40% of the sample accounted for only six percent of the seed and five percent of the area planted with improved maize seed. Although 82% of households adopted improved maize to some degree, only 41.7% marketed their output, an indication of the subsistence nature of maize farming in Kenya.

Following [Cerulli \(2015\)](#), the study used a dose-response model to evaluate the impact of improved maize adoption on food security and market participation. The model allows for two estimation procedures: a control function estimation by OLS regression under the conditional independence assumption and an IV regression assuming that the adoption decision is endogenous. IV regression was estimated in two steps using Heckman bivariate selection model and 2SLS. The study used data collected from a representative sample of 1344 households across six agro-ecological zones in Kenya. The marketed share of household's maize produce was at least 11.67 percentage points higher for adopters than non-adopters. Market participation increased with adoption intensity and fertilizer rate (kg/acre). The proportion of maize harvest sold in the market declined with age and family size. The marketed share of total maize production was on average higher in highland zones than in all other zones. However, a comparison of adopters and non-adopters within zones show the average impact on those that adopted (ATET) is highest in drier zones indicating the great potential improved varieties have in improving livelihoods in these zones.

Households that adopted improved maize were less food insecure and stored their maize for three months longer than non-adopters. Severity of food insecurity also decreases with adoption intensity, education, asset endowment and use of fertilizers. However, food insecurity increased with age and family size. Compared to high tropics, households residing in other agro-ecological zones were more food insecure. To address food insecurity problems in Kenya, results indicate a need for a strategic policy on food security that considers the concentrated nature of the maize farming sector. Such a policy could aim at food self-sufficiency for small farms and promote commercial production by largescale producers for national strategic reserves. From the results, there are farmers producing maize in more than five hectares or planting over 100 kilograms of improved seed. Results show that farmers store maize for up to six months and therefore there is need for postharvest policies that promote safe on-farm grain storage.

Chapter 3: Evaluating the role of migration as an adaptive and social protection strategy in semi-arid regions of Namibia

Abstract

This chapter investigates the nexus between migration and well-being of the farm families in Namibia by evaluating its impact on consumption expenditure, food budget share, dietary diversity and adaptive capacity. Using survey data from a representative sample of 653 households, it employs Lewbel's constructed instruments approach for identification. It finds rural poverty and lack of economic opportunities to be the main reasons for migration. Although tertiary education and technical training of the migrants are key determinants of remittances received by migrant-sending households, over 70% of migrants did not possess such qualifications. Migrant-sending households had lower consumption spending and relatively higher food expenditure share, suggesting relative deprivation. Although consumption spending increased with number of migrants, quality of human capital had greater impact on well-being. Migration had a positive impact on household's adaptive capacity but an inverse relationship between number of migrants and adaptation suggests failure of local adaptive strategies. The study finds a statistically significant impact of migration on agricultural input expenditure, but mainly through spending on tractor-hire services. Loss of family labour is somehow, through remittances, countervailed and compensated by mechanization. Developing markets for credit, inputs and farm output, and preparing migrants for participation in labour markets and self-employment through training can further enhance the impact of migration and build resilience to socioeconomic and climate shocks. Due to self-reinforcing poverty traps in poor households, targeted public programs that support higher education and technical training are recommended.

Key words: Namibia, semi-arid lands, migration outcome, vulnerability, climate risk, consumption spending dietary diversity, food budget share, adaptive capacity

3.1 Introduction

3.1.1 Overview

The nexus between migration and the wellbeing of the rural families in arid and semi-arid regions remains a significant gap in the migration and climate change literature. Many of the studies reviewed presumed a unidirectional flow of remittances from the migrants to their rural families, but a study on migration in Namibia ([Frayne, 2004](#)) indicated a reciprocal interaction through rural-urban linkages. Urban unskilled migrants who have limited social contact with their rural families are very vulnerable to food insecurity in the cities. Given that most rural households in arid regions of Southern Africa are classified as poor in national statistical agencies ([Dian Spear et al., 2014](#)), the impact of migration on household wellbeing and adaptive capacity is not obvious across households of different social and economic status. Rural-urban migration has been on the increase in Namibia since independence and there is need for a better understanding of its impacts on the wellbeing and adaptive capacity of the rural communities most vulnerable to negative impacts of climate change. Urban poverty is increasing in cities and opportunities to find work are dwindling for most unskilled migrants ([Frayne, 2004](#)). In view of the foregoing, the impact of migration on rural households' wellbeing and adaptive capacity in Namibia is largely unknown. This study bridges this gap by characterizing the migration process in Namibia, analyzing the characteristics of migrants and evaluating the effect of migration on household consumption expenditure, food spending, dietary diversity and adaptive capacity.

3.1.2 Households' vulnerability to climate shocks in arid and semi-arid regions

Arid and semi-arid lands are home to slightly more than a third of the world's population and comprise over 40% of the earth's land surface ([Fraser et al., 2011](#)). One of the key features of semi-arid climates is rainfall variability and this is bound to increase with climate change ([Batisani & Yarnal, 2010](#)). Climate change-induced droughts are likely to push dryland ecosystems beyond the biophysical thresholds and lead to long-term decline in agricultural productivity, ([Fraser et al., 2011](#)). [Batisani and Yarnal \(2010\)](#) find evidence of a decreasing number of rainy days and increased duration of dry spells in Botswana. Vulnerability to risks associated with climate change might worsen social and economic statuses for societies dependent on resources that are sensitive to climate variability ([Adger et al., 2003](#); [Conway & Schipper, 2011](#)). This might make subsistence agriculture a more tenuous source of livelihood and households will have a greater incentive to diversify their income sources. For example, Livestock farmers in Namibia are likely to suffer losses due to shrinking pastures and small farm units will not be viable ([Reid et al., 2008](#)). In Namibia, there is a recognized risk that future climate change could induce economic decline and negatively affect employment opportunities especially for the poor and unskilled labour ([Reid,](#)

[2007; Reid et al., 2008](#)). The frequency and intensity of extreme events like droughts will increase and the projection of temperature rise by 2100 is between 2°C and 6°C ([Reid, 2007; Reid et al., 2008](#)).

3.1.3 Past responses to climate-related risks

To address the risks related to climate change, scholars have proposed several interventions at both national and farm level. One such intervention is the use of climate insurance as an instrument for ex-ante risk reduction that allow countries most affected by climate change to purchase insurance-like products to cover specific climate risks ([Bals et al., 2006; Linnerooth-Bayer & Mechler, 2006](#)). This idea has not received much attention at a national level due to its technical and political ramifications.

At the farm level, index-based crop and livestock insurance are instruments for risk transfer designed to overcome the shortcomings of normal farmers insurance against random weather events ([Alderman & Haque, 2007b; B. J. Barnett et al., 2008; Chantararat et al., 2013; Hazell & Hess, 2010; Jensen & Barrett, 2017; Mahul & Skees, 2007; Meze-Hausken et al., 2009](#)). Some of the shortcomings of insurance include the high transactions cost¹⁰ of monitoring losses and settling claims. Crop and livestock index insurance are designed to address moral hazard issues by using indicators that are not affected by individual behaviours such as rainfall or vegetation cover([Alderman & Haque, 2007a](#)). The small farmer has to pay an annual premium and receive payments when an index exceeds a certain predetermined threshold.

However, while the idea of index-based agricultural insurance is conceptually appealing to researchers and policy makers, faulty design, high basis risk and insufficient pay-outs may jeopardize its performance ([Shirsath et al., 2019](#)). The increasing frequency and severity of droughts in Africa is likely to make such initiatives unattractive to investors. Farmers who suffer significant losses are likely to lose trust in such schemes if the basis¹¹ risk is high. This option therefore might not be for the vulnerable poor smallholder farmers especially those involved in staple crops production ([Binswanger-Mkhize, 2012; Brick & Visser, 2015; V. H. Smith, 2016; Visser et al., 2019](#)).

Considering the lack of proper climate risk financing for smallholder agriculture in the context of uncertainty caused by climate variability, farmers have used other self-insuring mechanisms, such as income diversification into non-farming enterprises, as well as investment in adaptive technologies, assets and social networks ([Binswanger-Mkhize, 2012; Elum et al., 2017](#)). Migration, the subject of this chapter, is another strategy that households have always used in response to environmental disasters.

¹⁰ Some of the transactions cost in an agricultural setting would involve the collection of household-level actuarial data for the purpose of risk classification and claim validation.

¹¹ Basis risk is the mismatch between the index and farmer's actual losses, usually caused by poor design and the distance between index measurement location and the farmer's field (geographical).

Communities in the semi-arid lands of Africa and Asia have for decades used internal and seasonal migration to survive droughts ([Laczko & Sheean, 2010](#)). However, this option is becoming increasingly less viable owing to increased population pressure, climate change, and resource conflicts ([McCabe et al., 2014](#)).

To address some of the gaps identified above, this study seeks to answer three key research questions in the context of Namibia. First, do households with migrants have better welfare outcomes than households with no migrants? Secondly, does the impact of migration on household consumption expenditure differ between short-term frequent monthly spending and less frequent annual spending? Lastly, does spending on agricultural inputs and adaptive capacity of rural families differ by household's migration status?

The rest of the chapter is organized as follows. Section 3.2 presents a brief literature review focusing on migration as a livelihood diversification strategy and as an enabler of enhanced agricultural productivity and climate change adaptation. Section 3.3 discusses the conceptual framework outlining the pathways migration could affect key outcomes. The section also presents the empirical strategy and sampling. Section 3.4 gives summary statistics of the migrants, characterizes the migration process, and compares the migrant and non-migrant households on observables. Section 3.5 presents the empirical results and section 3.6 concludes with a synthesis of the results and recommendations.

3.2 Literature review

3.2.1 Overview of migration in Namibia

Studies on migration in Namibia are few and data on migration is scarce. The international Organization for Migration (IOM) and the government of Namibia released the country's first migration profile in 2015 ([Olivier, 2016](#)). The 2011 national census shows that the urban population has increased to 43% from 33% in the last decade and the rural population has shrunk by about ten percentage points ([NSA, 2011](#)). Many of the studies related to migration focus on urban poverty, housing, unemployment and food insecurity in Windhoek city, the main migration destination ([Frayne, 2004](#); [Karuaihe & Wandschneider, 2018](#); [Pendleton et al., 2014](#)). The other important destinations for Namibian migrants include Oshakati in the central north, Swakopmund and Walvis Bay on the Western coast and Rundu. There is little information on the characteristics of the migrants, their motivation, or the migration process.

From an historical perspective, there were strict limitations on the movement of people during the colonial and apartheid periods in Namibia and the majority of the black people were confined to demarcated reserves in the countryside and within certain areas of the big cities, such as the black township in Katutura ([Niikondo, 2010](#)). These restrictions were legislated and implemented through influx

control and pass laws. The people who could move from rural areas to towns were mainly men brought to work in factories. These men lived in single-squatter houses and were by law not allowed to bring their families. The influx rule was abolished in 1977, following the end of apartheid legislation, and triggered rural-urban migration, rapid urbanization, and the expansion of the informal settlement ([Seckelmann, 1997](#)). Over two-thirds of migrants to the city of Windhoek live in squatter camps, mainly made of corrugated iron sheets and not serviced by municipal council ([Niikondo, 2010](#)). [Kollamparambil \(2017\)](#) argue that while migration to formal areas reduce social inequality, moving into informal settlements and unemployment increases the social inequality gap.

Despite Namibia's classification as an upper middle-income country, urban poverty is pervasive in Windhoek. Unemployment rates are high and most residents reside in informal settlements with poor access to municipal services ([Frayne, 2004](#)). Rural-urban linkages are a key survival strategy for migrants in urban areas, especially when the migrant is temporarily unemployed ([Harris & Todaro, 1970](#)). Food transfers from rural areas are the most common form of transfer and households without rural linkages are more vulnerable to food insecurity ([Frayne, 2004](#); [Karuaihe & Wandschneider, 2018](#); [Pendleton et al., 2014](#)). Migrants use these links between urban and rural economies to overcome challenges associated with scarce employment opportunities in the urban formal economy ([Frayne, 2007](#)). Life for the urban poor is sometimes more risky and uncertain than for those in the rural areas, but they are prompted to stay rather than return by the hope of finding employment ([Niikondo, 2010](#)).

3.2.2 Role of migration and livelihood diversification

Migration is one of the livelihood diversification and adaptive strategies rural families could use to manage current socioeconomic and environment shocks while also improving their capacity to cope with future risks ([Grace et al., 2018](#); [Tacoli, 2009](#)). Much of the recent scholarly work on migration has focused on international migration, looking at the increasing role of diaspora remittances to social and economic development of the recipient developing countries ([Richard H Adams & Page, 2005](#); [Giuliano & Ruiz-Arranz, 2009](#); [Gupta et al., 2009](#); [Nyamongo et al., 2012](#); [Siddique et al., 2016a, 2016b](#); [Zezza et al., 2011](#)). In Africa for example, remittances increased fourfold between the period 1990 – 2010 and surpassed official development aid ([Ratha et al., 2011](#)).

[Mendola \(2008\)](#) has argued that the costs associated with migration can outweigh its benefits. Although many studies show that international migration tends to reduce poverty and improve quality of life, the high mobility and entry costs associated with it mean that the poor tend to engage in low-return internal migration ([R. Adams et al., 2008](#); [Mendola, 2008](#); [Wouterse, 2012](#)). In their study of migration's effects on income diversification in rural Burkina Faso, [Wouterse and Taylor \(2008\)](#) show that the destination of

the migrants and the economic activity they engage in are crucial. Even when migration is domestic, migrant skills, social networks and economic opportunities to apply the skills acquired, are important determinants of migration's outcomes. As a result, the net benefits of migration vary across social groups.

The impact of migration on the wellbeing of rural families, through their receiving remittances, differs spatially and contextually. For instance, studies show a positive impact of migration on the reduction of stunting among children, due to improved nutrition in Guatemala, Tajikistan and El Salvador ([Azzarri & Zezza, 2011](#); [Carletto et al., 2011](#); [De Brauw, 2011](#)). There is also evidence that migration can reduce household vulnerability to shocks related to sharp increases in food prices and smooth consumption in such periods. [Mergo \(2016\)](#) finds that migration also increased consumption expenditure among migrant-sending households in Ethiopia, although male migrants have a greater impact than their female counterparts do on improvement of their families' wellbeing. Migration affects household consumption through reducing the number of people in the household, a change in labour productivity, and remittances. In Namibia, in many households it is the more active members who move, leaving behind younger children and the elderly ([Greiner, 2011a](#)). The income effect from remittances increases access to food and health for the receiving household ([Zezza et al., 2011](#)). Migration can also influence a household's consumption and production practices through flow of new information from migrant about new crops and production technologies ([Karamba et al., 2011](#)).

Some studies have also found migration to have a neutral or negative impact on household wellbeing. For instance, [Wouterse and Taylor \(2008\)](#) find no evidence of any significant impact of migration on crop and livestock production in Burkina Faso. In Ghana, [Karamba et al. \(2011\)](#) did not find significant impact of migration on food expenditure, but that it did seem to shift consumption patterns to less nutritious foods like sugar and sugary beverages like soft drinks among the migrant households. While migration was associated with lifting about 40% of migrant households above the vulnerability threshold in Kosovo, it had little impact on the extremely poor ([Möllers & Meyer, 2014](#)).

The current study will evaluate whether migration has any significant impact on the household wellbeing indicators of rural households living in the arid and semi-arid regions of Northern Namibia. The wellbeing indicators include household consumption expenditure, relative food expenditure share, dietary diversity scores, adaptive capacity and spending on agricultural input. Consumption expenditure outcomes include frequent expenditure items, such as food and other regularly recurring expenses, and less frequent expenditure, such as school fees, health and investment in improved technologies. The hypothesis is that indicators of wellbeing are better for migrant households than for non-migrant ones. However, if push

factors are the main drivers of migration, such that poor households send more unskilled migrants from the home, then migration is likely to have no significant impact on selected key outcomes.

3.2.3 Migration and climate change adaptation

This relationship between migration and climate change has not received much attention in standard theories of migration ([Black et al., 2011](#)). The traditional view of migration in relation to deteriorating environmental conditions, such as devastating droughts, famine and flooding, has been that of a last resort following the failure of local adaptation strategies ([Black et al., 2011](#); [Wang et al., 2013](#)). Such migrants are loosely referred to as environmental refugees ([Myers, 2005](#)). An example of adaptive migration is the famous “dust bowl migration” where thousands of Americans moved to California and other Pacific coastal states following a prolonged drought and economic recession in the 1930s ([James N Gregory, 1989](#); [James Noble Gregory, 1991](#); [Robert McLeman, 2006](#); [Oakies, 1989](#)). Mobility therefore becomes an important adaptive response to climate risk when the impacts of climate change on natural resources and environment reach certain thresholds ([Adamo, 2008](#); [Bardsley & Hugo, 2010](#)).

Migration has also been seen as an intelligent proactive diversification strategy for dealing with the risk of a future threat to livelihood from climate change ([Boano & Morris, 2008](#); [Dessai et al., 2004](#); [Kniveton et al., 2008a, 2008b](#); [R. A. McLeman & Hunter, 2010](#)). The common thesis of these studies is that climate change drives migration patterns. Climate-induced migration is expected to increase in scale and scope, and much of it will be in developing countries ([Feng et al., 2010](#); [Rechkemmer et al., 2016](#); [Webber & Barnett, 2010](#)). Households facing uncertainty about climate are more likely to use migration as an ex-ante adaptive strategy ([Alem et al., 2018](#); [Barrios et al., 2006](#)). Climate factors such as water scarcity and rainfall variability have been singled out as the main drivers of the ‘push’ type of migration from rural to urban areas ([Marchiori et al., 2012](#); [Menon, 2009](#)). However, it is important to highlight that migration is a complex issue and attributing it to climate change can be problematic ([Bardsley & Hugo, 2010](#)). There are many drivers of migration that include, inter alia, environmental, socioeconomic and behavioural, and therefore it is highly unlikely that climate change would be the sole motivation for migration ([Black et al., 2011](#); [Black et al., 2008](#); [Castles, 2002](#); [Kniveton et al., 2008a](#)). This study will not attempt to establish a causal link between migration and climate change but rather, while controlling for key drivers of migration, will focus on how key outcomes for communities vulnerable to negative climate-change impacts differ according to a household’s migration status.

3.2.4 Effect of Migration on agricultural productivity and adaptive capacity

Scholars are now shifting research focus to the role of migration in diversifying traditional agrarian-based livelihoods, spreading risk and increasing the resilience of migrant rural families to climate change ([Laczko & Sheean, 2010](#); [Tacoli, 2011](#)). Recent studies have looked at the extent to which remittances received by migrant-sending households relax liquidity constraints and enhance the uptake of high-cost adaptive strategies and technologies ([Karanja Ng'ang'a et al., 2016](#); [L. D. Nguyen et al., 2015](#)).

Although in principle, migration through remittances can enable rural agrarian families improved their adaptive capacity by investing in adaptive technologies or non-farm activities, few empirical studies exist on this subject, and findings are largely inconclusive. For instance, [Taylor and Lopez-Feldman \(2010\)](#) find evidence using household survey data in Mexico that migration raised land productivity and per capita income. However, a study in El Salvador found no effect of migration on agricultural input use and was instead associated with reduced land and labour productivity because farming by migrant households was less intense than in non-migrant households ([Damon, 2010](#)). In the Philippines, migration was found to have no impact on relaxing credit constraints ([Quisumbing & McNiven, 2010](#)). In Kenya and Vietnam, migration increased the likelihood of investing in high cost adaptive technologies and was found to compliment other local adaptation strategies ([Karanja Ng'ang'a et al., 2016](#); [L. D. Nguyen et al., 2015](#)). Similar results were obtained in Bangladesh where households engaging in international migration were found to have higher chances of investing in modern agricultural technologies ([Mendola, 2008](#)).

Lucrative international migration involve high 'up-front' costs, which most poor households may be unable to meet. If, as Black et al (2011) suggest, those most vulnerable to climate change impacts are the poor, then such barriers further aggravate their situation. Migrants from such backgrounds might also be lacking in education and skills further alienating them from employment and economic opportunities at the target local destinations. [Greiner \(2011b\)](#) argues that, unlike well off families who use migration to move up the social ladder, poor migrant-sending households are caught in a subsistence trap, which negatively affects the migrants' capacity in such networks to save or invest. It is interesting to establish whether households that receive remittances in the wider semi-arid zones of Northern Namibia use them for consumption smoothing or for investment in short-term and long-term adaptive strategies.

The current chapter will evaluate the impact of migration on uptake of adaptive technologies. The first hypothesis proposed is that poor households engage in low return type of migration and remittances received from migrants do not meet the threshold for investment in adaptation technologies, such as stress-tolerant crops and livestock. Adaptation could also include investing in less risky non-farm business.

The second proposition is that much of the remittances received are used for consumption rather than investing in long-term adaptive technologies.

3.3 Methodology

3.3.1 Theory of change and impact pathway of migration

The study conceptualize migration not just as a household's strategy to cope with short-term socioeconomic shocks but also an enabler of long-term investment in other adaptive strategies, hence building resilience against climate risks (Figure 3-1). Rural-urban migration in Namibia is driven, not just by the wage differentials between rural and urban areas, but also by perceived spatial opportunities in the urban areas. Under the current conceptual framework, households facing effects of climate variability send migrants to either pursue education for better future welfare or look for work to diversify family income.

Migrant-households' wealth status, social networks, kinship ties, skill sets, and the demographic characteristics of the household heads determine both the migration and its impact on wellbeing indicators. Wealthier households are more likely to have skilled human capital and can afford to send migrants to destinations that are more lucrative with high returns. Poor households on the other hand are likely to send unskilled migrants to less lucrative migration destinations with low probability of finding work. Wealth status could also indicate households' capacity for self-employment or to generate labour demand in the rural setting, which might negatively affect the propensity among the unskilled potential migrants to migrate.

The neoclassical theory of migration ([E. S. Lee, 1966](#)) describes push factors that encourage movement away from rural areas. At village level, these include high poverty levels, mismatch of opportunities with acquired skills by the educated youth, poor infrastructure, adverse climate, land scarcity and high-income variability. The new economics of labour migration posits a joint migration decision that is made at household level ([Stark & Bloom, 1985](#)). The decision to migrate is likely to be coordinated and collective at household level when the prospects for better returns on migration are good and mobility costs are high, or if the motive is to pursue education. In reality, there are cases where the decision to migrate could be individual rather than joint, especially among the youth with no opportunity to match their acquired non-farm skills. The main assumption in the current study regardless of how the migration decision is made, like in ([Harris & Todaro, 1970](#)), the migrants retain their ties to their rural families in a way that their earnings in urban sector affect welfare of their kin that they left behind.

There are also pull factors at the migration destination; these include perceived better opportunities, better amenities and higher wages. Existing social networks and kinship ties at the target destination are equally important. There exists evidence that large pools of earlier migrants from the same place of origin facilitate future migration from the same area ([R. Adams et al., 2008](#)).

The characteristics of migrants drive both migration and its outcomes. An educated migrant with extended social networks and non-farming skills is both more likely to migrate ([Lanzona, 1998](#)), and to get employment at the destination, than an unskilled or a less educated migrant. Young people with high aspiration for better life are more likely to migrate when compared to older people. Similarly, married women are less likely to migrate than single women are. Young men are generally more likely to migrate than females, partly because of the job structures in urban areas, and partly because male migrants are less vulnerable during the migration process ([Lall et al., 2006](#)). These could constitute endogenous push factors of migration process or what [E. S. Lee \(1966\)](#) referred to as personal factors.

Policies aimed at improvement of communication and transport infrastructure, rural electrification and market development may open up new opportunities for young people in the rural areas and reduce the likelihood of outmigration. Policies that support manufacturing, affordable housing and security in urban areas will act as pull factors attracting potential migrants. Lack of policy planning may lead to unintended consequences of migration like development of slums and insecurity ([Lall et al., 2006](#)). This is a particular concern in Namibia where, for example, formalized land tenure is a precondition for accessing municipal services in Windhoek despite the majority of the city dwellers living in informal settlements where they cannot own land under existing land policy ([Karuaihe & Wandschneider, 2018](#)).

The impact pathways through which migrants to urban areas can influence household welfare outcomes and climate change adaptation in their rural home areas are remittances, information flow and technology transfer. The amount of remittances received by household is a function of the migrant-specific characteristics like gender, age, marital status, education, professional training as well as other factors such as destination, industry of work, duration of migration, social networks and type of migration.

The rural household can use the remittances and information received from migrants to cope with short-term socioeconomic shocks to food security and health, and to make community contributions. They can also invest directly in long-term adaptation strategies like stress tolerant crops, water harvesting and management, improving human capital through education and training, as well as, investing in non-

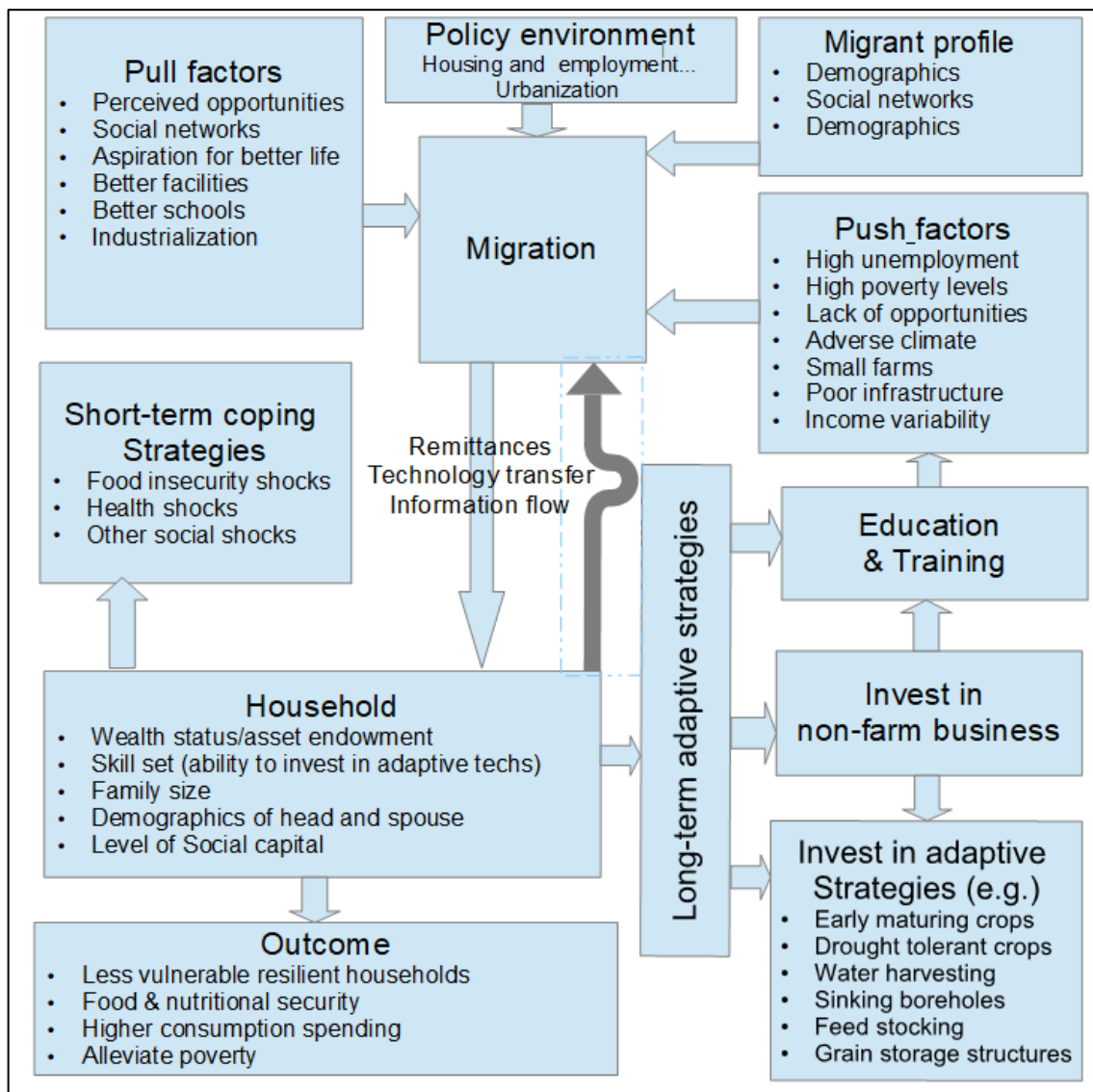


Figure 3-1: Conceptual model of Impact pathway of migration (source: author)

farming businesses. Households can also use income earned from non-farm enterprises to enhance their adaptive capacity further. Migration leads to loss of family labour and affect agricultural productivity but the net effect of this would depend on the opportunity cost of labour in the rural setting. Harsh climate and lack of well-functioning factor and produce markets might imply low opportunity cost of labour in agricultural sector in the context of Namibia. Furthermore, the effects of family labour loss through migration can partially be countervailed by using remittances to hire tractor services especially during land preparation periods. Since consumption expenditure among the migrant-sending households could also be affected by the reduction in the number of the remaining family members, the study also estimates the relative food expenditure share by household's migration status.

3.3.2 Analytical framework (Empirical model of impact evaluation)

One of the major challenges in evaluating causal impacts of migration using cross sectional survey data is the perverse endogeneity and lack of appropriate exogenous instruments that are correlated with migration decisions but uncorrelated with the errors in the outcome equation. Most of the push factors driving an individual's decision to migrate are also likely to affect outcome variables of interest at the household level. The challenge is that an instrument that works for one circumstance might not work in another context.

The missing data problem, or lack of a credible counterfactual, can be resolved by employing experimental methods in migration studies ([McKenzie & Yang, 2010](#)). However, such experiments tend to be expensive where they involve tracking the migrants to their destinations and tracing their families back to their rural home villages (and countries in the case of international migration). For observational studies, [Lewbel \(2012\)](#) proposes using error heteroscedasticity to construct instruments using available exogenous covariates to identify and estimate endogenous regressors. He later demonstrates that the assumptions required for identification are also applicable when the endogenous covariate is binary ([Lewbel, 2018](#)). Here we present these assumptions and application in the context of migration as an endogenous regressor, due to either unobserved heterogeneity (*omitted variable bias*) or reverse causality. The model can be presented as

$$Y_i = \mathbf{X}'\beta_1 + M_i\gamma + U\alpha_1 + v_1 \quad (24)$$

$$M_i = \mathbf{X}'\beta_2 + U\alpha_2 + v_2 \quad (25)$$

Where Y_i is the outcome variable of interest (*consumption expenditure, food security and adaptive capacity in present case*) for household i , \mathbf{X} a vector of exogenous covariates, M is the endogenous migration variable and β_1, β_2 and γ are parameter vectors. U is a common unobserved or omitted variable that directly determines both the migration decision and outcomes of interest. V_1 and V_2 are uncorrelated with the exogenous variables and are independent of each other.

Let $\varepsilon_1 = \alpha_1 U + V_1$ and $\varepsilon_2 = \alpha_2 U + V_2$. Key assumptions for identification of the reduced form model are $E(\varepsilon_1 X) = 0$ and $E(\varepsilon_2 X) = 0$.

For structural model identification, one would make the strong assumption that at least some of the elements of β_1 are equal to zero for the standard instrument variable estimation to be consistent. In the absence of identifying restrictions and heteroscedasticity of ε_2 , [Lewbel \(2012\)](#) argues that the structural model is identified if the restrictions $Cov(X, \varepsilon_2^2) \neq 0$ and $Cov(Z, \varepsilon_1 \varepsilon_2) = 0$. $Z \in \mathbf{X}$, represents

generated valid instruments for migration that are constructed from the mean-centred exogenous covariates \mathbf{X} and the vector of residuals, $\boldsymbol{\varepsilon} = (\varepsilon_1, \varepsilon_2)$, from the auxiliary first stage regression.

$$Z = (X_j - \bar{X}) * \boldsymbol{\varepsilon} \quad (26)$$

Since Z is a subset of the \mathbf{X} vector, no additional information outside of the model is required. The key assumptions are that ε_1 and ε_2 are independent ($\varepsilon_1 \perp \varepsilon_2 | Z$) and $E(\varepsilon_1) = 0$. These two assumptions ensure that the key identifying assumption $Cov(Z, \varepsilon_1 \varepsilon_2) = 0$ holds.

[Lewbel \(2018\)](#) shows that one can achieve identification even when the orthogonality condition of the errors is violated. Accordingly, the procedure is implemented in two steps. In the first step, $\hat{\beta}_2$ is estimated, using either logit or probit models, by regressing the endogenous migration dummy on exogenous covariates \mathbf{X} . The goal is to obtain the residuals $\hat{\varepsilon}_2$ i.e.

$$\hat{\varepsilon}_2 = M_i - X' \hat{\beta}_2$$

In the second step, $\hat{\beta}_1$, and γ are estimated using linear 2SLS regression of Y_1 on endogenous M using \mathbf{X} and $Z \hat{\varepsilon}_2$ as instruments. By construction $E(Z) = 0$. Stata routine `ivreg2h` developed by [Baum et al. \(2012\)](#) is used for estimation. This provides three sets of estimates: the classical IV estimates that use excluded instruments, estimates using only the generated instruments, and estimates using both the excluded instruments and generated instruments. The results section gives a comparison of the results obtained using the constructed instruments and those obtained using both the excluded instruments and generated instruments.

This study uses destination of migrants as instrument for migration decision. Intuitively, target destination would directly influence migration, but it is unlikely to affect the wellbeing outcomes of those that remain in rural homes except through remittance flow. The second excluded instrument is the number of extended family members that are not part of the household, employed outside the region of residence for more than 5 years. These established kinship ties are an important source of information and could offer temporary support systems to migrants, but are less likely to affect the outcomes of interest directly. [Karanja Ng'ang'a et al. \(2016\)](#) used this instrument in their study on migration and self-protection against climate change among Kenya's pastoral communities. The third excluded instrument is the degree of social networking available, as measured by the number of informal networks, community organizations or clubs. These could be crucial in mobilizing resources needed to cover the cost of migration. Although the third instrument passes the first stage, the exclusion restriction is likely to be violated and therefore the three instruments are used together with the constructed instruments in this estimation. All the

instruments pass Hansen’s J-validity test with high *P*-values. ([Lewbel, 2018](#)) recommend combining both the generated and standard instruments for increased efficiency.

3.3.3 Study Area

The study area covers three administrative regions, Omusati, Oshana and Oshana, situated in the Central North Namibia (Figure 3-2). The Northern regions are home to most of Namibia’s population ([M. N. Angula & Kaundjua, 2016](#)). Namibia is one of the driest country in sub-Saharan Africa with average annual precipitation of 25 mm in Southwest and 700 mm in the North East ([M. Angula, 2010](#); [Reid et al., 2008](#)). The country is characterized by hot and dry climate with extremely variable rainfall in both space and time ([Republic of Namibia, 2011](#)). The temperatures increase in Namibia has been thrice the global average temperature rise reported in the 20th century. The Northern region is characterized by alternating floods and droughts while droughts dominate the Southern region ([Kgabi et al., 2016](#)). Most households reported to have experienced changes in the occurrence of extreme climatic events pattern and had negatively been affected (Table 3-1). Although soils are mainly sandy, most families practice mixed subsistence farming, with the main crops being pearl millet (*Locally known as Mahangu*) and sorghum ([Uno, 2005](#)). This is evident in Table 1 where all interviewed households grew millet and majority of them sorghum. One of the most popular improved pearl millet cultivar is a composite of early maturing, open pollinated variety called Okashana-1 ([Uno, 2005](#)). Legumes and especially cowpeas are also commonly grown (Table 3-1).

Table 3-1: Background information of the study area (Source: Author)

		Omusati (n=288)	Oshana (n=190)	Oshikoto (n=175)	All (n=653)
Crops	Planted millet	100	100	99.43	99.54
	Grew sorghum	88.89	85.79	78.86	85.17
	Grew legumes	63.89	66.32	69.71	66.06
Livestock	Kept poultry (%)	94.1	93.68	92.00	93.42
	Kept cattle (%)	47.92	32.11	45.71	42.81
	Kept goats (%)	77.78	57.37	61.14	67.38
	Kept local pigs (%)	64.58	57.89	40.00	56.05
Other support	Government relief (%)	61.11	91.58	87.43	77.03
	Social security	27.43	17.89	23.43	23.58
	Old age pension grant	45.83	22.63	28.00	34.3
Perceived climate change	Affected by change in dry spells (%)	75.69	79.47	84.57	79.17
	Affected by change in drought (%)	77.78	80.53	89.14	81.62
	Affected by change in wet season (%)	72.57	68.95	74.29	71.98
	Affected by floods (%)	49.65	77.89	37.71	54.67

Poultry is the most common livestock type, kept by over 90% of households in all the three regions. Goats and local pigs are also popular, probably because of their resilience to harsh conditions in dry areas. Cattle, which require more pasture and water, are kept by 47% of households in Omusati, 32% in Oshana and 45% in Oshikoto regions respectively. Many households still rely on government relief and other transfer payments especially during the droughts.

3.3.4 Sampling

The study used primary survey data collected from a representative sample of 653 rural households in arid regions of Northern Namibia. A multistage sampling procedure was used to generate a self-weighted probabilistic sample. The study covered seven constituencies in three administrative regions, namely Omusati, Oshana and Oshikoto (Figure 3-2). The constituencies are Onesi, Oshikuku and Otamanzi in the Omusati region, Okaku and Ongwediva in the Oshana region, and Olukonda and Omuthiya in the Oshikoto region.

Field research involved a preliminary visit to all the selected study regions to generate sampling frames and to pilot the survey tool with the local people. A list of all the villages in each constituency was obtained at the constituency office, and the number of villages required for each constituency was randomly selected using probability proportionate to size sampling (PPS). The second step involved visiting the selected villages and listing all the households in each of them with the help of the village headmen or elders. Ten households from each of the villages were then randomly selected, with an additional five for possible replacements. This exercise was carried out in May 2017 and used as the basis for the survey logistics and a revision of the survey instrument. Two trained teams, each consisting of five enumerators and a supervisor, collected the data from 653 households, using Computer-Assisted Personal Interviewing (CAPI), between July and September 2017.

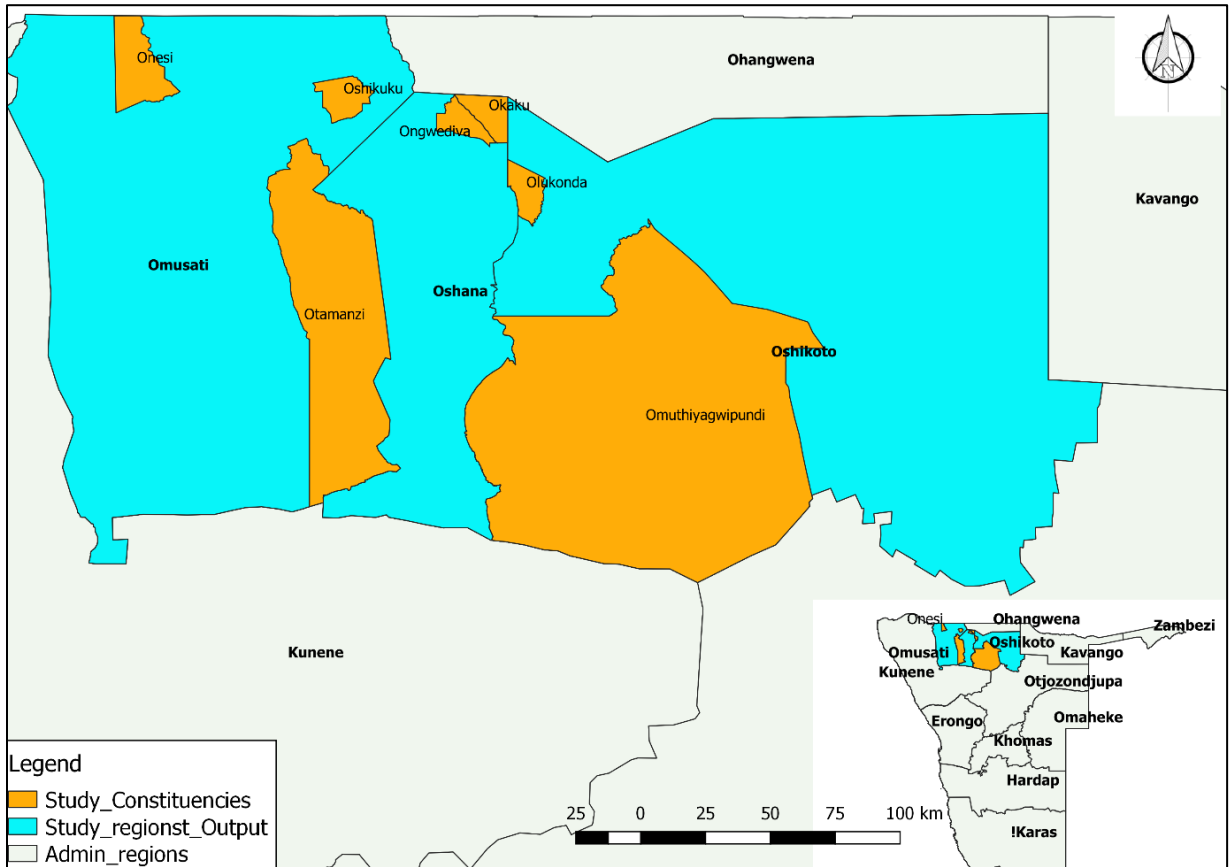


Figure 3-2: Study area map showing regions and constituencies covered (source: author)

3.4 Data description and descriptive analysis

The following section gives a brief description and gender-disaggregated summary statistics of the key demographic, social, and economic characteristics of migrants. The section also characterizes migration processes to shed light on the reasons for migration as well as on target destinations. It also gives a descriptive analysis comparing the migrant and non-migrant households to determine if they are statistically different on observable social, economic, and institutional characteristics.

3.4.1 Gender-differentiated migrant characteristics

Age: Most migrants were young, with an average age of 32 years. Female migrants were slightly younger (30 years) than their male counterparts (33 years) (Table 3-2).

Education: The average education of migrants in our sample was grade 10, implying that most migrants had completed junior secondary¹² school. More female migrants than male had completed both junior and senior secondary school (Figure 3-3). Over a third of those who completed grade 10 did not proceed to grade 12, an entry requirement for enrolment in tertiary institutions. This translated to low transition rates (21.2%) to tertiary education. These results almost mirror the World Bank's statistics of 20.69% enrolment at tertiary level. The data shows that more females than males have enrolled in tertiary education and the gap has been widening since 2008 (Figure 3-4). Transition to university education was very low among migrants, with 13% enrolling for undergraduate and only 2% for postgraduate degrees (Table 3-2).

Migrants who drop out of school after primary school and those who do not complete secondary school can acquire necessary skills through vocational training. However, the data suggests low access to technical and vocational education and training (TVET) colleges. Only about six per cent of migrants had attended these colleges. In their paper on income mobility and poverty dynamics, [Woolard and Klasen \(2005\)](#) observe that lack of education keeps families in poverty traps. Formal education and non-farming experience are likely to be rewarded more in the non-farming sector ([Junge et al., 2015](#)).

¹² After successfully completing the grade 10 examination, the students receive a junior secondary certificate. Those who proceed write a final Cambridge-moderated exam in grade 12 and receive a senior secondary certificate that allows them to be admitted to tertiary-level institutions.

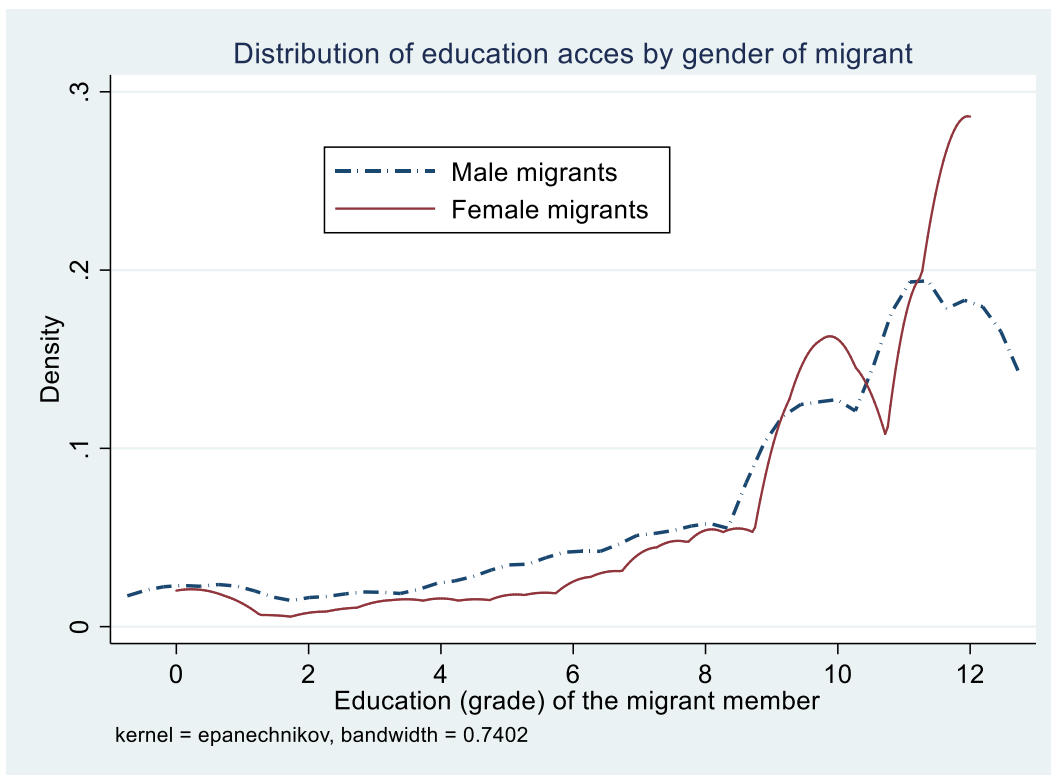


Figure 3-3: Distribution of Education by gender of migrant members (Source: Author)

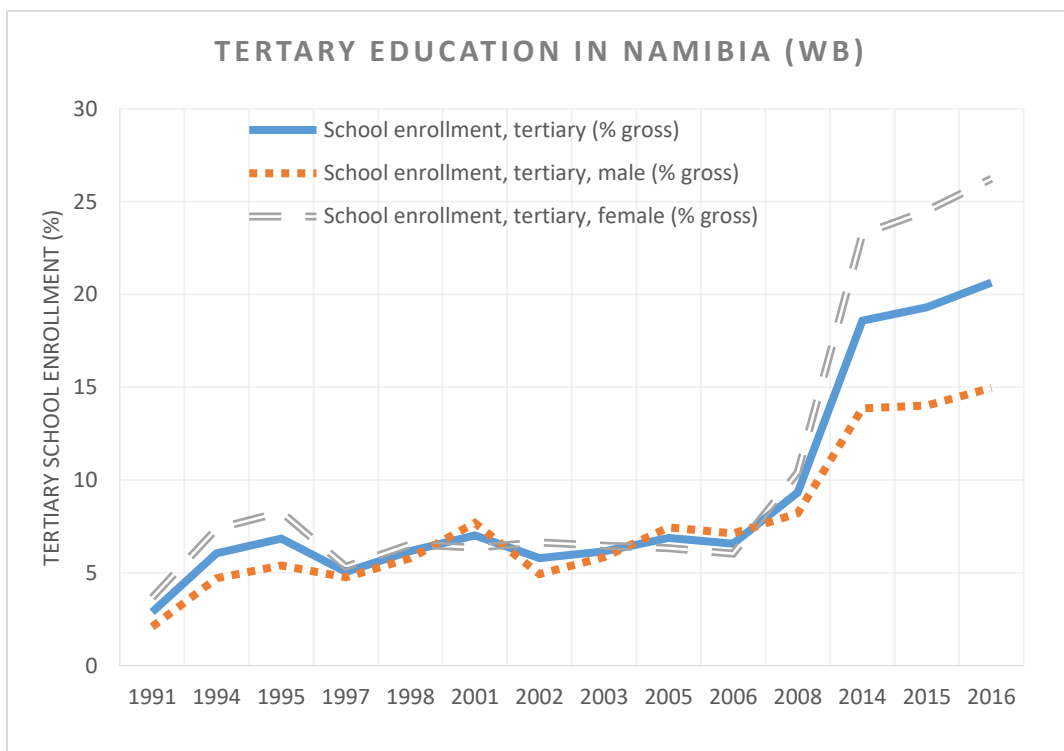


Figure 3-4: Tertiary education enrolment by gender (source: by author using WB open data).¹³

¹³ Ratio of total enrolment at tertiary level to the population of those that successfully completed secondary education. <https://data.worldbank.org/> WB Total tertiary enrolment was 21% and the result from this study is 21.16%.

Table 3-2: Demographic and economics characteristics of migrants (Source: Author)

		Female n=554)	Male (n=609)	All (n=1,163)
Demographic characteristics	Age (years)	30	33	32
	Education (Grade)	10	9	10
	Vocational training (%)	5.05	6.57	5.85
	Tertiary-certificate (%)	3.43	1.97	2.67
	Tertiary-diploma (%)	3.97	2.63	3.27
	Tertiary –Bachelor’s degree (%)	15.88	10.67	13.16
	Tertiary (post graduate) (%)	2.35	1.81	2.06
Marital status of the migrant	Married (monogamous) (%)	16.06	17.41	16.77
	Single (%)	81.95	81.28	81.6
	Divorced/windowed (%)	1.98	1.31	1.64
Relation to the head (%)	Household head	2.16	7.88	5.16
	Spouse	1.62	0.82	1.2
	Child	58.3	53.04	55.55
	Grandchild	22.92	25.29	24.16
	Sister/brother	5.96	5.75	5.85
	Other relatives	8.12	6.4	7.22
	Unrelated friend	0.9	0.82	0.86
Training	No Professional training	71.7	64.4	67.8
	Police/Army	5.2	9.9	7.7
	Teacher	6.1	3.4	4.7
	Mechanic/ Welder	0.9	6.9	4.0
	Carpenter/ Plumber/ Mason	1.8	4.9	3.5
	Accountant	4.0	2.0	2.9
	Nurse	4.9	0.5	2.6
	Driver	0.0	4.6	2.4
	Engineer	1.1	2.3	1.7
	Hairdresser/Barber	1.6	0.2	0.9
	Tailor	1.6	0.0	0.8
	Doctor	0.9	0.5	0.7
	Lawyer	0.2	0.5	0.3
Occupation	Salaried employment	36.64	34.49	36.54
	Not working	26.35	22.99	24.59
	Student	18.05	12.64	15.22
	Informal business	10.65	6.24	8.34
	Artisan (carpenter, plumber, welder)	2.17	9.36	5.93
	Wage labour	1.62	8.05	3.71
	Registered formal business	1.62	3.94	2.84
	Agriculture (farmer)	1.99	1.31	1.89
	Other	0.91	0.98	0.94

Professional Training: Over two-thirds of the migrants had no post-school skills training, the majority of them being female. The proportion of female migrants without training was 72%, while that of males was 64%. The most common form of training for migrants was police or army (7.7%), which attracted mainly males. More female migrants than male engaged in professional training such as teaching, nursing and accountancy. Male migrants on the other hand trained as mechanics, welders, carpenters, masons, plumber and drivers. Very few migrants had training in medicine, law or engineering.

Marital status: Only a fifth of migrants were married and those mostly in a monogamous relationship. Fewer than two per cent were either divorced, separated or widowed.

Relation to the head: Most of the migrants were children or grandchildren of the household heads. Household heads comprise only five per cent of migrants and most of these were male.

Occupation: Slightly more than a third of the migrants obtained some salaried job, as domestic workers, teachers, security guards, drivers, or in the police and army. More female migrants (36.64%) were in salaried employment than their male counterparts (34.5%). However, a quarter of the migrants had no employment and many of these were female. There were more female student migrants (18%) than male student migrants (12.64%). While more females than males were self-employed in informal businesses, more males than females worked as artisans or as wage labourers.

3.4.2 Migration characterization

Motivation to migrate: The main motivation for 44% of the migrants was to seek a better life and better opportunities (36%). Slightly more male migrants (46%) than female migrants (42%) identified this as their main motive. More females (12%) than males (10%) moved because of better schools in the target destination. Motivation to migrate for six per cent of female and four per cent of male migrants came from relatives.

Reason for migration: Lack of job opportunities in the rural homes was the main reason that 36% of females and 42% of males gave for migrating. More female than male migrants migrated to acquire education. The proportion of female and male migrants who migrated because they got a job was 28% and 33% respectively. Very few migrants moved to start a business or because they got married (Table 3-3).

Facilitation: Almost three-quarters of migrants moved on their own, suggesting that the decision to migrate is not always made at the household level. Results suggest that kinship ties rather than social networks are more important as a determinant of migration. Only about one per cent migrated with the help of friends and neighbours.

Duration in the destination: The average length of time spent in the destination is between 1 and 5 years, for 45% and 40% of female and male migrants respectively. Slightly less than a fifth of the migrants had stayed in the migration destination for between five and ten years. Slightly more than a tenth had stayed at their destination for over ten years.

Remittances: The proportion of migrants who sent remittances to their families back in the rural areas was 38.26% (Table 3-3). The proportion of men sending remittances was slightly larger (39.4%) than that of female migrants (37%). The average amount of remittances received annually by migrant-sending household was N\$4672.88. The average amount male migrants remitted was N\$4755.48, compared to N\$4575.21 sent by female migrants. Subsection 5.1 will present an empirical analysis of key determinants of the amount of remittances received by the households from which the migrants came, with special emphasis on the role of education and training.

Table 3-3: Gender disaggregated characterization of migration process (Source: Author)

		Female (n=554)	Male (n=609)	All (n=1163)
Motivation	Seek better life	42.4	46.0	44.4
	No opportunities in the village	34.8	36.5	35.7
	Better schools	12.3	9.9	11.0
	Invited by relatives	6.1	3.9	5.0
	Droughts	1.3	2.3	1.8
	Marriage	2.5	1.1	1.7
	Moved permanently	0.5	0.3	0.4
Reason for moving	Look for employment	35.7	42.4	39.2
	Got a job	28.3	33.2	30.9
	Acquire education	25.8	17.4	21.4
	Start own business	2.9	2.3	2.6
	To join parents	2.9	2.1	2.5
	Married	2.5	1.1	1.7
	Other reasons	1.8	1.5	1.7
Migrated through	Own (n=854)	69.3	77.2	73.4
	Relative/ family (n=290)	28.9	21.3	24.9
	Friend/Neighbour (n=11)	1.3	0.7	0.9
	Contractor/Agent (n=1)	0.2	0.0	0.6
	Government support (n=7)	0.4	0.8	0.1
Duration	<6 months	9	9	9
	6months-1 year	18	19	18
	1-5 years	45	40	42
	5-10years	16	18	17
	>10 years	12	14	13
Remittances	Remittances	37.0	39.41	38.26
	Amount of remittances (NAD)	4575.21	4755.48	4672.88

3.4.3 Destination and form of migration

Figure 3-5 shows the most common migration destinations in Namibia. The city of Windhoek was the destination of choice for 43% of migrants. Walvis Bay was the second most popular destination city with 9% of migrants, followed by Oshakati (6.8%), Ondangwa (5.5%), Swakopmund (4%) and Ongwediva (3.4%). It is clear from the figure that the main form of migration is internal rural-urban. International destinations accounted for only one per cent of rural outmigration in the sample. Previous studies in the Southern Africa region, covering seven countries including Namibia, have shown that households with international migrants were more likely to receive remittances both in-kind and cash, compared to those of internal rural-urban migrants ([Crush & Caesar, 2017](#)).

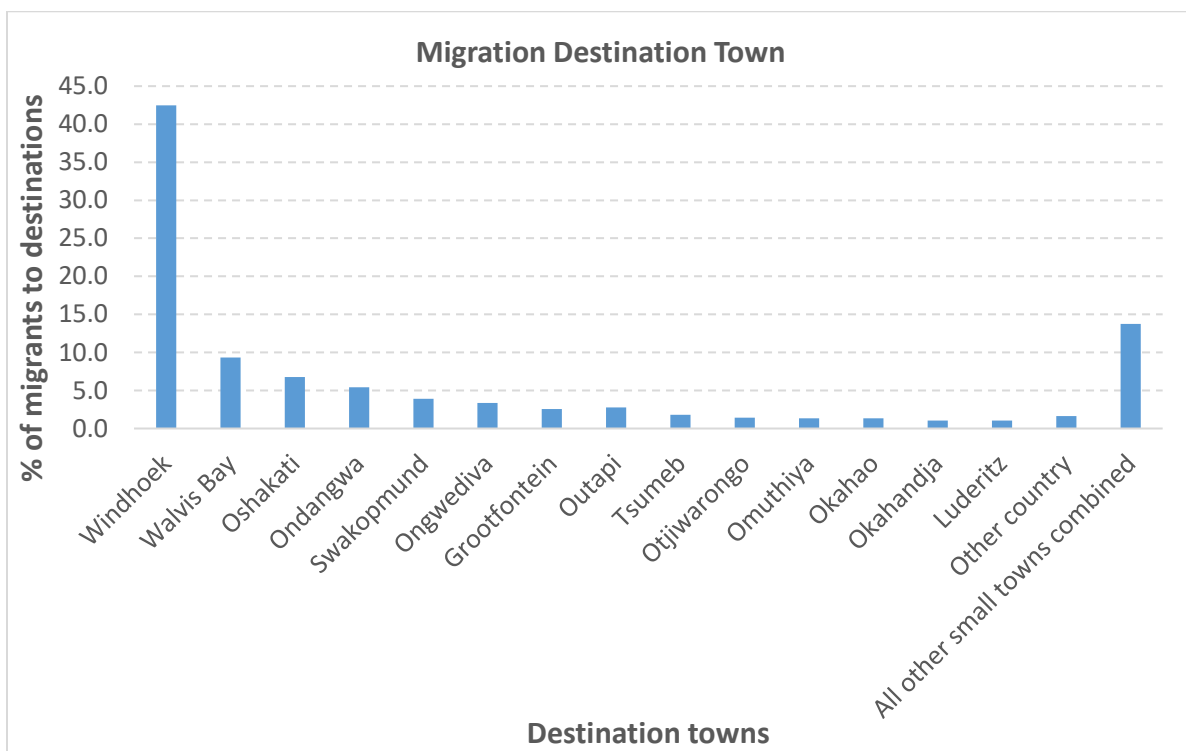


Figure 3-5: Migrants' destination towns (Source: Author)

3.4.4 Summary statistics by household's migration status

This section gives a comparative descriptive analysis of key variables by households' migration status. Migrant-sending households comprise 61% of the 653 households in the survey and two-thirds had more than one migrant. However, only about half the migrant-sending households received remittances, albeit irregularly. Results show that migrant-sending households and those that had no migrant were similar in many individual, household and social characteristics (Table 3-4). The average age of the household head was 61 years, and this did not differ significantly by migration status of the households. Past studies show that young Namibians usually migrate to towns and cities, leaving behind children and the elderly in the rural villages ([Greiner, 2011a](#)).

The two groups were about the same for 'level of education of the household head' at 5.6 years, and for average household size (6 persons). The average farm size was 6.5 hectares and did not differ significantly between the two groups. The average cultivated land was 3.6 ha, about half of the farm size. At least three-quarters of the households received government drought relief and the difference in this by households' migration status was not significant. The two groups had about the same number of livestock assets, although migrant households had slightly more. On average, the households had two adult members contributing to household income. Farm income from both crops and livestock was about the same between the two groups of households, but migrant-sending households' non-farming income was N\$7400 higher than that of households without a migrant. Pension income also did not differ significantly by household migration status.

The two groups were similar in terms of access to social networks. These include membership in social groups, number of social groups an individual belonged to, and number of friends and other households that a family could turn to in time of need. Looking at the outcome variables, migrant-sending households seem to be better off than non-migrant households are.

Migrant-sending households had a significantly higher annual income, by about N\$3900; monthly income was higher by approximately N\$200 and food spending by about N\$70. The results also suggest that the migrant-sending households were slightly better off in terms of food security. Figure 3-6 shows the distribution of annual and monthly expenditure, food expenditure and dietary diversity scores. Household dietary diversity score was constructed following [Swindale and Bilinsky \(2006\)](#), as a simple count of the number of food groups that the households consumed.

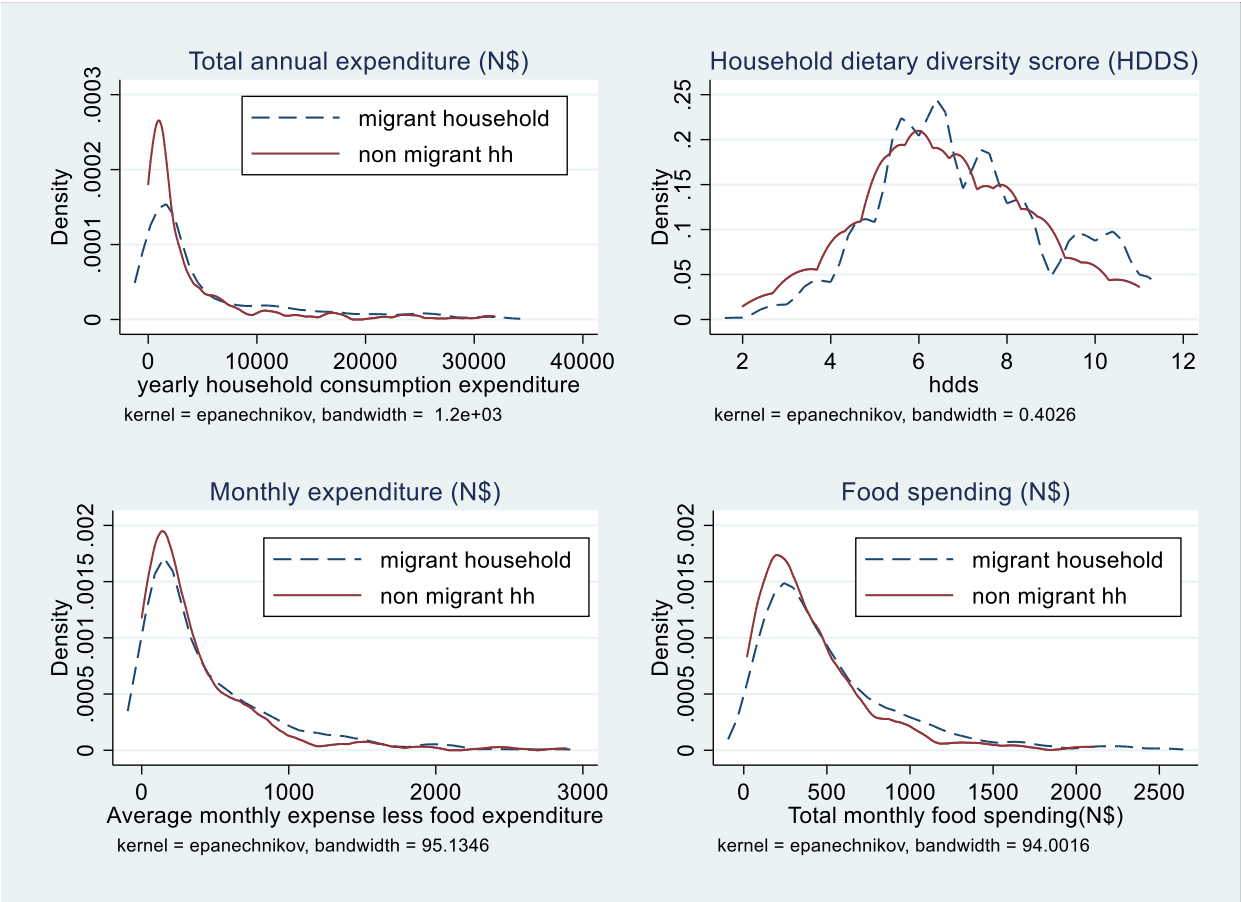


Figure 3-6: Distribution of key welfare outcomes by household's migration status (Source: Author)

Table 3-4: Summary statistics by migration status (Source: Author)

Variable	Control (n=253)		Treatment (n=400)		Whole sample (n=653)		Statistical test	
	Mean	Std. Err.	Mean	Std. Err.	Mean	Std. Err.	Mean difference	
Individual	Household head age (years)	60.70	1.05	62.20	0.85	61.62	0.66	-1.504
	Household head education	5.63	0.25	5.66	0.20	5.64	0.16	-0.0265
	Male head	0.48	0.03	0.40	0.02	0.43	0.02	0.083**
Household	Access to mobile money services	0.19	0.02	0.27	0.02	0.24	0.02	-0.082**
	Household size (Adult equivalent)	5.38	0.19	5.76	0.16	5.62	0.12	-0.379
	Farm size (ha)	6.34	0.27	6.66	0.23	6.54	0.18	-0.321
	Area under crop (acre)	3.61	0.15	3.57	0.10	3.58	0.08	0.0358
	Tropical livestock units (tlu)	4.90	0.62	6.16	0.64	5.67	0.46	-1.26
	Members with vocational training	0.11	0.02	0.17	0.02	0.14	0.02	-0.06
	Members with tertiary training	0.12	0.03	0.10	0.02	0.11	0.02	0.02
	Asset index	-0.17	0.09	0.11	0.08	-1.67e-09	0.06	-0.28**
	Accessed seasonal forecasts	0.53	0.03	0.55	0.03	0.54	0.02	-0.02
Income	Government drought relief	0.79	0.03	0.76	0.02	0.77	0.02	0.0395
	Adults contributing to household income	1.66	0.08	1.59	0.06	1.62	0.05	0.0676
	Off farm income (N\$)	7694.70	2342.48	15124.03	2360.62	12245.59	1711.94	-7429.30**
	Crop income (N\$)	1282.64	234.68	1267.69	250.37	1273.48	178.17	14.96
	Livestock income (N\$)	241.98	85.70	756.95	238.41	557.43	150.01	-515*
	Pension income (N\$)	8253.76	2080.26	9496.50	1443.80	9015.01	1195.83	-1242.7
Social networks	Number of social networks	0.22	0.03	0.23	0.03	0.22	0.02	-0.00761
	Group membership	0.16	0.02	0.16	0.02	0.16	0.01	0.00
	Number of friends	3.28	0.41	3.56	0.30	3.45	0.24	-0.28
	Households that can be reached to help	1.44	0.10	1.63	0.10	1.55	0.07	-0.19
Outcome	Yearly expense (N\$)	4773.99	829.98	8725.65	1235.01	7194.61	824.98	-3951.7**
	Monthly expense (N\$)	420.31	41.03	645.56	90.48	558.29	57.79	-225.20**
	Total monthly food expenditure (N\$)	442.91	37.74	511.84	21.66	485.13	19.77	-68.93*
	Household dietary diversity score (hdds)	6.69	0.12	7.08	0.10	6.93	0.08	-0.386**
	Months of inadequate food provisioning	1.43	0.15	1.47	0.12	1.45	0.10	-0.030

*** p<0.01, ** p<0.05, * p<0.1 [Exchange rate was 1 USD = 13.45 NAD at the time of the survey]

3.5 Estimation Results and Discussion

3.5.1 The role of education and training as drivers of remittances

Education and training are key determinants of migration outcomes as they increase a migrant's chance of finding a job in the non-farming sector. Since the most common impact-pathway of migration on household wellbeing indicators is through remittances, the hypothesis that tertiary training and post-school skills training have an impact on remittances is tested using data from 1163 migrants in the sample. A combination of exogenous and constructed instruments using Lewbel's approach is employed to deal with self-selection and omitted variable bias. Self-selection could arise because of other unobserved variables such as the innate ability of the migrants and individual motivation to send remittances like altruism or self-interest. The level of education and training of the household head is used as an instrument for the education of the migrant. Parent education attainment can predict the education achievement of their own children ([Davis-Kean, 2005](#)). These instruments directly affect the education of the migrants but are likely to be uncorrelated with the unobserved factors (*innate ability, altruism, self-interest etc.*). The instruments (both exogenous and generated) pass the Hansen J validity test (Table 3-5).

The amount of money sent in remittances to recipient households did not vary by either the age or gender of the migrant. However, remittances received by households varied by region. Remittances received by recipient households in the Omusati region were higher by N\$929 than those in Oshana and by N\$898 than those in Oshikoto.

Basic education in Namibia was free and compulsory up to grade 10 at the time of the survey. Results show that households that invested in tertiary-level education for their children received significantly higher benefits than those that did not. On average, a migrant with a college or university training sent at least N\$1155 more than those that did not have a tertiary-level education. These results provide evidence of the importance of post-school skills training in enhancing migration outcomes. Migrants having skills training on average sent at least \$1230 more than those without any training. Equipping migrants with post-school skills training, increases their likelihood of either finding a job or being able to become self-employed. Migrants who had salaried employment on average sent to their rural families N\$ 1725 more than those engaged in other activities like farming and wage labour. The self-employed migrants on average sent about half of the amount sent by migrants who had salaried employment.

Remittances sent by a migrant head (rural family head who has temporarily gone to town to work), were significantly higher, by N\$4000, than if the sender was a child or a grandchild, and by N\$4829 than those sent by any other household member. The amount of remittances increased the longer migrants spent at the destination, possibly because they would have had time to get better jobs and develop their social networks in their new destination areas of residence.

Table 3-5: Drivers of the amount sent as remittances (N\$) by migrants to rural families (Source: Author)

VARIABLES	(1)	(2)	(3)	(4)
	Generated Instruments		Generated and Excluded Instruments	
	coef	se	coef	se
Migrant has higher education (dummy)	1,157.95**	508.43	1,155.83**	505.73
Migrant has post-school skills trainings	1,232.93**	514.28	1,234.38**	515.27
Home region (base category=Omusati)				
Home region: Oshana	-929.21*	496.86	-929.18*	496.81
Home region: Oshikoto	-898.39**	410.20	-898.33**	410.11
Migrant age	12.06	14.00	12.07	14.00
Migrant sex (1=male;0=female)	-55.35	385.33	-55.27	385.21
Salaried employment (1=yes;0= no)	1,725.34***	400.17	1,725.57***	400.44
Self-employed (1=yes;0= no)	898.29***	309.93	898.65***	310.25
Migrant's relation to household head: (base category =head)				
Relation to head: child	-3,990.47***	810.58	-3,990.27***	810.70
Relation to head: others	-4,828.32***	867.51	-4,828.21***	867.47
Relation to head: grandchild	-4,008.06***	819.36	-4,008.01***	819.36
Migration duration	372.27*	221.60	372.31*	221.65
Destination: Windhoek	268.28	372.54	268.67	372.05
Destination: abroad	18,843.68	16,845.75	18,844.16	16,846.45
Destination: Other towns	240.52	297.47	240.85	297.15
Affected by total crop failure	-467.25*	254.47	-467.21*	254.49
Affected by d low yields due to climate	394.44	246.99	394.34	247.00
Income of livestock products	0.18*	0.11	0.18*	0.11
Constant	2,642.36***	943.25	2,642.12***	943.32
Observations	1,163		1,163	
R-squared	0.17		0.17	
Hansen J statistic JP	0.97		0.99	

*** p<0.01, ** p<0.05, * p<0.1 [Exchange rate was 1 USD = 13.45 NAD at the time of the survey]

3.5.2 Impact on annual consumption spending

This subsection presents the results of three estimators: standard IV, generated instruments and a combination of both the standard exogenous and generated instruments (Table 3-6). Compared to non-migrant households, rural families with migrants have significantly lower less frequent annual consumption spending like health, education, clothing and housing or investment in off-farm enterprises. Standard IV regression results show households with migrants had N\$8,000 lower consumption spending than non-migrant families. Results of the standard IV are higher than those estimated using the generated instruments (N\$4,872) and a combination of standard and generated instruments (N\$3,080). Since combining both the standard and generated instruments increases efficiency ([Lewbel, 2018](#)), we report the results of combined exogenous and constructed instruments, as shown in column 5 of Table 3-6.

The negative coefficient on annual consumption spending suggest that migrant households were relatively poor compared to families that had no migrant members. [C. Nguyen and Vu \(2017\)](#) however note that the lower consumption expenditure among the migrant-sending households could also be due to the reduced number of the remaining family members. The intuition here is that the members of the relatively richer households in the communities are entrepreneurs or commuting to work in the rapidly urbanizing towns of Outapi, Oshakati, Ongwediva and Ondangwa as well as other small towns like Oshikuku, Ruakana and Omuthiya ([Frayne & Pendleton, 2001](#)). Furthermore, the next section shows a relatively high monthly food budget share among migrant-sending households.

Most of the migrants lacked post-school training that would give them critical skills to obtain better jobs. The results corroborate previous research, which shows that most migrants go to Windhoek and are poor, food insecure, unemployed and live in informal settlements in the city ([Pendleton et al., 2014](#)). Conceptually, poverty induces migration and although the concept is well documented in the context of international migration ([Adepoju, 2004](#); [De Haas, 2005](#)), it could also apply to internal rural-urban circular type of migration.

However, results suggest households can leverage on the number of migrants to improve their consumption spending. An additional migrant in a family was associated with an N\$987 increase in less frequent consumption spending, *ceteris paribus*. However, as already illustrated in in previous section (Table 3-5), increasing the quality of human capital has more impact on household welfare than increasing the number of migrants.

Annual consumption spending in male-headed households was N\$2,000 less compared to households headed by females. Training, participation in non-farm economic activities and wealth endowment as measured by physical assets, livestock and land holding, were associated with higher consumption

spending. Having a member in the household with vocational training increased average consumption spending by about N\$3,357, *ceteris paribus*. Having a household head with non-farming occupation increased average consumption spending by at least N\$2,763.

Households that had registered for mobile money services on average spent between N\$3,742 and N\$4,205 more than households that did not have access. Wealth endowment, as measured by physical assets, livestock assets and land holding, was associated with higher consumption spending. Increasing livestock ownership by one tropical unit led to an increase in annual consumption spending by between N\$325 and N\$341.

Table 3-6: Impact on less frequent annual consumption spending (Source: Author)

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
	StdIV		GenInst		GenExtInst	
	coef	se	coef	se	coef	se
Migration status	-8,050.86**	3,847.96	-4,871.77	5,040.03	-3,079.76*	1,863.25
Number of migrants	2,700.82**	1,142.17	546.85	818.62	986.72**	475.80
Oshana	109.53	1,676.31	-360.60	1,378.41	335.01	1,074.13
Oshikoto	-812.76	1,426.06	-948.57	1,242.10	-312.58	1,039.97
Male head	-2,663.19**	1,135.35	-2,354.32**	1,087.19	-1,916.41**	823.78
Head age	-111.10	168.00	-19.81	142.75	-16.70	119.46
Head age2	0.79	1.28	0.32	1.16	0.28	0.96
Head education	-160.00	189.63	-1.35	160.46	23.69	128.31
Head has training	5,829.40**	2,821.39	2,263.06	2,229.68	1,994.90	2,011.07
Members with vocational training	5,556.60*	3,318.22	3,269.22***	1,266.33	3,357.02***	1,151.96
Control over life decisions	1,727.25***	575.44	1,597.25***	507.25	1,620.42***	428.90
Households that can reached to help	1,399.31*	798.31	1,105.65**	535.61	785.64*	441.13
Number of dependents	-309.14	261.97	-312.71	209.24	-330.99*	177.45
Number of youths	-347.20	421.76	87.10	328.91	126.04	266.48
Number of middle age	345.29	559.37	101.11	483.62	266.48	425.59
Head main occupation: nonfarm	3,682.98**	1,646.94	3,045.76**	1,409.56	2,763.19**	1,171.45
Head main occupation: farmer	900.08	1,147.53	818.04	993.03	761.23	820.93
Access to mobile money services	3,657.90**	1,441.05	4,205.81***	1,386.23	3,742.65***	1,075.83
Asset index	1,747.29***	604.10	1,140.60***	433.55	984.31**	383.25
Tropical livestock unit (tlu)	424.83**	168.66	341.31***	95.71	325.20***	88.95
Farm size (ha)	185.96	128.95	208.89*	113.64	206.17**	98.57
Accessed seasonal forecasts	-2,384.15**	1,140.08	-1,111.77	1,028.11	-1,301.45	825.92
Received government relief	-1,387.22	1,778.23	-538.74	1,350.59	-720.97	1,049.17
Risk taking behaviour	-74.15	399.00	-91.58	361.74	-101.68	290.69
Affected by dry spell	-46.54	1,321.99	257.21	1,150.08	95.78	904.87
Constant	-188.63	7,269.87	-3,776.05	5,849.51	-5,524.44	4,591.78
Observations	646		646		646	
R-squared	0.27		0.23		0.23	
Hansen J statistic	0.65		0.99		0.99	

*** p<0.01, ** p<0.05, * p<0.1 [Exchange rate was 1 USD = 13.45 NAD at the time of the survey]

3.5.3 Impact on frequent monthly consumption spending (N\$) and food Budget share

Results indicate that on average, monthly consumption spending among migrant-sending households was significantly less by between N\$740 and N\$705 than for non-migrant households (Table 3-7). This relative deprivation of migrant-sending households is further confirmed by a higher monthly food budget share. However, an additional migrant resulted to an increase in the household's monthly consumption spending by N\$128 or US\$10 *ceteris paribus*. This is associated with a three-percentage point reduction in the monthly food budget share. This further confirms our hypothesis that money received by migrant-sending households in cash remittances are spent on necessities.

Like in annual consumption spending, the quality of a household's human capital, engaging in non-farm economic activities and wealth endowment are evidently the key drivers of monthly consumption spending. Having a household head with post-school skills and technical training was associated with at least N\$820 or US\$60 increase in monthly consumption spending. Similarly, an additional member with vocational technical training led to a N\$238 increase in consumption spending. Having a household head engaged in non-farming activities was related to a four-percentage point reduction in food budget share. Households who received government drought relief had relatively higher food budget share than other households, indicating their vulnerability and relative deprivation compared to other households. Other factors associated with higher monthly consumption spending are access to mobile money services, increase in income from informal businesses, livestock and physical assets.

Table 3-7: Impact on monthly consumption expenditure and food budget share (Source: Author)

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Total monthly expenditure				Food share of monthly budget (%)			
	GenInst		GenExtInst		GenInst		GenExtInst	
	Coef	Se	coef	se	coef	se	coef	se
Migration status	-740.21**	327.44	-705.38***	226.63	19.18**	8.12	15.52***	5.38
Number of migrants	117.94**	46.19	128.42***	44.93	-3.69***	1.00	-3.64***	0.89
Oshana	-32.34	77.62	-21.14	76.68	-3.05	2.20	-2.87	2.13
Oshikoto	242.98***	87.48	285.96***	83.45	-4.80**	2.42	-4.70**	2.36
Male head	-66.36	87.96	-84.80	84.63	-0.61	1.95	-1.10	1.85
Head age	16.37	10.40	13.05	10.29	-0.10	0.34	-0.09	0.34
Head age2	-0.09	0.08	-0.07	0.08	0.00	0.00	-0.00	0.00
Head has training	776.18***	202.52	822.93***	196.87	1.82	3.52	1.97	3.42
Members with vocational training	229.24**	103.86	238.65**	101.98	-0.50	2.03	-0.24	1.98
Having control over life decisions	-6.91	38.88	15.34	36.26	0.88	1.02	0.77	1.02
Number of dependents	-21.69	14.74	-22.48	14.43	-0.03	0.43	0.06	0.40
Numbers of youths	19.70	24.67	20.87	24.41	0.03	0.58	0.08	0.57
Number of middle age members	37.22	38.00	30.77	37.15	-1.21	0.97	-1.30	0.95
Households that can be reached to help	-4.15	22.39	-4.98	22.56	-0.97**	0.39	-0.91**	0.37
Members contribution household income	-0.37	36.04	19.06	32.99	2.50***	0.97	2.31***	0.90
Income from informal business	0.02***	0.00	0.02***	0.00	-0.00***	0.00	-0.00***	0.00
Head occupation: nonfarm	148.80	99.91	150.95	92.79	-4.38*	2.65	-4.14	2.54
Head occupation: farmer	5.91	76.58	-13.84	72.94	-0.95	1.98	-1.09	1.93
Access to mobile money services	395.37***	93.60	404.20***	90.02	-0.57	2.17	-0.30	2.03
Asset index	152.96***	23.75	150.82***	23.57	-1.28**	0.60	-1.16**	0.58
Accessed seasonal forecasts	6.85	68.54	1.10	64.88	12.38***	1.93	12.88***	1.86
Received government relief	-57.28	89.67	-49.85	82.77	4.99**	2.27	4.64**	2.17
Risk taking behaviour	87.90***	24.17	99.03***	23.00	-1.09	0.69	-1.14*	0.66
Shortage of wild products (fruits, mopane)					9.11*	4.67	7.97*	4.22
Drying water sources	-53.30	74.24	-82.30	71.90	7.88***	2.13	7.88***	2.09
Constant	144.98	359.50	90.05	339.20	45.14***	11.61	47.42***	11.21
Observations	646		646		646		646	
R-squared	0.14		0.15		0.09		0.11	
Hansen J statistic	0.62		0.67		0.46		0.45	

*** p<0.01, ** p<0.05, * p<0.1 [Exchange rate was 1 USD = 13.45 NAD at the time of the survey]

3.5.4 Impact on food expenditure and household food dietary diversity

Migration had no significant impact on food spending and dietary diversity (Table 3-8). The two outcomes did not differ by gender or across regions. Education and training positively affected household food spending and dietary diversity. An extra year of schooling of the head led to an increase in food spending by N\$14.23. Having a household head with any form of post-school training increased the average spending on food by N\$175. Schooling and training increase the likelihood of obtaining higher returns through either a better paying non-farming job or self-employment. Larger households had less diversified diets, which could be an indication of food and nutrition insecurity. Having a household head whose primary occupation is farming led to less spending on food, probably because they grow their own food. These households also had less diversified diets because of the reliance on millet and high poverty levels in such households that mainly depend on highly risky farming.

Households whose members had registered for mobile money services spent more on food spending than those that had no access to such services. Mobile money services indicate access to financial services and those registered for the service can more easily make transactions or receive remittances. Wealth endowment increased both food spending and dietary diversity. Household food spending also increased with an increase in non-farming income. Because of the subsistence nature of agriculture and its inherent risks, non-farming income signals less participation in farming and more consumption of purchased food. Households affected by exposure to extreme temperatures and dry spells were more diversified in their diets. Dry spells and high temperatures reduce people's capacity to grow their own food, making them more reliant on markets and on food relief from the government. Harvesting rainwater led to more diversified diets because such households can grow other crops to supplement pearl millet (Mahangu) and sorghum.

3.5.5 Impact on uptake of adoption strategies

The results indicate that migrant households had two more adaptive strategies on average than non-migrant households (Table 3-8). However, there is a significant inverse relationship between the number of migrants and the households' adaptive capacity. This could point to a failure of other local adaptation mechanisms for those households, forcing them to use migration as an adaptive strategy rather than an enabler of the adaptation process. The paucity of empirical research linking migration and climate change adaptation makes it difficult to pick a general trend or draw conclusions. The results of this study corroborate findings by [Alem et al. \(2018\)](#) that households use migration to cope with climate risk *ex ante* and study by [Karanja Ng'ang'a et al. \(2016\)](#) which found migrant households in pastoral communities to have higher adaptive capacity due to relaxed credit constraint.

The number of adaptive strategies adopted increased with the age, membership to social group and educational level of the household head. However, there was a negative correlation between a household head's occupation in nonfarm economic activities and adaptive capacity, indicating the high opportunity cost of engaging in high-risk subsistence farming. They can earn better returns on their training in the non-farming sector and pay less attention to farming. Results also suggest that households with fewer opportunities may be forced to explore more non-farming adaptive strategies. On the other hand, those households whose head's primary occupation was farming also had fewer adaptive strategies, signalling lack of capacity to adapt due to subsistence nature of farming and poverty.

Adaptive capacity of the household increased with asset ownership, income, household size and land area cultivated. Expanding the cultivated area requires more family labour, especially for poor households who can hardly afford to hire labour. This study also shows that households that perceived changes in high temperatures and dry spells had more adaptive strategies, suggesting the importance of creating awareness about climate change, exposure to climate risk, and alternative adaptive options available to communities. Past exposure to droughts that led to total crop failure and experiencing a decline in resources such as wild fruits and mopane worms might have led households to diversify livelihoods, resulting in higher adaptive capacity. The uptake of adaptive strategies differed by region. Households in the Omusati region reported more adaptive strategies than those in the Oshana and Oshikoto regions.

3.5.6 Impact on agricultural input use

Results suggest a significant impact of migration on input use (Table 3-9). Compared to households without migrants, migrant-sending households on average spent between N\$240 and N\$245 on agricultural inputs. Households reported receiving remittances from migrants during land preparation for tractor hire services. Results support farmers' report. Migrant households on average spent N\$238 more on tractor hire services compared to non-migrant households. These results further support the role of migration in relaxing liquidity and credit constraints in agricultural sector. A study by [Mendola \(2008\)](#) among rural households in Bangladesh found families with international migrants more likely to invest in costly yield-enhancing technologies. [Gray \(2009\)](#) made a similar finding in Ecuador where international remittances increase investments in agriculture. [N. McCarthy et al. \(2009\)](#) found international migration to facilitate transition away from agriculture in rural Albania. However, internal rural-urban migration increased agricultural incomes and improved labour productivity. [Taylor and Lopez-Feldman \(2010\)](#) found evidence using household survey data in Mexico that migration raised land productivity and per capita income.

Table 3-8: Impact on food spending, household dietary diversity index and uptake of adaptive strategies (Source: Author)

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Total food spending				dietary Diversity score				Adaptive capacity			
	GenInst		GenExtInst		GenInst		GenExtInst		GenInst		GenExtInst	
	coef	se	coef	se	coef	se	coef	se	coef	se	coef	se
Migration status	-184.46	252.70	-186.85	233.86	-0.97	0.79	-0.60	0.73	2.28*	1.29	2.05**	0.82
Number of migrants	44.16	49.18	44.60	45.69	0.18	0.15	0.11	0.13	-0.49***	0.16	-0.48***	0.15
Oshana	13.93	42.96	13.88	43.00	-0.26	0.20	-0.25	0.19	-2.01***	0.42	-1.99***	0.42
Oshikoto	53.35	38.22	53.46	38.07	-0.27	0.19	-0.29	0.19	-1.20***	0.41	-1.15***	0.41
Male head	-6.59	31.41	-6.72	31.24	-0.11	0.16	-0.09	0.15	0.39	0.36	0.38	0.36
Head age	2.83	4.57	2.82	4.57	-0.01	0.02	-0.01	0.02	0.18***	0.05	0.18***	0.05
Head age2	-0.01	0.04	-0.01	0.04	0.00	0.00	0.00	0.00	-0.00***	0.00	-0.00***	0.00
Head education	14.23***	4.76	14.23***	4.77	0.06***	0.02	0.06***	0.02	0.14***	0.05	0.14***	0.05
Group membership									2.75***	0.49	2.87***	0.48
Head has training	174.83**	73.61	175.00**	73.32	0.06	0.31	0.04	0.31	-0.80	0.68	-0.76	0.67
Members with vocational training	44.54	39.84	44.56	39.85	0.16	0.18	0.16	0.17	0.42	0.36	0.43	0.36
Members with tertiary education	33.28	51.62	33.20	51.52	0.05	0.25	0.07	0.25	0.29	0.47	0.23	0.46
Household size	-2.48	5.28	-2.47	5.27	-0.05**	0.02	-0.05**	0.02	0.24***	0.06	0.23***	0.06
Head occupation: farmer	-64.96*	33.60	-65.01*	33.42	-0.26*	0.16	-0.26*	0.16	-1.26***	0.37	-1.33***	0.37
Head occupation: non-farmer	-31.77	41.36	-31.73	41.34	0.26	0.21	0.25	0.20	-2.11***	0.46	-2.09***	0.46
Access to mobile money services	143.77***	41.34	143.86***	41.35	0.09	0.19	0.08	0.18	0.31	0.38	0.36	0.38
Asset index	74.84***	13.69	74.84***	13.70	0.35***	0.05	0.35***	0.05	0.32***	0.12	0.31***	0.11
Members contributing income	18.62	17.65	18.60	17.63	0.00	0.08	0.00	0.07	-0.02	0.18	-0.02	0.17
Area under crops (ha)	-5.17	8.70	-5.22	8.51	0.06	0.04	0.07*	0.04	0.33***	0.09	0.32***	0.09
Tropical livestock units (tlu)	-1.47	1.11	-1.48	1.07	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.01
Log income	5.20***	1.58	5.20***	1.58	0.03***	0.01	0.03***	0.01	0.08***	0.02	0.08***	0.02
Received government drought relief	17.51	37.69	17.43	37.58	-0.03	0.18	-0.02	0.17	1.07**	0.42	1.04**	0.42
High temperatures	42.87	36.92	42.91	36.85	0.50***	0.18	0.50***	0.18	0.26	0.34	0.28	0.34
Dry spell	55.23	38.64	55.18	38.66	0.27	0.19	0.28	0.19	0.87**	0.41	0.84**	0.40
Rain harvesting	20.13	35.38	20.03	35.14	0.31*	0.17	0.32**	0.16				
Received seasonal forecast					0.90***	0.15	0.89***	0.15	1.91***	0.33	1.96***	0.33
Experienced crop failure									1.46***	0.33	1.38***	0.32
Declining resources (fruits, mopane)									4.95***	1.17	4.93***	1.15
Constant	177.86	199.04	179.09	192.98	6.01***	0.85	5.82***	0.82	-0.48	1.86	-0.13	1.82
Observations	644		644		646		646		646		646	
R-squared	0.24		0.24		0.25		0.28		0.34		0.34	
Hansen J statistic	0.34		0.38		0.73		0.52		0.54		0.57	

*** p<0.01, ** p<0.05, * p<0.1 [Exchange rate was 1 USD = 13.45 NAD at the time of the survey]

However, [Mendola \(2008\)](#) found local rural-urban migration, usually by the poor who cannot afford cross-border mobility and entry cost, to have no significant effect on agricultural productivity. [Wouterse and Taylor \(2008\)](#) made similar findings in Burkina Faso. Our results are consistent with other studies that find remittances from migrants to partially compensate for effect of lost farm labour ([Gray, 2009](#); [N. McCarthy et al., 2009](#); [Taylor et al., 2003](#)). A regional comparison shows that households who reside in Oshikoto region spent about N\$160 on inputs and specifically about N\$120 on tractor services. Value of input used increased with age, partly because older people above the age of 60 received government old-age pension grant. An additional grade in household head's education was associated with at least N\$21 expense on inputs. Having a household head with post-school skills, training increased spending on inputs by N\$300 and on tractor-hire services by between N\$150 and N\$170. Education and training increase the prospects of labour market participation.

Household characteristics that had significant effect on input use include household size, asset holding, cultivated area and exposure to shocks. Input use increased with household size, perhaps indicating availability of family labour especially for weeding. This can allow them to cultivate more area, which requires more inputs. This can be seen in hire spending on tractor services. Similarly, households with more wealth endowment, as measured by assets in the current case, are able to hire labour and can afford to purchase inputs. Increasing cultivated area by a hectare increased spending on inputs by N\$176 and on tractor services by N\$145.

Households that had been impacted by prolonged duration of dry spells spent less on inputs. Droughts can lead to loss of livelihood assets and increase vulnerability to food insecurity and poverty. Faced with uncertainty, risk averse households may choose to use own save seeds instead of purchasing certified seeds. Households that had faced conflicts related to livestock theft used more inputs suggesting a shift to crop farming. On the other hand, theft of household assets resulted in a reduction in input spending signaling a decline in wealth endowment. Sickness or injury of the main breadwinner in the households also resulted in reduction in input use. Loss of the main breadwinner was associated with increased input use. This might be the case where the main breadwinner was employed in non-farm sector forcing the family to rely more on agriculture following his or her demise.

Table 3-9: Impact of migration on the use of agricultural inputs

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Value: all inputs (N\$)				Value: tractor services (N\$)			
	GenInst		GenExtInst		GenInst		GenExtInst	
	coef	se	coef	se	coef	se	coef	se
Migration status	240.37*	122.97	245.89**	121.43	237.77**	112.24	237.73**	108.97
Number of migrants	-19.38	31.95	-32.35	27.19	-28.69	29.14	-31.86	24.77
Oshana	85.21	73.20	89.34	71.85	50.31	61.97	52.38	61.39
Oshikoto	157.40**	78.75	161.52**	77.55	120.30*	70.39	124.44*	69.46
Male head	37.75	63.51	55.78	60.56	38.98	55.26	55.26	53.17
Age of the household head	8.78***	2.41	9.02***	2.36	7.88***	2.12	8.31***	2.05
Education of the household head	21.41**	10.41	24.64**	10.02	16.66*	9.27	20.49**	9.02
Household head with post-school skills training	301.89**	122.23	310.21***	117.69	172.95*	89.61	153.87*	84.24
Household members with vocational training	-87.09	83.93	-86.58	82.75	-111.54*	58.92	-107.35*	58.25
Head occupation: nonfarm	26.89	150.37	58.24	148.80	47.16	130.06	57.19	129.56
Household head is self employed	67.62	168.62	17.36	163.57	15.16	142.17	-0.20	140.42
Household head has salaried employment	-114.10	189.38	-197.38	175.41	-83.03	150.65	-130.35	143.61
Household size	24.00*	12.82	26.52**	12.30	28.17***	10.57	28.86***	10.45
Access to mobile money services	20.15	68.74	51.82	63.21	37.66	57.72	50.88	55.34
Asset index	50.50**	25.20	46.78**	23.67	41.95**	20.45	42.88**	18.97
Area under crops (ha)	176.26***	21.83	178.74***	21.40	141.83***	17.73	145.02***	17.39
Tropical livestock units (tlu)	-1.15	3.87	-1.16	3.67	-3.70	3.71	-3.77	3.66
Log income	0.51	2.96	0.88	2.91	-0.25	2.57	0.17	2.53
Received government drought relief	25.63	74.33	13.27	73.99	28.63	68.48	27.21	68.41
Received seasonal forecasts	43.35	60.10	42.92	58.90	22.64	51.67	17.06	50.81
Affected by crop failure	-34.43	57.55	-32.30	56.30	-47.23	49.89	-43.15	49.50
Affected by dry spell	-150.96**	73.15	-152.93**	71.66	-94.93	63.61	-88.38	62.72
Affected by low yields due to climate shocks	-82.40	68.33	-77.66	64.61	-18.09	59.69	-13.71	58.72
Affected by conflicts related to livestock theft	512.78***	170.06	485.75***	160.62	503.83**	198.13	481.93**	194.13
Affected by theft of household assets	-376.85**	155.73	-401.42***	153.33	-353.53**	144.98	-370.48**	144.99
Affected by large fall in price of farm produce	324.78**	145.73	341.08**	143.80	279.93**	112.30	276.92**	111.92
Affected by large fall in livestock prices	-527.00**	206.06	-542.98***	190.51	-250.86	161.55	-266.42*	149.45
Affected by illness of the main breadwinner	-233.54***	89.18	-240.22***	86.03	-169.09**	75.56	-181.85**	73.53
Affected by loss of the main breadwinner	167.62**	69.05	168.07**	67.28	155.08**	64.89	148.37**	64.06
Constant	-368.74	228.17	-409.03*	221.96	-272.87	200.78	-333.82*	195.91
Observations	646		646		646		646	
R-squared	0.20		0.20		0.22		0.22	
Hansen J statistic	0.93		0.95		0.82		0.80	

*** p<0.01, ** p<0.05, * p<0.1 [Exchange rate was 1 USD = 13.45 NAD at the time of the survey]

3.6 Conclusion

Migration has the potential to offer opportunities for livelihood diversification and social protection for communities faced with negative effects of climate change in arid and semi-arid lands. The link between migration and environmental factors and disasters has not received much attention in the past ([Melde, 2017](#)). Namibia's rural population remains vulnerable to the negative effects of climate change. Most of the existing studies have focused on how changes in climate affect people's mobility, looking at migration as a response to those changes as well as an adaptive strategy. Another emerging body of literature has shifted focus to look at migration as an enabler of climate-change adaptation by relaxing liquidity and credit constraints through remittances, information flow, and technology transfer. This study contributes to this growing body of literature by evaluating how migration affects wellbeing indicators of vulnerable communities living in semi-arid environments and whether it has an impact on their adaptive capacity.

The study found most migrants to be young and their main motivating factors to migrate were to look for work or seek better education. Poverty and a lack of economic opportunities in the rural villages are the main push factors driving migration to towns and cities. The most common form of migration is rural-urban, which has low entry costs but also less lucrative. The most popular destination for most migrants is Windhoek and previous studies show an increasing rate of urban poverty especially among the unskilled migrants who live in informal settlements.

Many of the migrants lacked post-school skills training and tertiary education. Past studies have identified these as key factors for migrants to secure better returns on employment in the non-farming sector. Only a fifth of migrants accessed tertiary education and most of these were female. The findings show that higher education and post-school skills training are key determinates of the amount received in remittances by recipient households and therefore of migration impact on wellbeing indicators.

Migrant-sending households on average spent significantly less on consumption expenditure and had relatively higher food budget share, than households with no migrants. The results suggest that migrant households were relatively deprived compared to families without migrants. However, consumption expenditure increased with the number of migrants in a household, resulting to a decline in the share of the monthly budget devoted to food. Results seem to suggest that households can leverage on the number of migrants to increase their welfare, but it is improvement in human capital through training that had bigger impact on well-being outcome. Our results illustrate that focusing on improving the quality of human capital rather than the quantity of migrants would yield more benefits to the households.

Overall, the migrant-sending households had slightly more adaptive strategies, but households' adaptive capacity declined with number of migrants, perhaps indicating failure of local adaptation mechanisms for

poor households. Relatively deprived households would rather meet basic needs first before investing in costly adaptive strategies. Heavy reliance on government drought relief and cash transfers for the elderly (*old age pension grants*) may also reduce people's incentive for self-protection. More than three-quarters of the households received government drought relief.

We find a statistically significant positive impact of migration on agricultural input use, but mainly through spending on tractor-hire services. Respondents said that migrants usually sent money during land preparation when tractor services are most needed. Loss of family labour is somehow, through remittances, countervailed and compensated by mechanization. Results from empirical research on the impact of migration on agricultural output and income are inconclusive but many studies do find remittances to countervail the effects of farm-labour loss ([Gray, 2009](#); [Miluka et al., 2007](#); [Taylor et al., 2003](#)). Developing markets for inputs and farm output can further enhanced the role of migration in improving agricultural productivity.

Based on the findings of this study, migration has the potential to be an adaptive and risk mitigation strategy against climate variability, but poverty, lack of post-school skills training and a low transition to tertiary-level training are key barriers. There is a need for public policy on targeted, if not universal, higher education and youth training to unlock the benefits of migration as a livelihood diversification strategy and an enabler of climate-change adaptation. Establishing technical vocational education and training (TVET) facilities where communities can easily access them will enhance technical skills of the youth who drop out of schools. Education and training directly affect labour market participation while providing a pathway out of poverty trap for families.

Development of input and output markets, investment in supporting infrastructure and increasing awareness of existing on-farm and off-farm adaptive options are prerequisites for the utilization of remittances in long-term adaptation and resilience. Investment in rural electrification, transport and communication infrastructure can open new opportunities for rural farm and non-farm enterprises.

Chapter 4: Evaluating the access, use and impact of climate information on wellbeing and adaptive capacity

Abstract:

There is consensus that improved climate information is a crucial tool for managing climate risk in agriculture and other climate-sensitive sectors of the economy. Despite improvements in climate information forecasting, the African continent has generally not benefitted and information on its impact is scanty. The current study seeks to examine the level of access to climate information, its integration in farm decision-making and to evaluate its impact on the adaptive capacity and food security of farm families. The study uses propensity score matching, with a sensitivity analysis for hidden bias, to evaluate the impact of climate information using data collected from a representative sample of 653 households across three regions of Northern Namibia. Results show that only half of the households had access to climate information and many farmers relied primarily on traditional knowledge to make decisions about crop and livestock production. Information was mainly obtained from either the radio or the farmer's peers, but trust in these sources was low. Respondents rated the information received as insufficient for decision-making. Many of the households without access to climate information also had little knowledge of alternative adaptive strategies. The likelihood of receiving climate information increased with the number of migrants per household, household size, social networks, trust and participation in community decision-making processes, but declined with age. Although most households were female-headed, male heads were more likely to receive climate information. Households receiving climate information had more diversified diets and significantly higher spending on food. These households also engaged in more adaptive strategies, but on a small scale. Community empowerment through enhanced access to extension services, information on alternative adaptive choices, development of markets, and rural infrastructure are prerequisites for access to and effective utilization of improved climate-forecast information for successful adaptation.

4.1 Introduction

4.1.1 Background

The importance of climate-information forecasting¹⁴ in an environment where the main economic activity is rain-dependent cannot be overstated. Rain-fed agriculture is the dominant source of livelihood for millions of rural families in Sub-Saharan Africa ([Cooper et al., 2008](#)). High rainfall variability is a characteristic of arid and semi-arid agro-ecosystems and adversely affects crop and livestock production; this problem is exacerbated by climate variability. Such agro-ecosystems are mainly located in Sub-Saharan Africa (SSA), where countries have limited financial and technical capacities to deal with the negative impacts of climate variability ([Thomas & Twyman, 2005](#); [UNFCCC, 2007](#)). [Barrios et al. \(2008\)](#) provide evidence that climate change has in the past contributed to poor agricultural performance in Sub-Saharan Africa compared to the rest of the world. This trend will continue to deteriorate, as the most important staple crops in the SSA region, maize, millet, sorghum and cassava, are projected to decline as a result of climate change ([Schlenker & Lobell, 2010](#)).

Research has shown that African economies are sensitive to climate variability and more specifically to changes in temperature and precipitation ([Acevedo et al., 2018](#); [Dell et al., 2012](#); [Dell et al., 2014](#); [Jury, 2002](#)). This is largely because of the agricultural sector's relatively high share of the total GDP in Africa compared to the rest of the developing world ([Barrios et al., 2006](#); [Diao et al., 2007](#); [Jury, 2002](#); [Szirmai, 2012](#)). Overreliance on rain-fed agriculture and on hydroelectric power are two key factors that have curtailed economic growth in Africa following the trend towards declining rainfall since the 1960s ([Barrios et al., 2010](#)). Taken together, these factors make Africa the most vulnerable region worldwide to the negative effects of climate change ([Challinor et al., 2007](#)).

Given the importance of the agricultural sector for food security and the vital role of energy in social and economic transformation ([Wolde-Rufael, 2006](#)), seasonal climate information forecasting and early warning systems are vital to planning and risk mitigation in key economic sectors like agriculture, water, health and transport ([Hellmuth et al., 2007b](#)). Droughts and variations in rainfall occur commonly in Southern Africa, with frequency of up to four droughts per decade ([Mogotsi et al., 2012](#)). Households that rely on farming in these agro-climatic conditions operate under highly risky conditions and providing

¹⁴ Climate information in the context of this study refers to seasonal climate forecast and early warning system. The term seasonal climate forecast was used to differentiate it from daily weather forecasts. The term "seasonal climate forecast is commonly used in literature ([Amegnaglo et al., 2017](#); [Hartmann et al., 2002](#); [T. Krishnamurti et al., 1999](#); [T. N. Krishnamurti et al., 2000](#); [Ziervogel & Calder, 2003](#)). Early warning against prolonged dry spells, droughts, and flooding was included because of its importance for planning in livestock and crop production decisions.

them with timely climate information forecasts can be a good risk-mitigation strategy ([Luseno et al., 2003](#); [Vogel & O'Brien, 2006](#)). This is of significance to Namibia, which despite being the driest country in Sub-Saharan Africa has most of its rural population heavily dependent on agriculture. To underscore the severity of this problem, the President of the Republic of Namibia declared a state of emergency¹⁵ on 6 May 2019 following recurrent droughts since 2013. Although there is a drought monitoring centre in the Southern African region, lack of drought forecasting and of institutional capacity to mitigate droughts hinders the management of drought-related risks in the region ([Nhamo et al., 2019](#)).

Past studies have indicated a remarkable improvement in predicting rainfall patterns and major climatic events since the devastating drought in the Southern African region in 1991/1992, but there is little empirical research on how this has been used and what impact it has had on adaptive strategies and the welfare of rural communities. The current level of access to and use of climate information, and its impact on rural communal households in Namibia, is largely unknown.

This thesis will contribute to the literature by looking at the perceived role of climate forecast information and early warning systems in the production choices made by farmers in the semi-arid regions of Northern Namibia. It will also provide a better understanding of the level of current access to and integration of such information in the production decisions. Lastly, the study evaluates the impact of climate information on household adaptive capacity and food security using propensity score matching with a sensitivity analysis for hidden bias.

4.2 Literature review

4.2.1 The role of climate information forecasting and early warnings

The use of improved seasonal climate-information forecasting and early warning systems can improve farm earnings by allowing farmers to adjust their management decisions. Savings and improvements in efficiency and productivity can be made by the use of timely and reliable long-range climate forecasts ([Camacho & Conover, 2019](#); [Jury, 2002](#)). Policy makers can also use the information to develop a national disaster preparedness plan, advise citizens, and build buffer stocks, while the private sector can use it to prepare and plan for regional food needs ([Dilley, 2000](#); [Hellmuth et al., 2007a](#); [A. G. Patt et al., 2007](#)).

The 1997/1998 forecast by the Southern Africa Regional Climate Outlook Forum (SARCOF) is a good example of an instance where policy makers, humanitarian organizations and lending institutions in the

¹⁵ Declaring state of emergency allows the state to mobilize all government ministries, state agencies and other stakeholders to escalate relief effort to assist the affected communities. The government can also ask for international assistance. Following the declaration, the government allocated \$40m for food relief, livestock offtake and water supply. The government made a similar declaration in May 17 2013 ([Wilhite et al., 2014](#))

region used forecast information to plan adequate response options for an anticipated drought resulting from an El Niño weather pattern ([O'Brien et al., 2000](#)). [Ziervogel et al. \(2010\)](#) discuss how municipalities could utilize seasonal climate forecasting to plan and manage water resources. Recently cases of flooding in major cities have been increasing, leading to the loss of lives and property because of poor planning and a lack of preparedness. Mozambique, having been twice hit by two major tropical cyclones, Idai¹⁶ and Kenneth,¹⁷ in just five weeks between March 14 and April 25, 2019, is a case in point ([Boykoff et al., 2019](#); [Devi, 2019](#); [Scully, 2019](#); [Tumwine, 2019](#)).

At the farm level, [Amegnaglo et al. \(2017\)](#) and [Roudier et al. \(2014\)](#) demonstrate how West African farmers use seasonal climate forecasting to adjust planting dates, planting area, crop and crop variety choices, and level of fertilizer application. In the Southern Africa region, improved seasonal climate forecasting could be a risk-management tool for farmers and help to improve food security ([O'Brien et al., 2000](#); [Ziervogel et al., 2005](#); [Zinyengere et al., 2011](#)). Increased yield and crop loss reduction have been associated with the effective use of seasonal climate forecasting by farmers in Senegal ([Roudier et al., 2014](#)). CGIAR's study for the CCAFS (*Climate Change, Agriculture and Food Security*) program across West Africa, East Africa and South Asia showed that farmers who received weather information made changes to their farming practices like adopting improved crop varieties, short-cycle and drought-tolerant crops, but that better output prices were a major incentive for these changes.

For seasonal climate forecasting to be meaningful, institutional and infrastructural support is needed. Indeed, [Babcock \(1990\)](#) argues that increased accuracy of weather forecasts does not necessarily translate to increased farmer welfare, especially for those producing commodities with inelastic demand. Other factors, such as credit constraints, lack of working financial markets and socio-cultural beliefs based on experience might limit a farmer's response to such opportunities.

Improved climate information forecasting, if used well, could be an important adaptive and mitigation tool to cushion African agriculture against shocks related to climate variability ([Roudier et al., 2014](#); [Weaver et al., 2013](#)). With the right information about future climate events, the farmer can decide on the number of livestock to keep based on the availability of feed, what composition of livestock to have, and what crop varieties to plant, before extreme climate events. However, climate forecast information remains underutilized as a tool for climate risk management and enhancing food security in southern

¹⁶ An intense tropical cyclone described at the time as one of the worst in decades to hit the region. It made a landfall in the city of Beira on 14 March 2019 killing hundreds and affected over 1.85 million people in Mozambique alone. It also affected Zimbabwe, Malawi and Madagascar.

¹⁷ The second tropical cyclone that hit Mozambique, just six weeks after Idai, killing at least 38 people and destroying thousands of homes (([Le Page, 2019](#)) ([Page, 2019](#)))

Africa ([Vogel & O'Brien, 2006](#)). The next section explores why this is the case in spite of all the attention given to climate change and its impacts in SSA.

4.2.2 Access and use of climate information by end-users

There has been a great improvement in predicting rainfall patterns and in early warning systems, both in accuracy and lead-time ¹⁸([Hansen, 2002](#); [Kusunose & Mahmood, 2016](#); [O'Brien et al., 2000](#); [Vogel & O'Brien, 2006](#); [Ziervogel & Calder, 2003](#)). However, farmers' lack of capacity to understand and assimilate such information could be a major barrier to the effective use of improved climate forecasting ([James W. Mjelde et al., 1998](#)). While it is important to generate such information, understanding its relevance and ensuring that it is accessible and available to potential users are even more crucial ([Dilley, 2000](#); [Haigh et al., 2015](#)). Communicating the uncertainty associated with forecasting and integrating such information in decision making by the end users is key to the successful management of risks to agricultural sector caused by climate variability ([Haigh et al., 2015](#); [Hansen et al., 2004](#)).

The technical complexities of climate information at the point of dissemination and the mismatch between the released information and farmers' needs are some of the major limitations to effective utilization. For instance, in Southern Africa, farmers indicated that they would prefer to receive a seasonal climate forecast with a lead-time of six months, but that the forecast only came to them two to three months before the onset of the rains ([O'Brien et al., 2000](#); [Ziervogel et al., 2005](#)). In some cases, farmers received the information after they had already purchased the seeds ([A. Patt & Gwata, 2002](#)). Less precise climate forecasts received earlier in the season might be more valuable than more accurate predictions that are received close to the start of the season ([James W Mjelde et al., 1988](#)). Research in Senegal has shown that complementing seasonal climate forecasts with technical advice on crop choice and inputs greatly enhances the value of the information to the farmer ([Tall et al., 2014](#)).

Many agrarian rural families in Sub-Saharan Africa have no access to climate information forecasts. A study conducted over two decades ago to understand users' perspective on and response to the 1997/1998 El Niño forecast found that more than half of the smallholder farmers in Southern Africa did not receive that information ([O'Brien et al., 2000](#)). [Luseno et al. \(2003\)](#) found that only about a fifth of the pastoralists in East Africa had access to scientific climate information and the majority relied on traditional knowledge. Dissemination of climate information to end users remains poor with little contact between farmers and extension staff ([Luseno et al., 2003](#); [Vogel & O'Brien, 2006](#); [Ziervogel et al., 2005](#)).

¹⁸ This is the length of time between the time the forecast is issued and the occurrence of the predicted phenomenon. Long lead-time allows farmers time to prepare and plan.

Of the few who receive climate information, a high proportion integrate it in their decision-making. Poor access and utilization of climate information could be attributed in large part to lack of proper targeting and inclusion of such groups in pre-season climate outlook forums ([Archer, 2003](#); [A. G. Patt et al., 2007](#)). Other constraints on seasonal climate forecast utilization, such as the credibility and legitimacy of the forecast information, its scale and timing, and farmers' capacity to interpret the forecast information, are discussed in papers by [A. Patt and Gwata \(2002\)](#), [Millner and Washington \(2011\)](#) and [Amegnaglo et al. \(2017\)](#). Measurement and prediction errors notwithstanding, several studies have found significant yield benefits for farmers who integrate climate forecast information in their production decisions ([A. Patt et al., 2005](#); [Roudier et al., 2014](#)).

4.2.3 Sources and dissemination of Climate information forecast and early warning systems in Africa

Following the devastating drought of 1983/84 and subsequent droughts of 1991/1992 and 1994/1995 as a result of El Niño events, interest in and awareness of the important role of climate forecast and early warning systems in the management of climate risk increased in Africa, as well as in the rest of the world. In the light of this increased awareness, a workshop on reducing vulnerability to climate variability in Southern Africa was held in Zimbabwe in 1996, where the idea of having regional climate outlook forums for the different regions in Africa was conceived ([Ogallo et al., 2008](#)). The World Meteorological Organization (WMO), national meteorological services, and other stakeholders organized the first regional climate outlook forum (RCOF) to form consensus on a seasonal climate forecast that would be useful to climate-sensitive sectors of the economy ([Ogallo et al., 2008](#); [A. G. Patt et al., 2007](#)). The three most active RCOFs in Africa include the *PRÉvisions Saisonnières en Afrique de l'Ouest* (PRESSAO) in West Africa, the Southern Africa Regional Climate Outlook Forum (SARCOF) and the Greater Horn of Africa Outlook Forum (GHACOF) covering East African countries (Kenya, Uganda, Rwanda, Burundi, Ethiopia, Sudan, South Sudan, Djibouti, Eritrea and the United Republic of Tanzania). The drought-monitoring centres (DMCs) in these regions have annually since 1997 brought together climate experts, from Africa and beyond, to form consensus forecasts for the upcoming season. PRESSAO and SARCOF meet once a year and GHACOF meets twice, reflecting the unimodal (one wet season) and bimodal (two wet seasons) climate patterns in the respective regions. Pre-season workshops are also organized to enhance the capacity of national meteorological services (NMS) to produce and to improve the quality of the seasonal climate outlook in their respective countries ([Harrison et al., 2007](#); [Mullen, 2007](#); [Ogallo et al., 2008](#)).

Like other countries in the Southern Africa Development Community (SADC) region, Namibia's national meteorological service (NMS) receives the forecast consensus information in both soft and hard copy from SARCOF for further distribution to other users in Namibia. The forecast information is provided in tercile

4.3 Methodology

4.3.1 Conceptual framework

Once provided by the meteorological service departments, some climate forecast information is a global public good. The goal of the regional climate outlook forums has been to make the information accessible by as many end-users as possible. The cost of dissemination is in most cases absorbed by the public sector through various government agencies. The producer must then make the economic decision whether to invest time in accessing and using that information in his or her production decisions. The producer elects to use scientific climate information if the expected utility of using it U_{sci} exceeds his/her reservation utility U_{tk} . i.e. $U_{sci} > U_{tk}$. The forecast must include new and relevant information that supplements a farmer's traditional knowledge and helps reduce the uncertainty associated with farming under climate variability.

Access to climate information is modelled as a binary choice variable, taking a value of one for households that have access to climate information and zero otherwise. Social-cultural, demographic, economic and institutional factors determine the likelihood of **accessing** climate information, as illustrated in Figure 1. One can think of these as demand-side factors affecting the producer's need for climate forecast information. For instance, subsistence farmers operating on a small scale with little access to markets may not see the need actively to seek new information beyond the traditional knowledge that they have access to historically.

Regular government relief assistance and cash transfers like non-contributory old age pensions ([Levine et al., 2011](#)), provide households with social insurance and might reduce their incentive to seek information that would help them reduce the risks of crop failure or loss of livestock. Membership in social networks, migration, education, contact with extension staff, and possession of communication assets like radio, television and mobile phones, are posited to increase the likelihood of accessing climate information.

On the other hand, it is the supply-side factors, mostly related to the attributes of the forecast information as perceived by the end-users and strategy for dissemination by relevant agencies, which mainly determine the **utilization of climate information** in decision-making. These factors could constitute barriers to the effective utilization of the forecast and include such things as the legitimacy and credibility, scale, technical complexity, and timing of the forecast ([A. Patt & Gwata, 2002](#)). Legitimacy, trust and credibility issues can arise if the probabilistic nature of the forecast is not well understood by users, thereby reducing its value ([Ziervogel & Downing, 2004](#)).

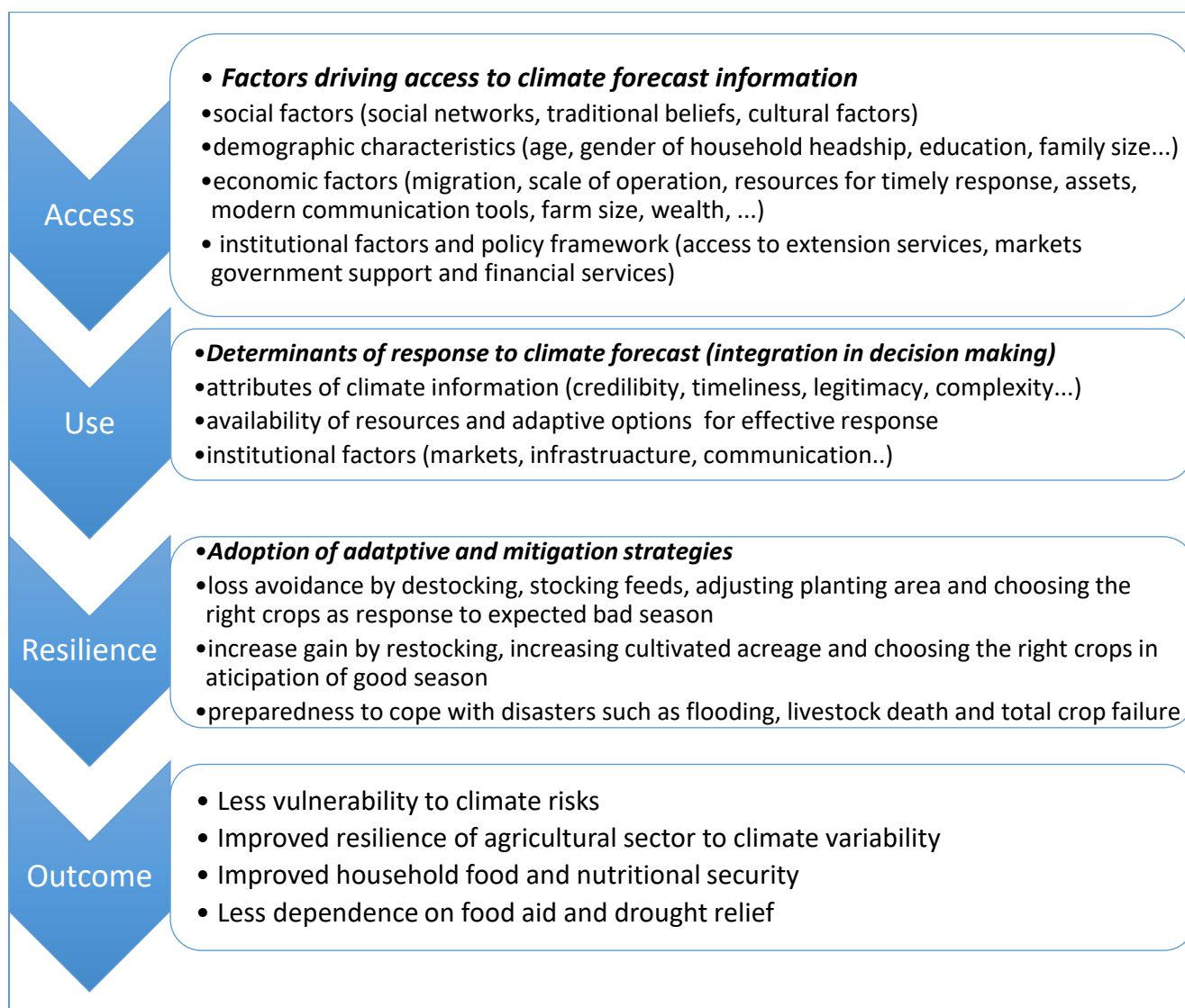


Figure 4-1: Drivers of access and use of climate forecast information and impact pathway (source: author)

Even after accessing seasonal climate forecasting and early warning systems, both individual characteristics and institutional factors could affect the successful integration of such information by producers in production decision choices and local adaptive strategies. Some of the factors include age, education, wealth endowment, access to financial services, input and output markets, trust, and risk attitudes. Access to climate information could help resource-poor farmers lower the risk of incurring losses by reducing the area planted, destocking, diversifying farm enterprise, and migrating in response to drought prediction.

Farmers with low resource endowment are least likely to benefit from the good season that usually follows prolonged dry spells or droughts due to trade-offs between investing in yield-enhancing improved inputs for future returns and the immediate need to feed their families. Loss of livestock during a drought

means that many smallholder farmers have to cultivate less land as they have fewer draft animals available for ploughing ([O'Brien et al., 2000](#)). Wide access to and integration of climate forecast information in production decision-making has significant potential to reduce vulnerability to climate variability through strategic farm investments and loss avoidance. The outcome would be the enhanced resilience in the agricultural sector, reduced vulnerability to climate risks, improved food security, and reduced reliance on government emergency relief.

The 'treated group' includes households that received climate information in general, including early warnings, and the 'control group' comprise households that did not receive such information. Even though the households' selection into study sample was random, access to climate forecast information and early warning is not. This could lead to self-selection bias. The next section presents mean comparisons between the treatment and control groups on key covariates used later for impact evaluation. Individuals in the two groups are then matched based on their conditional probability of receiving information and the conclusions are tested for the sensitivity to the presence of hidden bias.

4.3.2 Empirical model

As in other observational studies that do not have the benefit of randomizing the treatment assignment, the main challenge is creating a counterfactual that will allow the attribution of differences in outcomes between the two groups to the treatment. By letting $\tau_i \in [0,1]$ denote the dummy describing access to climate forecast information, and y_i denote the outcomes of interest, defined in the current study as the number of adaptive strategies adopted by a household and food security indicators, potential outcomes can be defined following [Angrist and Pischke \(2008\)](#)

$$y_i = \begin{cases} y_{i1} & \text{if } \tau_i = 1 \\ y_{i0} & \text{if } \tau_i = 0 \end{cases} \quad (27)$$

Where y_{i1} is the outcome for a household that received climate information and y_{i0} denotes the outcome for the same household had it not had access to climate forecast information. The observed outcomes can then be written as

$$y_{i1} = y_{i0} + (y_{i1} - y_{i0})\tau_i \quad (28)$$

The effect of climate forecast information on the outcome variable of interest is given as $(y_{i1} - y_{i0})$.

The average treatment effect of the climate information forecast is given in Eq. 29.

$$\frac{E(y_i)}{ATE} = \underbrace{E\{y_{i1} - y_{i0} | \tau_i = 1\}}_{ATT} + \underbrace{\{E(y_{i0} | \tau_i = 1) - E(y_{i0} | \tau_i = 0)\}}_{\text{Selection bias (ATENT)}} \quad (29)$$

The first term on the right-hand side (RHS) indicates the average effect of receiving climate forecast on outcomes for the treatment group and the second term shows what the average treatment effect would have been for the control group had they received treatment. Self-selection bias is likely because households that have communication assets, higher resource endowment, and better social networks are more likely to access climate forecast information. To control for self-selection bias, the study applies the propensity score matching technique proposed by [R. P. Rosenbaum and B. D. Rubin \(1983\)](#). This is the conditional probability of receiving climate forecast information given a set of observable characteristics ([Rosenbaum & Rubin, 1984](#)). Households with similar propensity scores are statistically similar in observed covariates regardless of their treatment status. The conditional independence between treatment assignment and potential outcomes, given the observed covariates ($Y_{i0}, Y_{i1} \perp \tau_i | X_i$ for all i), further allows for an unbiased estimation of the treatment effect ([Dehejia & Sadek, 2002](#); [Imai & Van Dyk, 2004](#); [Rosenbaum & Rubin, 1984](#)). X_i is a vector of observable characteristics that affect both the treatment assignment and outcomes. The propensity score is estimated using the probit model (Eq 30).

$$Pr(\tau_i = 1 | X_i) = Pr(\tau_i^* > 0 | X_i) = 1 - \Phi(-X\beta) \quad (30)$$

Where $\Phi = (2\pi)^{1/2} \exp\left(\frac{-X\beta^2}{2}\right)$, $0 < Pr(\tau_i = 1 | X_i) < 1$, i.e. the overlap condition requires that for all X_i within the unit interval, there is a positive probability of either participating or not participating (*common support condition*). It would be difficult to compare the two groups for covariate values whose probability of being treated is one or zero ([Keisuke Hirano & Imbens, 2001](#)). The logit model $\left\{Pr(\tau_i = 1 | X_i) = \frac{\exp(X\beta + \epsilon)}{1 + \exp(X\beta + \epsilon)}\right\}$ is also commonly used to estimate the propensity scores ([Dehejia & Sadek, 2002](#); [Rosenbaum & Rubin, 1984](#)).

Matching algorithms

The study used matching with replacement, which allows a single treatment unit to be matched to multiple units in the control group. This matching technique minimizes the propensity score distance between the treatment unit and the nearest units in the control group, thereby reducing bias ([Dehejia & Sadek, 2002](#)). The chapter presents the results of three matching algorithms, namely nearest neighbour matching with a caliper of 0.1, caliper (radius) matching, and kernel matching. Nearest neighbour matching, compare the units in the control group with the least difference in propensity score, to a unit in the treatment group. For radius matching, a caliper (*maximum propensity score difference or tolerance level*) of 0.1 is chosen for this study to improve the quality of the matches. The study employs the psmatch2 estimation routine developed by [Leuven and Sianesi \(2018\)](#). The routine performs propensity score matching, common support graphing, and covariate imbalance testing.

4.3.3 Test for hidden bias with Rosenbaum bounds

The object in this section is to test how strong the effect of unobserved variables on access to climate information would have to be for it to undermine the inference of the matching results. Let $\pi_i(\mathbf{X}_i, \mathbf{u}_i) = Pr(\tau_i = 1 | \mathbf{X}_i, \mathbf{u}_i)$ where π_i is the conditional probability of receiving climate information for *household*_{*i*} presented as a function of both the observable covariates \mathbf{X}_i and unobservable factors \mathbf{u}_i . Similarly, $\pi_j(\mathbf{X}_j, \mathbf{u}_j) = Pr(\tau_j = 1 | \mathbf{X}_j, \mathbf{u}_j)$ represents the probability of *household*_{*j*} receiving same information.

$$\pi_i(x_i, u_i) = F(x_i\beta + \gamma u_i) \quad (31)$$

Then, following [Becker and Caliendo \(2007\)](#), the possible effect of the unobserved characteristics can be evaluated by checking if γ in Eq. 5 is significantly different from zero; otherwise, two households with the same set of covariates \mathbf{X}_i will have different probabilities of receiving climate information.

Empirically, two households with a similar set of covariates ($x_i = x_j$) could differ in the probability of receiving treatment owing to unobserved factors, leading to hidden bias. Assuming the F in Eq. 31 takes the form of a logistic distribution, then

$$\frac{\pi_i(x_i, u_i)}{1 - \pi_i(x_i, u_i)} \bigg/ \frac{\pi_j(x_j, u_j)}{1 - \pi_j(x_j, u_j)} = \Gamma = \frac{\exp(x_i\beta + \gamma u_i)}{\exp(x_j\beta + \gamma u_j)} = \exp\{\gamma(u_i - u_j)\} \quad (32)$$

Sensitivity analysis shows how changing the value of γ could, in the present case, alter the inference about the effect of the climate information on target outcomes ([Becker & Caliendo, 2007](#)).

The odds of *household*_{*i*} being treated is $\frac{\pi_i(x_i, u_i)}{1 - \pi_i(x_i, u_i)}$ and that of *household*_{*j*} is $\frac{\pi_j(x_j, u_j)}{1 - \pi_j(x_j, u_j)}$.

$$\frac{1}{\Gamma} \leq \frac{\pi_i(x_i, u_i)}{1 - \pi_i(x_i, u_i)} \bigg/ \frac{\pi_j(x_j, u_j)}{1 - \pi_j(x_j, u_j)} \geq \Gamma \quad (33)$$

The value of $\Gamma=1$ if there are no differences in unobserved factors ($u_i = u_j$) between the two groups or there is no hidden bias ($\gamma = 0$). $\Gamma > 1$ when there is unobserved bias.

4.4 Data sources and descriptive statistics

4.4.1 Data source

This chapter uses the same data set described in Chapter 3, from the same 653 households across three regions in Northern Namibia. For this chapter, data was collected on what farmers perceived to be the role of and need for climate information in crop and livestock production. It also includes data on the access to and integration of such information in farm decision-making, common channels of information, the level of trust in those channels, and the sufficiency of information from them.

4.4.2 Summary statistics by access to climate forecast information

This section presents a summary of descriptive statistics for the key variables, with mean comparisons between the treatment and control groups. A *t*-test was used to check for balance on the observable characteristics between the two groups (Table 4-1). A significant difference could indicate the presence of selection bias between the two groups. The mean differences in outcomes were significant between the two groups. Households in the treatment group had a higher dietary diversity score, higher spending on food, and more adaptive strategies than the control group. Based on observable characteristics, the results also indicate that the households in the two groups were significantly different.

Household heads in the treatment group were on average three years younger and had a year more of schooling than those in the control group, *ceteris paribus*. Most of the households were female-headed in both the treatment (54%) and control groups (57%). The average household size was six persons. The two groups had the same average landholding (6.5ha) and cultivated almost the same area of land. Participation in social groups was higher among the households in the treatment group than in the control group. However, there was strong community support for ceremonies like weddings or funerals. Over three-quarters of the households in both the treatment and control groups relied heavily on government food and drought relief. The households in the treatment group had a significantly higher off-farm income and slightly more pension income than those in the control group.

Households with access to climate information had slightly more livestock of all types compared to those without such information. On average, 43% of households had cattle (cows, bulls and oxen), 67% small ruminants, 56% pigs, 31% donkeys, and almost every household had poultry. Almost all households (95%) owned mobile phones, three-quarters owned at least a radio and 16% owned a television. Ownership of radios and televisions was higher among households that had access to climate forecast information.

Selection bias is dealt with in section 4.5 by using propensity score matching, which shows that the two groups are similar, based on observable covariates after matching. A sensitivity analysis is also conducted and demonstrates that the results are robust to hidden bias.

Table 4-1: Mean comparison test between treatment and control groups (Source: Author)

Variable	Climate Information		Mean comparison test		All (N=653)
	Treatment (n=376)	Control (n=277)	mean diff	Std. Err.	
	Mean	Mean			
<i>Outcome variables</i>					
Dietary diversity (hdds)	7.32	6.39	0.93***	0.15	6.93
Total food spending (N\$)	566.92	374.12	192.80***	39.31	485.13
Adaptive strategies	12.23	9.07	3.16***	0.41	10.89
<i>Head characteristics</i>					
Head age (years)	60.56	63.06	2.51*	1.34	61.62
Male head (%)	45.58	40.22	5.36	3.92	43.38
Head education (grade)	6.00	5.16	0.84**	0.32	5.64
<i>Household characteristics</i>					
Number of migrants	2.0	1.5	0.50**	0.154	1.8
Household size	5.9	5.3	0.61*	0.20	5.6
Farm size (ha)	6.52	6.57	0.05	0.36	6.54
Cultivated area (ha)	3.69	3.44	0.25	0.17	3.58
Social networks	19.41	11.19	8.22***	2.78	16.06
Government relief	78.99	74.37	4.62	3.36	77.03
Off-farm income (N\$)	31520.06	7428.91	24091.15***	8031.32	21300.69
Pension income (N\$)	10266.22	7316.61	2949.62	2418.73	9015.01
Mobile money service	27.73	18.05	9.68***	3.27	23.62
<i>Livestock assets</i>					
Cattle (%)	48.14	35.38	12.76	3.86	42.66
Small ruminants (%)	69.41	64.62	4.79	3.73	67.28
Poultry (%)	95.74	90.25	5.49**	2.06	93.42
Pigs (%)	60.90	49.46	11.45***	3.92	56.05
Donkeys (%)	33.78	27.44	6.34*	3.62	31.09
<i>Communication assets</i>					
Television ownership	16.22	6.50	9.73***	2.41	12.23
Radio Ownership	84.31	62.09	22.21***	3.43	74.92
Mobile phone ownership	95.48	93.14	2.34	1.81	94.5

*** p<0.01, ** p<0.05, * p<0.1

4.4.3 Source, trust and sufficiency of information

Radio was the main channel of communication, through which 70% of farming families received agricultural and climate information (Table4-2). Only 18% had complete trust in this information, and 38% rated information from the radio as insufficient for decision-making. About a quarter of farmers received information from friends and family; a fifth of them trusted this source but only 36% rated such information as sufficient for decision-making. Six per cent of farm families received information via television and rated this medium slightly higher for trustworthiness and sufficiency of information for decision-making. Only 5.5% received information via their mobile phones, despite 95% of households owning them. The level of trust in and the rating of the sufficiency of information from mobile phones for decision-making are low. Digital technology could potentially be used successfully for information dissemination, but this would require investment in extending network connectivity and the rural electrification infrastructure.

Less than 1% of households interviewed indicated that they had received climate and farming information through extension services, suggesting that there is very little contact between farmers and extension staff. This finding corroborates other studies that have found gaps in extension services as boundary institutions for information dissemination in southern Africa ([O'Brien et al., 2000](#); [Vogel & O'Brien, 2006](#)). Access to extension services increases significantly both the likelihood of accessing climate information, and also of integrating it in farm decision making ([Amegnaglo et al., 2017](#); [A. Patt & Gwata, 2002](#)).

Table 4-2: Channels for climate and agricultural information (Source: Author)

Information channel	Use channel	Trust in channels				Sufficiency
	% responses	Not at all	Somewhat	Moderate	A lot	(%)
Radio (n=456)	69.7	7	39	36	18	38
Family and friends (n=154)	24.0	5	33	42	20	36
Television (n=40)	6.1	2	40	43	15	40
Mobile phone (n=36)	5.5	3	72	25	0	25
Community meetings (n=18)	2.8	0	44	45	11	33
Newspapers (n=15)	2.3	0	27	53	20	40
Village leaders (n=9)	1.4	0	22	33	45	44
Teachers (n=3)	0.5					
Extension workers (n=2)	0.3					
Internet (n=1)	0.2					

4.4.4 Access to and use of climate information

The following section discusses in more detail how farmers perceive the role of climate information in their livestock and crop production decisions respectively. Table 4-3 shows that 44% of the respondents perceived climate information to be important in their decision-making in livestock production. This was about the same proportion of farmers who owned cattle (cows, bulls and oxen), the animals most affected during droughts due their high feed and water requirements.

The proportion of households that reported having received relevant information for decision-making in livestock management was 45%. When asked how they used the information received in the past, almost half of them had stocked livestock feed in preparation for a dry season or drought, and 36% reported having taken advantage of the information to sell the animals while they were still healthy. Only 6% of households ever took advantage of the information provided to increase their herds in anticipation of good weather, probably because of the financial capital outlay that would be required.

To capture the potential use of climate information, households that had not received climate information that was relevant to livestock management, were asked how they would use it if it became available. About a quarter said they would store livestock feed and 23% said they would sell their livestock while still healthy to avoid loss of value or even death due to drought. Only 3% would increase the size of their herd if they received climate information predicting future favourable weather.

Although 62% of households, perceived climate forecast information as having a role in their crop-management decisions, only half actually received it. Limited access to climate information by rural communities has also been reported in West Africa ([Tarhule & Lamb, 2003](#)) and Southern Africa ([O'Brien et al., 2000](#)). When asked how they used the information, 81% of households reported changing planting dates and 45% stored grain (Table 4-3). During past periods of inadequate rainfall, 46% planted short-cycle crops while one-third opted for drought-tolerant crops.

The majority (82%) of those that had not received climate information said they would adjust their planting time and 46.5% would store grains in anticipation of poor rains in coming seasons. However, only a few would have adopted adaptive crops, indicating low awareness about them and other alternative adaptive strategies in the study area. Only 16% would have planted short cycle crops and 18% drought tolerant crops. Most households grew millet (*mahangu*) and sorghum using saved seed from previous harvest. The results show there is great potential for the role of climate information and awareness on climate change adaptation.

Table 4-3: Access and use of climate information for decision making in livestock and crop production

Does receiving future climate information have any role in your livestock management?		44.10%
	Currently receive information (44.87%)	Do not receive information (n=360)
	How do you use it	How would you use it
Stock livestock feed	49	24
Sell animals while still healthy	36	23
Store water for animals	2	4
Migrate to look to better areas	10	4
Increase herd when good rains expected	6	3
Shift to small ruminants	1	1
Does receiving future climate/weather information (<i>like when to expect drought or good rain</i>) have any role in your crop management?		62.63
	51% Received Climate information for crop production (n=339)	49% do not receive climate information received (n=314)
	How do you use it	How would you use it
Change planting time	81	82
Store grain	45	46
Short cycle crops	46	16
Drought tolerant crops	32	18
Plant maize	8	0

4.5 Estimation results

4.5.1 Determinants of access to climate forecasting information

Results indicate that on average, households residing in the Omusati region were 22% and 15% more likely to access climate information than families living in the Oshana and Oshikoto regions respectively (Table 4-4). The likelihood of receiving climate information declined with age. Male heads were more likely to receive climate information than their female counterparts, *ceteris paribus*. This is particularly important given that most household heads are elderly, and a majority are female. Families whose main occupation is farming were on average more likely to access climate information than those who were self-employment, in salaried employment, or not working. This indicates the subsistence nature of agriculture with limited commercial farming opportunities that could attract those in formal or self-employment.

Interestingly, migrant households are on average more likely to receive climate information. Households reported that migrants mostly sent remittances during the time when land was being prepared and crops planted, signaling their interest in supporting farm activities. Migrants are likely to receive climate information because unlike rural areas, there is electricity in urban areas where they have access to television.

The extent of a household's social networks and a higher level of perceived trust among people within the village increased likelihood of receiving climate information. Households whose heads are involved in community decision-making are also more likely to receive information than those that do not participate at all in such decisions.

As expected, owning a television increased the likelihood of receiving climate information by 20%. Similarly, owning a radio increased that likelihood by 29%. [Muema et al. \(2018\)](#) found similar results in Kenya. The results clearly show that, based on observables, the treatment group (households that received information) are significantly different from the households assigned to the control group before matching. Table 4-6 shows the results of the covariate-balancing test between the two groups after matching.

Table 4-4: The probit estimation of the determinants access to climate information

VARIABLES	Probit		Marginal effect	
	Coef.	se	dF/dx.	se
<i>Region (Omusati =base outcome)</i>				
Oshana	-0.538***	0.155	-0.211***	0.061
Oshikoto	-0.378***	0.146	-0.149***	0.057
<i>Head characteristics</i>				
Head gender	0.197*	0.117	0.076*	0.045
Head age	-0.012**	0.005	-0.004**	0.002
Head education	-0.006	0.018	-0.002	0.007
Head training	0.028	0.038	0.011	0.015
<i>Primary occupation (farming=base outcome)</i>				
Pensioner	-0.179	0.169	-0.070	0.066
Salaried employment	-0.604**	0.242	-0.237**	0.095
Not working	-0.444***	0.157	-0.174***	0.061
Self employed	-0.580**	0.242	-0.228**	0.096
Other occupations	-0.427	0.396	-0.169	0.121
<i>Household characteristics</i>				
Household size	0.035*	0.020	0.014*	0.008
Number of migrants	0.095***	0.032	0.037***	0.012
Access to mobile money service	0.155	0.139	0.060	0.053
Number of relatives in the village	-0.034**	0.016	-0.013**	0.006
Households that can give financial assistance	0.026	0.031	0.010	0.012
Households that can give assistance in kind	-0.026*	0.014	-0.010*	0.005
Number of social networks	0.210**	0.106	0.082**	0.041
Trust in the village	0.157**	0.067	0.061**	0.026
<i>Participation in community decision making</i>				
Very little	0.453***	0.162	0.169***	0.060
Somewhat	0.443***	0.173	0.164***	0.063
Moderately	0.689***	0.187	0.244***	0.065
A lot	0.445***	0.169	0.165***	0.062
Government aid support	0.433***	0.142	0.171***	0.056
<i>Wealth (Land and income)</i>				
Area under crops (ha)	0.017	0.034	0.007	0.013
Farm size (ha)	-0.020	0.017	-0.008	0.007
Off farm income	0.005	0.004	0.002	0.002
Pension income	-0.012*	0.006	-0.005*	0.003
<i>Wealth: Assets ownership</i>				
Television	0.553***	0.195	0.199***	0.070
Radio	0.742***	0.131	0.289***	0.051
Bicycles	0.001	0.182	0.000	0.071
Vehicles	0.091	0.398	0.035	0.153
Constant	-0.494	0.416		
<i>Model</i>				
Observations	648		648	
LR chi2(32)	141.73		141.73	
Pseudo R-squared	0.160		0.160	

*** p<0.01, ** p<0.05, * p<0.1

4.5.2 Test of common support and quality of the matches

Given that the average treatment effect on the treated group (ATT) is defined only in the region of common support, the overlap of the distributions of the propensity scores of the treatment and control groups were examined before and after matching (Figure 4-2). The figure shows a good overlap of the two distributions after matching, reducing the mean bias from 13.3% to only 3.9% (Table 4-5). Based on the observable covariates, the two groups are statistically similar in their likelihood of receiving climate information and well balanced after matching (Table 4-6). As expected, the pseudo-R-square and the likelihood ratio are low after matching. The null hypothesis is therefore maintained that, conditional on propensity scores, the two groups are similar on observable covariates. These differences observed between the outcomes of the two groups can therefore be attributed to climate information.

Table 4-5: Summary of covariate balancing

Sample	Ps R2	LR chi2	p>chi2	MeanBias	MedBias	B	R	%Var
Unmatched	0.16	141.73	0.000	13.3	11.2	100.2*	0.97	50
Matched	0.017	17.6	0.982	3.9	3.5	30.9*	1.14	50

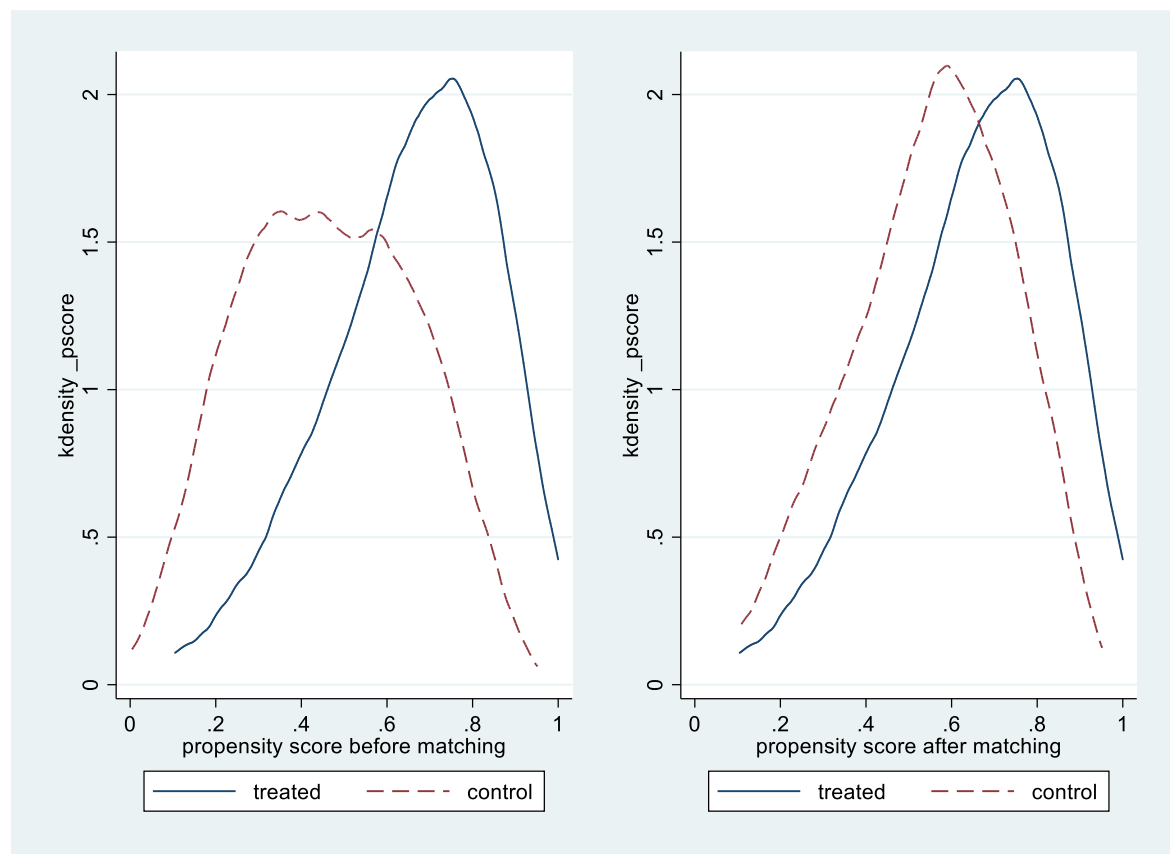


Figure 4-2: Distribution of the propensity scores before and after matching (source: Author)

Table 4-6: Covariate balancing test after matching

Variable	Mean		%bias	t-test	
	Treated	Control		t	p>t
Oshana	0.29	0.29	0.1	0.02	0.985
Oshikoto	0.26	0.29	-7.6	-1.01	0.312
<i>Head characteristics</i>					
Head gender	0.45	0.42	6.4	0.86	0.388
Head age	60.45	61.54	-6.4	-0.88	0.377
Head education	5.95	5.79	3.9	0.53	0.596
Head training	1.42	1.34	5.3	0.77	0.441
<i>Primary occupation (farming=base outcome)</i>					
Pensioner	0.27	0.29	-2.9	-0.39	0.698
Salaried employment	0.09	0.07	6.2	0.88	0.38
Not working	0.24	0.24	1.3	0.18	0.858
Self employed	0.07	0.09	-7.7	-0.98	0.327
Other occupations	0.04	0.04	-0.5	-0.06	0.949
<i>Household characteristics</i>					
Household size	5.81	5.72	3.1	0.42	0.672
Number of migrants	1.98	1.85	6.5	0.86	0.392
Access to mobile money service	1.07	0.94	7.7	1	0.318
Number of relatives in the village	0.27	0.31	-9.9	-1.23	0.220
Households that can give financial assistance	2.22	2.41	-4.7	-0.81	0.421
Households that can give assistance in kind	1.60	1.64	-2.4	-0.31	0.755
Number of social networks	2.18	2.54	-9.1	-1.57	0.117
Trust in the village	0.27	0.25	3.5	0.41	0.680
Trust in the village	2.06	2.04	2.8	0.37	0.712
<i>Participation in community decision making</i>					
Very little	0.22	0.24	-5.6	-0.74	0.461
Somewhat	0.19	0.18	3.7	0.5	0.618
Moderately	0.19	0.16	9.1	1.17	0.244
A lot	0.21	0.21	-0.5	-0.07	0.944
Government aid support	0.79	0.84	-11.3	-1.66	0.097
<i>Wealth (Land and income)</i>					
Area under crops (ha)	3.67	3.74	-3.5	-0.45	0.654
Farm size (ha)	6.50	6.44	1.3	0.18	0.854
Off farm income	10058.00	9404.10	1.7	0.39	0.700
Pension income	8527.00	7862.70	2.3	0.39	0.697
<i>Wealth: Assets ownership</i>					
Television	0.15	0.18	-10.4	-1.18	0.239
Radio	0.84	0.86	-3.6	-0.59	0.556
Bicycles	0.12	0.09	10.4	1.4	0.163
Vehicles	0.03	0.04	-5.8	-0.63	0.530

4.5.3 Impact of climate information

Households that reported receiving climate information that they used for decision-making, either for crop or livestock management, on average adopted more adaptive strategies than those that did not receive information (Table 4-7). Recipients of climate information on average spent from between N\$137 and N\$153.73 more on food than did the non-recipients. This explains the significantly higher score on dietary diversity among households that had access to climate information. The differences in measures of food security, i.e. months of inadequate household food provisioning (MIHFP) and household food insecurity access scale (HFIAS), between the two groups of households were not significant. This could be explained by the regular distribution of government food relief in the villages that cushion households against severe food shortages.

Table 4-7: Impact on adaptive strategies uptake, food spending and dietary diversity

Variable	Neighbour matching		Kernel matching		Radius matching	
	ATT	S.E.	ATT	S.E.	ATT	S.E.
Number of adaptive strategies	1.99***	0.45	2.10***	0.42	2.14***	0.39
Dietary diversity (%)	7.70***	1.93	7.97***	1.82	7.65***	1.63
Total food spending	153.73***	45.97	136.71***	45.55	136.8***	42.31
MIHFP	-0.12	0.29	0.07	0.28	0.13	0.25

*** p<0.01, ** p<0.05, * p<0.1

4.5.4 Test for Hidden Bias for average treatment effects with Rosenbaum rbounds

The Rosenbaum's rbounds test was conducted to ascertain whether unobserved variables have a significant influence on the impact results in a way that might affect the inference. The test statistics suggests that there is no evidence of over-estimation or under-estimation of the impact results. Results are insensitive to hidden bias caused by unobserved factors or omitted covariates. This implies that the results are robust to hidden bias and are unlikely to change because of unobserved factors.

Critical values of gamma show that unobserved confounders would have to increase the odds of receiving climate information by 80% to change the inference on the adaptive strategies. Similarly, unobserved factors would have to increase the odds of receiving climate information by 85% to change the conclusions made on household dietary diversity. The critical value of gamma for impact on household food spending is 1.15.

Table 4-8: rbounds Sensitivity analysis for average treatment effects (Source: Author)

Gamma	Total food spending		Household dietary diversity score		Adaptive strategies	
	sig+	sig-	sig+	sig-	sig+	sig-
1	0.01	0.006996	1E-10	1.2E-10	7.00E-10	7.00E-10
1.05	0.02	0.002111	2E-09	8.1E-12	7.80E-09	5.20E-11
1.1	0.05	0.000582	1E-08	5.1E-13	6.60E-08	3.70E-12
1.15	0.10	0.000148	1E-07	3.1E-14	4.40E-07	2.50E-13
1.2	0.17	0.000035	6E-07	1.8E-15	2.40E-06	1.60E-14
1.25	0.27	7.80E-06	3E-06	1.1E-16	1.10E-05	1.00E-15
1.3	0.38	1.70E-06	1E-05	0.0E+00	4.20E-05	1.10E-16
1.35	0.50	3.30E-07	5E-05	0.0E+00	1.38E-04	0
1.4	0.62	6.30E-08	1E-04	0.0E+00	4.04E-04	0
1.45	0.72	1.20E-08	4E-04	0.0E+00	1.05E-03	0
1.5	0.81	2.10E-09	0.001	0.0E+00	2.48E-03	0
1.55	0.87	3.60E-10	0.002	0.0E+00	0.01	0
1.6	0.92	5.90E-11	0.005	0.0E+00	0.01	0
1.65	0.95	9.60E-12	0.009	0.0E+00	0.02	0
1.7	0.97	1.50E-12	0.017	0.0E+00	0.03	0
1.75	0.98	2.30E-13	0.029	0.0E+00	0.05	0
1.8	0.99	3.50E-14	0.046	0.0E+00	0.08	0
1.85	1.00	5.20E-15	0.070	0.0E+00	0.12	0
1.9	1.00	7.80E-16	0.102	0.0E+00	0.16	0
1.95	1.00	1.10E-16	0.142	0.0E+00	0.22	0
2	1.00	0.00E+00	0.190	0.0E+00	0.28	0

4.6 Discussion and Conclusion

Namibia is the driest country in Sub-Saharan Africa, with most of its rural population depending on climate-sensitive subsistence and rain-fed agriculture. There is consensus among scholars that climate variability could make this way of life increasingly untenable. Improved climate forecast and early warning systems have been suggested as tools to help mitigate and manage climate risks that are inherent in rain-dependent agriculture. However, Africa has not experienced the benefits of improved seasonal climate forecasting, and there is little evidence of its impact.

This study used a representative sample of 653 households from across three regions in Northern Namibia to assess the degree of access to, and use of, climate information in farming families' decision-making. In order to evaluate the impact of climate information on key outcomes, households that received climate information were the treatment group whilst those that did not were the control group. Propensity score matching with sensitivity analysis for hidden bias was used to evaluate the impact of climate information on household welfare and use of adaptive strategies. Propensity score matching for impact evaluation and the Rosenbaum's *rbounds* test routine were applied to test for hidden bias. The two groups balanced well on all covariates after matching and results were less sensitive to hidden bias.

The study finds that most households, when asked about the role of climate information and early warning systems in climate risk mitigation, value its use for decision-making in crop and livestock management. However, only half of the households in the study sample had received such information. Cattle are severely affected by droughts, and all farmers that owned cattle indicated they would benefit from early warning of droughts. Most information was obtained by listening to the radio or talking to friends. Interactive radio programs in local dialects could widen the coverage. Although 95% of households owned mobile phones, only 5% had received information through them. This indicates an opportunity that stakeholders have previously missed, which could be used to provide many rural families with relevant agricultural, market and climate information. There was little contact between the farmers and extension staff yet [A. Patt and Gwata \(2002\)](#) find that facilitated groups and functional extension services are the most effective way of communicating seasonal forecast information to farmers.

The responses to climate information by those households that received it were small in scale, with lack of resources and of information on alternative adaptive strategies being the key barriers. For instance, feed (*millet and sorghum stalks*) for livestock was mainly stored in small bundles on top of tree branches and in quantities that could only last the animals for a short time in the event of drought. Other farmers burnt the millet and sorghum residues during land preparation, suggesting a need for practical field training on how to preserve crop residues for animals using existing technologies like chaff cutting. The

limited choice of alternative stress-tolerant crops, the lack of well-functioning markets, and poor rural infrastructure hampered crop diversification. Access to markets can incentivize farmers to invest in improved crop varieties and seek necessary information, including seasonal climate forecasting, from the relevant sources. Current efforts to disseminate seasonal climate forecast to communal populations are supply-driven and are unlikely to succeed if there is no attention to the demand component. Many households remain vulnerable to social and economic shocks and 77% relied on government relief. Households that had not received climate information indicated they would use it were they to receive it. However, they had little knowledge about alternative adaptive strategies such as stress-tolerant and early-maturing crops.

Households that reported receiving climate information on average, had adopted more adaptive strategies than those that did not. The most common adaptive strategies were grain storage, migrating, staggering cropping, using early maturing crops, changing planting and harvesting times, using earth dams, and using stress-tolerant crops. Livestock farmers also invested in supplementary feeding, rehabilitation of water points and water harvesting (*infield pits*). Communities mainly rely on millet (*Mahangu*) and sorghum for food. There is a need to explore other potential short-cycle and stress-tolerant crops that farmers can take advantage of to diversify their crops and livelihoods. Most of the crops available to farmers are susceptible to environmental stress and diseases ([Dian Spear & Chappel, 2018](#)). Increasing their adaptive choices would increase the use and value of climate information.

Dietary diversity and food spending were significantly higher among households that had access to climate information. However, there were no significant differences between the two groups on the other measures of food security, namely months of inadequate household food provisioning (MIHFP) and household food insecurity access score (HFIAS). One plausible explanation is the regular provision of government food relief in the villages. The lack of effective dissemination of targeted climate information and of an enhanced capacity for effective response could imply sustained dependence on emergency drought relief from the government rather than sustainable long-term adaptive measures.

In conclusion, the provision of climate information has the potential to enhance the adaptive capacity of communities as well as their nutritional security. However, access to climate information does not alone guarantee its effective use or its integration in decision-making on the farm. Other forms of institutional support, such as extension services and an improved communication network infrastructure, input markets, produce and financial markets, and the relaxation of resource constraints should be complementary. There is a need for improved collaboration between state and non-state actors to ensure timely dissemination of relevant information to farmers and other stakeholders who need it.

Chapter 5: Conclusion, synopsis and policy implications

5.1 Introduction

Extreme climate events, like droughts in semi-arid areas of the tropics, often trigger subsistence crises. An increase in their frequency could further entrench existing stratification and social inequalities ([Ribot et al., 2005](#)). This dissertation explored three ways of improving resilience and enhancing the adaptive capacity of households vulnerable to such adverse climatic events. These include the use of improved adaptive seed technologies, migration, and the effective use of climate information and early warning systems.

Arid and semi-arid lands are home to slightly more than a third of the world's population and comprise over 40% of the earth's land surface. One of the key features of semi-arid climates is high rainfall variability and this is likely to increase with climate change ([Fraser et al., 2011](#)). The adverse effects of climate change will increase farming communities' vulnerability to socioeconomic and environment-related risks. Subsistence farming in developing countries, where agricultural productivity is low, will become more difficult for many households already ravaged by food insecurity and poverty.

The use of improved adaptive crops, such as stress-tolerant and short-cycle varieties, could help households to minimize risks and build resilience through surplus production in good seasons and loss avoidance in drought situations. To assess the impact of such varieties on market participation and food security, this study used representative survey data from 1344 households covering the six agro-ecological zones in Kenya. It used a control function technique with a dose-response function to account for both the adoption decision and intensity of adoption.

Credit and financial constraints form major barriers to effective climate change adaptation through the adoption of adaptive technologies and livelihood diversification. A growing body of literature has made the case for migration as an enabler of climate-change adaptation by relaxing liquidity constraints through remittances. Even with the best of efforts, farm-based adaptation, such as using stress-tolerant crops, may fail in the face of prolonged and frequent droughts. Migration is gaining prominence as a livelihood diversification strategy, providing the migrant-sending households an additional source of income, while enabling them to invest in non-farming enterprises. However, those most affected by the adverse effects of climate change are the vulnerable poor, who are likely to be excluded from the potential benefits of migration by mobility and entry costs. The third chapter of this dissertation characterized the migrants

and the migration process, and evaluated the impact of migration on household well-being indicators such as food security, consumption expenditure, food budget share, dietary diversity, adaptive capacity and spending on agricultural inputs. Namibia, being one of the driest countries in sub-Saharan Africa, seemed a sensible choice for this study. The study used survey data collected from a representative sample of 653 households across three regions of Northern Namibia, namely Omusati, Oshana and Oshikoto. It employed a combination of both the standard and Lewbel's constructed instruments using heteroscedastic errors for identification and estimation.

Climate information, like adaptive technologies and migration, provides a tool for risk mitigation and planning, and has a wide range of applications to areas such as rain-fed agriculture and disaster management. There have been improvements in seasonal climate forecasting in developing countries and empirical studies have shown evidence of positive impacts on productivity and loss avoidance at the farm level. However, access to and utilization of climate information remain low in the Southern African region and there is little insight into its impact on farm families in the dry areas of Namibia.

This study used the same primary data mentioned above from Northern Namibia to assess the degree of access to and use of climate information by rural families when making decisions on the farm. Propensity score matching with sensitivity analysis for hidden bias was used to evaluate the impact of climate information on household welfare and adaptive capacity.

5.2 Synthesis of key findings

Chapter 2 details the relatively high adoption of improved maize observed across zones, but also highlights the low farmer-participation (41%) in grain market. The proportion of harvested maize sold by adopters was 12 percentage points higher than the proportion sold by non-adopters. Market participation increased with adoption intensity. However, the distribution of the quantities adopted, and the area planted with improved maize, indicates a skewed concentration towards large farms. The top 20% of households accounted for 63% of the total quantity and two-thirds of the area planted with improved maize. The bottom 40% accounted for six per cent of the quantity and five per cent of the area. Analysis by zone showed a higher impact on market participation for farmers in drier zones. Adopting households were more food secure and stored maize for longer duration than non-adopters. Larger families participated less in the market and were less food secure. Wealth and education were other key determinants of food security and market participation.

Chapter 3 discusses the role of migration as an adaptive and livelihood-diversification strategy for communities vulnerable to the adverse effects of climate variability. Push factors, such as rural poverty

and a lack of economic opportunities for young people in the rural areas, were found to be the main drivers of migration. Access to tertiary education and any post-school skills training of migrants were the main determinants of the amounts received in remittances by their rural families. Over three-quarters of migrants had no any form of training, and transition to tertiary education after secondary school was very low. Other studies tracking migrants to their destination in Windhoek and other towns in Namibia show that majority of the unskilled migrants are poor, living in informal settlements with limited access to services. This study shows that only 38% of migrants sent remittances back to their rural families and the average annual amount received per household was N\$4,672.88. Male migrants sent slightly more (N\$4,755.48) than their female counterparts who on average sent N\$4,575.21. Conversations with the recipients of these remittances revealed that the remittances were infrequent and irregular, the most substantial being money for land preparations to pay for tractor hire services. This is supported by the empirical results of this study which show migrant-sending households to have a significantly higher spending on agricultural inputs than households with no migrants. The results suggest that the migrant-sending households, when compared to non-migrant families, were poorer with significantly low consumption spending and a relatively high household food expenditure share. However, consumption spending increased with number of migrants in a household resulting to a reduction in the relative food expenditure share. Although wellbeing seems to increase with number of migrants, results suggest improving the quality of human capital through training can have greater impact on welfare through remittances.

The results indicate that Migration had a positive impact on household's adaptive capacity. However, there is a significant inverse relationship between the number of migrants and the households' adaptive capacity. This could point to a failure of other local adaptation mechanisms for those households, forcing them to use migration as an adaptive strategy rather than an enabler of the on-the-farm adaption process. The next step in publishing this work will be splitting the adaptive capacity into on-farm and off-farm adaptive strategies to establish whether migration has a differential impact on these two forms of adaptation.

Most farmers acknowledged the importance of climate information and early warning systems in farm decision making as a way of managing and reducing climatic risks. Only half of the households had access to climate information and most farmers relied primarily on traditional weather-related knowledge for decision-making in crop and livestock production. With increasing uncertainty due to climate variability, the traditional way of predicting climate and weather events is likely to become less reliable.

The common channels through which farmers received information were radio and from peers. However, many respondents had low trust in information from common channels and rated such information as insufficient for decision-making. Results show great-untapped potential for using digital technology for climate and agricultural information dissemination to farmers. For instance, 95% of households owned mobile phones and yet only 5.5% of households got information through them. Although few households owned a television, those who did trusted the information channeled through it more than radio and peer interaction. The likelihood of receiving climatic information increased with the number of migrants per household, household size, social networks, trust, and participation in community decision-making processes, but declined with age.

Households who had access to climate information had more diversified diets and significantly higher food spending. These households also engaged in more adaptive strategies, but the scale of adoption was small. Stocking of small bundles of livestock feed on top of tree branches and small grain storage facilities were common. Many families also had little information on alternative adaptive technologies and strategies.

5.3 Policy implications

Food security remains a great concern in Kenya despite the rising adoption rates of improved maize. In chapter 2, it was shown that improved seed could be used to increase the resilience of communities vulnerable to climatic risks by being food secure and having surplus for market. Results points to a need for policy that considers the skewed nature of improved maize adoption and production. Such policy could involve incentivizing large-scale producers to produce for strategic national grain reserves and to promote food self-sufficiency among small producers through better postharvest handling of maize produce to minimize losses and costs. This can be done by raising awareness of hermetic storage technologies like airtight metal silos and hermetic bags and promote their use. Small-scale farmers could then benefit from consumption smoothing and temporal price arbitrage later in the season.

The findings in Chapter 3 highlight the potential use of migration as an adaptive and a livelihood diversification strategy, but with a low transition to tertiary education and a lack of skills, the impact is much smaller and more insignificant than it could be. With an increasing frequency of droughts and climate variability, a growing population, and land scarcity, alternative non-farming sources of livelihood will become necessary. Effective migration can be an enabler of investments into non-farm diversification. Namibia must strategically invest in higher education and training for its youth in non-farming skills in order for migration to play an effective role as both an adaptive and a livelihood-diversification strategy. Equipping migrants with skills can greatly reduce vulnerability to climate risks and increase the resilience

of rural families in arid regions. After sharing the results of this study with the communities at local-level workshops in the villages, participants asked for the establishment of technical and vocational education and training (TVET) institutions in their constituencies where they could easily access them.

In Chapter 4, the study provides evidence of the significant impact that accessing climate and early warning information has on the adaptive capacity and dietary diversity of rural communities. However, the scale of adoption of the adaptive strategy was very small. The most common adaptive practice was storing livestock fodder, but only in small bundles on top of tree branches. Communities could benefit from technologies already available elsewhere that can process crop residues into livestock feed and improve utilization efficiency. Grain storage for food security was another common practice and enhancing households' storage capacity further could reduce reliance on government relief.

The study shows communities' lack of access to extension services. There is a need for training and the development of extension services for the effective dissemination of information on alternative adaptive options, and agricultural and climate information. The current information gap reduces the effectiveness of migration and other methods as means of adapting to climate change.

Levels of trust in the existing information channels were low, and many farmers said that the information provided was not enough for decision-making. Social media and digital technology could be used successfully to disseminate information, but this would require an initial investment in improved infrastructure such as rural electrification, communication networks and internet connectivity. Effective responsiveness to climate information will also require the development of well-coordinated input and output markets. The meteorological department should find a way of connecting with communities to build trust in scientific climate information.

In conclusion, no single adaptive strategy can insure the vulnerable communities residing in semi-arid regions effectively against climate risks. An integrated approach within a wider policy framework that addresses some of the gaps identified in each of the preceding chapters is recommended. It is possible for communities to take advantage of improved climate-information forecasting when deciding to invest in on-farm adaptive technologies like stress-tolerant crops and livestock, while using migration to invest in non-farming adaptive strategies. Migration can also be a livelihood-diversification and adaptive strategy.

5.4 Study limitations

One of the limitations of this study was the limited scope. Due to limited resources and time constraints, it was not possible to interview the migrants and the study obtained their demographic and

socioeconomic characteristics from their kin in rural homes. As a result, some of the migrant characteristics like occupation might have changed without the knowledge of their rural families. However, I do not think this might have significantly affected the results of this study. The study also did not consider commuting despite the rapid urbanization in Northern Namibia. There are residents who own business or commute to work in these towns. This is highlighted as an area for further research. Most respondents also could only speak their local dialects, but the study addressed this challenge by translating the questionnaire and thoroughly training enumerators who could speak the local languages.

The other limitation of this study relates to chapter 4 on access and use of climate information. The study was not detailed enough to capture the reasons why respondents had low trust on various channels of information was low and considered information received as insufficient for decision making. The study also could not establish why many farmers still rely on traditional sources of information even when the scientific seasonal climate forecast information is available. Lack of commercial oriented producers is another limitation in the current study in evaluating access to and use of climate information. These types of producers might actively seek and integrate such information in their planning and decision making.

5.5 Areas for further research

5.5.1 Improved adaptive seed technology

Further research in this area could include examining in detail the implication of land fragmentation and food security in Kenya. Small farm sizes may result in families not producing enough to meet their own subsistence needs even after adopting improved adaptive technologies. The results of this study have shown that the top quintile of improved maize adopters account for two-thirds of the improved seed adoption and the majority only purchase small quantities and have small farms. There is a need for a review of the policy on food security. In the case of Namibia, on-farm trials of various adaptive crops with a view to assisting farmers to diversify their livelihoods is recommended. Currently the most common crops are mahangu (millet) and Sorghum.

5.5.2 Migration

Future research on migration should also include commuting because of the growing urbanization in the Northern region. There is reason to believe that some non-migrant households in our study worked and owned shops in the nearby towns like Oshakati, Ondangwa, Ongwediva, Outapi, Omuthiya and Ruakana. This might explain why non-migrant households appeared to do better than migrant-sending households did.

5.5.3 Climate information

Further research on this topic could include exploring ways of using mobile phones to disseminate climate information, early warning on droughts and floods, and agricultural information. This might include sending out messages that farmers could listen to when their phone rings so that they do not have to read it. An RCT could be a good place to start. Over 95% of households had mobile phones but only 5.5% received climate and agricultural information through them. This could be extended to establish how these interventions influence the adoption and integration of climate information in farm decision. A similar RCT experiment with rural farmers in Colombia showed that farmers read the text messages sent to them via mobile phones on prices and customized weather forecast and found the information to be useful in production and marketing decisions ([Camacho & Conover, 2019](#)). Such a study could include both small and large-scale producers.

Further research could also establish why many farmers do not have much confidence in scientific climate information received through common channels and rate that information as insufficient for decision-making. Such information could be integrated into the generation and distribution of seasonal climate-forecast information.

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Appendix 1. Durbin Wu Hausman test for Endogeneity

Table 5-1 Appendix 1: Durbin Wu Hausman test for Endogeneity

VARIABLES	(1)	(2)	(3)	(4)
	% maize sold		Months of maize storage	
	Coef.	se	Coef.	se
Improved residuals	-19.320	16.585	1.480	1.596
Improved (1=adopter, 0=otherwise)	4.159	2.760	0.486*	0.266
Improved seed (kg)	0.089**	0.035	0.004	0.003
Male head	4.219*	2.416	-0.049	0.232
Household head age (years)	-1.004**	0.493	-0.066	0.047
Quadratic age	0.008*	0.004	0.001	0.000
Farming experience	0.613**	0.276	0.003	0.027
Quadratic experience	-0.011**	0.005	-0.000	0.000
Household head education (years)	0.299	0.252	0.021	0.024
Household size (Adult equivalent)	-0.902**	0.444	0.063	0.043
Group membership	-0.347	2.758	-0.153	0.265
<i>Food surplus (base category=food deficit)</i>				
No food surplus	4.078**	2.071	0.844***	0.199
Food surplus	14.714***	2.973	1.800***	0.286
Credit access	0.478	2.277	-0.371*	0.219
Tropical Livestock Units (tlu)	0.639**	0.301	0.042	0.029
Asset index	0.204	0.302	0.041	0.029
Log income	0.654	0.783	-0.048	0.075
Fertilizer rate (kg/acre)	0.036	0.027	0.003	0.003
Use commercial fertilizer	7.679**	3.467	0.214	0.334
Hosting big events	-5.752**	2.246	0.377*	0.216
Total area under maize (ha)	0.383*	0.223	-0.000	0.021
Farm size (ha)	0.090	0.114	0.010	0.011
Engaged in charcoal and timber	3.281	2.763	-0.518*	0.266
Engaged in carpentry	16.936**	7.092	-0.301	0.682
Distance to main market (km)	0.268**	0.109	0.005	0.010
<i>Agro-ecological zones (base category=high tropics)</i>				
Low tropics	-15.897***	4.503	-2.588***	0.433
Dry mid altitude	-17.570***	3.863	-3.860***	0.372
Dry transitional	-11.162***	3.300	-3.292***	0.318
Moist transitional	-4.298	2.804	-1.511***	0.270
Moist mid altitude	-8.260**	3.964	-1.666***	0.381
Constant	41.084**	20.010	6.309***	1.926
Observations	1,343		1,343	
R-squared	0.166		0.287	

*** p<0.01, ** p<0.05, * p<0.1

Appendix 2. Heckman selection model-two step estimates: regression model with sample selection and 2SLS

Table 5-2 Appendix 2: Regression model with sample selection

	Coef.	Std. Err.
<i>Quantity of improved seed (STD)</i>		
Male head	0.2042	0.3412
Household head age (years)	-0.1041	0.0679
Quadratic age	0.0008	0.0006
Farming experience	-0.0689*	0.0380
Quadratic experience	0.0012**	0.0007
Household head education (years)	0.0383	0.0325
Household size (Adult equivalent)	0.1307**	0.0601
Group membership	-0.4471	0.3875
Tropical Livestock Units (tlu)	0.1371***	0.0372
Credit	-0.3365	0.3047
Asset index	0.2912***	0.0376
Log income	-0.0444	0.1072
Fertilizer rate (kg/acre)	0.0068**	0.0036
Use commercial fertilizer	0.2249	0.3329
Hosting big events	0.7799**	0.3138
Total area under maize (ha)	1.3598***	0.0617
Engaged in charcoal and timber	0.4831	0.3924
Engaged in carpentry	-0.9598	0.9267
Distance to main market (km)	0.0014	0.0156
Low tropics	-0.6380	0.7379
Dry mid altitude	-2.5136***	0.6473
Dry transitional	-1.9397***	0.6007
Moist transitional	-0.3419	0.4733
Moist mid altitude	-1.2970**	0.5885
Short rain season	0.0220	0.5604
Both long and short seasons	-0.3245	0.3533
HAIL_STORMS	0.6783**	0.3024
LANDSLIDES	-0.5303	0.3591
LIVESTOCK_DEATH	0.3916	0.2707
Constant	2.4693	2.1016
<i>Adoption status (1=Yes, 0=No)</i>		
Male head	-0.0072	0.2043
Household head age (years)	0.0098	0.0428
Quadratic age	0.0000	0.0004
Farming experience	0.0616***	0.0259
Quadratic experience	-0.0013***	0.0005
Household head education (years)	0.0213	0.0252
Household size (Adult equivalent)	-0.0363	0.0384
Group membership	-0.2195	0.2348

Tropical Livestock Units (tlu)	0.0388	0.0367
Credit	0.0842	0.2340
Asset index	0.0167	0.0290
Log income	0.1252	0.0840
Fertilizer rate (kg/acre)	0.0025	0.0036
Use commercial fertilizer	1.1080***	0.1933
Hosting big events	0.1527	0.1943
Total area under maize (ha)	-0.0020	0.0724
Engaged in charcoal and timber	-0.3678	0.2651
Engaged in carpentry	1.4765**	0.6589
Distance to main market (km)	0.0043	0.0111
Short rain season	-0.5151	0.3164
Both long and short seasons	-1.4517***	0.1862
MORE_SHORTRAINS	0.5133***	0.1806
HOTTER_HOTMTHS	-0.9186***	0.2126
LANDSLIDES	-0.40159*	0.2253
LIVESTOCK_DEATH	0.5246***	0.1926
Constant	-1.9263	1.4675
Mills (lambda)	-0.2983	0.6879
rho	-0.0732	
sigma	4.0769	
Number of observations	1,342	
Censored observations	204	
Uncensored observations	1338	
Wald chi2(29)	1089.77	
Prob > chi2	0.0000	

*** p<0.01, ** p<0.05, * p<0.1

The Wald chi-square test rejects the null hypothesis that coefficients on regressors are zero. We see that the excluded instruments (past exposure to climate shocks) are strongly correlated with the endogenous variables. The mills ratio however indicates that the errors in the adoption level and selection equations are not strongly correlated (*p-value* = 0.6879).

The likelihood of improved maize adoption increased with years of farming experience. However, adoption intensity (quantity of improved seeds adopted) decrease with experience at an increasing rate. As people grow older, they farm less due do diminishing supply of family labour. This is because household size becomes smaller as children establish their own households after marriage or move to look for work in nonfarm sector. Indeed, adoption level increased with increase in family size. We also note that farmers responded to past shocks that were related to excessive rain by increasing adoption intensity. The response was different when the shocks were about high temperatures and dry conditions. Loss of livestock increased the likelihood that a farmer would adopt improved seed probably to diversify and spread risks.

Appendix 3. Test for multicollinearity

Table 5-3 Appendix 4: Variance inflation factor

Variable name	Variable label	VIF	1/VIF
improved2	Adoption status (1=Yes, 0=No)	2.08	0.48103
improvseed2	Treatment intensity	1.79	0.557643
headsex	Male head	1.14	0.875752
headage	household head age (years)	1.91	0.522963
experience	Farming experience	1.78	0.561016
headedu	Household head education (years) (headedu)	1.42	0.702071
hsize	Household size (Adult equivalent)	1.13	0.886931
group	Group membership	1.06	0.942385
tlu	Tropical Livestock Units (tlu)	1.27	0.786549
asset_index	Asset index	1.6	0.626412
fertrate	Fertilizer rate (kg/acre)	1.34	0.748866
Fert_use	Use commercial fertilizer (1=Yes, 0=No)	1.63	0.612674
events	Hosting big social events	1.06	0.940146
totalarea_ha	Total area under maize (ha)	1.85	0.539494
wood	Engaged in charcoal and timber	1.04	0.96201
carpentry	Engaged in carpentry	1.01	0.987045
bothseasons	Both seasons	1.67	0.598633
shortonly	short rain season	1.23	0.812341
credit	Credit access	1.07	0.933327
distmainmr~m	Distance to main market (km)	1.06	0.946894
lowtropics	Low tropics	1.38	0.724899
DMA	Dry mid altitude	2.01	0.497803
DT	Dry transitional	1.96	0.510353
MT	Moist transitional	1.99	0.502406
MMA	Moist mid altitude	1.73	0.578416
Mean VIF		1.49	

The variance inflation factors show a very weak correlation between independent variables. The overall average VIF is about 1.5 suggesting no need for further corrective measures. It also suggests that the estimated coefficients are stable.

Table 5-4: Pairwise correlation matrix

	headsex	headage	experience	headedu	hhsiz	group	tlu	Credit	asset_index	fertrate	fert_use	events	totalarea_ha
headsex	1												
headage	-0.080	1.000											
experience	-0.127	0.651	1.000										
headedu	0.311	-0.321	-0.271	1.000									
hhsiz	0.112	-0.015	-0.025	0.046	1.000								
group	0.001	-0.015	-0.025	0.103	0.010	1.000							
tlu	0.051	0.069	0.036	0.029	0.140	0.027	1.000						
Credit	0.037	-0.049	-0.016	0.121	0.062	0.157	-0.014	1.000					
asset_index	0.121	0.146	0.078	0.263	0.081	0.093	0.321	0.102	1.000				
fertrate	0.035	-0.014	0.005	0.130	0.026	0.028	-0.009	0.101	0.124	1.000			
fert_use	0.035	-0.040	-0.037	0.180	-0.072	0.030	-0.053	0.091	0.187	0.447	1.000		
events	0.044	-0.026	-0.062	0.078	-0.007	0.060	0.065	0.042	0.153	0.069	-0.004	1.000	
totalarea_ha	0.018	0.073	0.062	0.073	0.155	-0.006	0.297	0.053	0.341	-0.085	-0.106	0.071	1.000
WOOD	-0.028	-0.037	-0.046	-0.028	0.021	0.069	0.004	-0.019	-0.036	-0.042	-0.043	0.023	-0.036
CARPENTRY	0.015	-0.027	-0.022	0.013	0.007	0.011	-0.016	-0.004	-0.022	-0.004	0.041	-0.033	-0.015
distmainm_r_m	0.036	-0.010	0.003	0.001	0.094	-0.014	0.086	0.062	0.032	-0.025	-0.070	0.017	0.122
lowtropics	0.043	-0.002	-0.010	-0.024	0.157	-0.067	-0.011	-0.005	-0.051	-0.076	-0.141	-0.093	0.027
DMA	0.002	-0.002	0.012	0.002	-0.049	0.031	0.080	0.026	0.082	-0.106	-0.227	0.057	0.261
DT	0.033	0.041	0.000	0.082	-0.083	0.031	-0.102	0.010	0.172	-0.058	0.079	0.046	0.047
MT	0.043	-0.016	0.020	0.060	-0.062	0.028	-0.040	0.042	-0.028	0.230	0.272	-0.037	-0.116
MMA	0.027	-0.057	-0.058	0.078	0.139	0.067	0.074	0.036	-0.024	-0.001	-0.011	-0.008	-0.026
longonly	-0.011	-0.044	0.000	0.055	0.039	-0.020	0.064	-0.018	0.045	0.191	0.171	-0.027	-0.130
shortonly	-0.027	-0.085	-0.062	-0.018	-0.060	-0.007	0.005	0.003	-0.093	0.006	-0.016	-0.043	-0.078
bothseason	0.024	0.085	0.032	-0.043	-0.006	0.022	-0.063	0.016	0.005	-0.183	-0.153	0.047	0.163

	totalarea_ha	WOOD	CARPENTRY	distmainm_r_m	lowtropics	DMA	DT	MT	MMA	longonly	shortonly	bothseason
totalarea_ha	1.000											
WOOD	-0.036	1.000										
CARPENTRY	-0.015	-0.028	1.000									

distmainmr~m	0.122	0.028	-0.018	1.000								
I_lowtropics	0.027	-0.037	0.030	0.087	1.000							
I_DMA	0.261	0.019	-0.008	0.054	-0.079	1.000						
I_DT	0.047	-0.031	0.005	-0.051	-0.085	-0.139	1.000					
I_MT	-0.116	-0.012	-0.016	-0.125	-0.126	-0.206	-0.220	1.000				
I_MMA	-0.026	0.119	-0.027	-0.009	-0.080	-0.131	-0.139	-0.207	1.000			
longonly	-0.130	-0.051	0.032	0.010	-0.037	-0.177	-0.203	0.035	-0.057	1.000		
shortonly	-0.078	-0.007	-0.032	-0.030	-0.056	-0.043	-0.061	0.157	-0.092	-0.155	1.000	
bothseason	0.163	0.051	-0.014	0.006	0.064	0.189	0.222	-0.114	0.101	-0.864	-0.364	1.000
