Barriers and enablers to the adoption of practices to improve crop production and reduce vulnerability to climate risks in the semi-arid OmusatiRegion,Namibia

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Declaration of Authorship

I have read and understood the regulations governing the submission of an MSc dissertation, as contained in the rules of this University. I know the meaning of plagiarism and hereby declare that all of the work presented in this minor dissertation, save for that which is properly acknowledged, is my own.

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Date: 15/ 02 / 2018

Abstract

Namibia is almost entirely semi-arid or arid. With evaporation rates being higher than precipitation rates, farming conditions are extremely adverse. This is exacerbated by the impacts of climate change, namely increased temperature, decreased rainfall and higher rainfall variability, all of which are projected to worsen in the future. More than half of the population is reliant on rain-fed subsistence agriculture for their source of food but these challenging conditions mean that there is widespread food insecurity across the subsistence farming community in Namibia. This leads to a state of vulnerability and dependence on government support in the form of social grants, food aid and remittances from family members in urban areas.

The *locus* for this study is three villages: Omaenene, Okathitukeengombe and Oshihau, in the north-central Omusati region of Namibia. This research investigated local perceptions of climate change vulnerability, farming practices used in other regions that could reduce this vulnerability and finally barriers and enablers to the uptake of new farming practices. These objectives were answered through the use of a systematic literature review and interviews with the local community.

Findings revealed that the local population is already experiencing a hotter and drier climate, which has decreased their yield output. Many farmers are concerned about future climatic changes while some are comforted by support from the government or God. In both of these cases, the farmers are vulnerable because they are not currently adapting or planning to adapt to climate change. Although a majority of the farmers claimed that they are willing to try new farming practices, they are inhibited by: limited access to new information, mistrust of new farming practices as well as insufficient labour and resources.

Three adaptive farming practices – planting pits, bunds and composting – aimed predominantly at water harvesting, soil conservation and increasing soil quality were selected by the researcher, from a systematic literature review, as appropriate for the village sites. Some of the social and institutional enablers that could be enhanced to promote the uptake of these practices are: i) support from local authorities and possibly enlisting the help of religious and traditional leaders (including building trust within these networks), ii) enhancing information access predominantly through the radio, iii) explaining the severity of climate change and the value of adaptation practices, iv) establishing self-help labour groups and v) the creation of demonstrations sites. In the face of irreversible climate change, this research aims to contribute to empowering local people to adapt their farming practices to the harmful experienced and predicted impacts of climate change and climate variability.

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List of Acronyms

ACDI	African Climate and Development Initiative
ASSAR	Adaptation at Scale in Semi-Arid Regions
CFCs	Chlorofluorocarbons
CH_4	Methane
CO_2	Carbon Dioxide
CRAVE	Climate Resilient Agriculture in three of the Vulnerable Extreme northern crop-growing regions
CSIRO	Commonwealth Scientific and Industrial Research Organisation
GEF	Global Environmental Facility
ENSO	El Nino Southern Oscillation
EU	European Union
FAO	Food and Agriculture Organisation
GHG	Anthropogenic greenhouse gas
HIV	Human Immunodeficiency Virus
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IPCC	International Panel on Climate Change
IPCC AR4	United Nations Intergovernmental Panel on Climate Change Fourth Assessment Report
ITCZ	Intertropical Convergence Zone
LISA	Learning and Information Sharing for Agriculture
MAWF	Ministry of Agriculture, Water and Forestry
MET	Ministry of Environment and Tourism
NSA	National Statistics Agency
N_2O	Nitrous oxide
NNFU	Namibia National Farmers Union
RCP	Representative Concentration Pathways
UNDP	United Nations Development Program
UNEP	United Nations Environmental Program
UNFCCC	United Nations Framework Convention on Climate Change

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Chapter One: Introduction

Image: Traditional homemade basket used for storing maize and millet during winter. Photo taken during fieldwork by Nivedita Joshi.

Namibia is classified as 92 % arid or semi-arid - evaporation rates are higher than precipitation rates - making it the most arid country south of the Sahel region (Brown, 2009). Matambo and Seely (2012) explain that the monitoring and forecasting of environmental change has been practiced for centuries in Namibia and has historically allowed farmers to plan and cope with adverse farming conditions and strong climate variability. It is however believed that as the environmental conditions and socio-economic challenges are exacerbated by the ever-increasing impacts of climate change it is becoming increasingly more challenging to survive (Newsham and Thomas, 2009; Von Hase, 2013; Angula et al., 2016). The climate in Namibia is extremely variable with frequent floods and droughts that are difficult to predict and wreak havoc across the country (Newsham and Thomas, 2009). Extensive land degradation exists in northern Namibia as a result of the above-mentioned variable climate combined with increased population density on small pieces of land, the over-consumption of wood for fire and construction as well as intensive grazing due to overstocking (Klintenberg and Seely, 2004). Moreover, the land under cultivation is considered marginal, the soil is characterised as having low water retention and low fertility (Crawford and Terton, 2016). Despite these harsh conditions and the fact that crops fail as often as once in every three years, more than half of the Namibian population live in rural areas and rely on rainfed subsistence agriculture for their source of food (Reid et al., 2008; Barnes et al., 2012). This has led to widespread food insecurity: a lack of availability of sufficient quantity and quality of food to allow for a state of nutritional wellbeing at all times (Wheeler and Von Braun, 2013). It is speculated that 729 100 people in Namibia (out of a population of 2.2 million) are food insecure (WFP, 2017; FAO, 2016).

Numerous studies have shown how climatic changes have already impacted and will continue to impact, crop production and hence food security in northern Namibia (Newsham and Thomas, 2009; Government of Namibia, 2002; Barnes et al., 2012; Reid et al., 2008; UNDP, 2015). Trends over the past few decades in northern Namibia have indicated increased intensity and frequency of hot days as well as decreased rainfall and higher rainfall variability (Newsham and Thomas, 2011; UNDP, 2017). The number of days exceeding 34^0 C per year between 2046 – 2065 in north-central Namibia is expected to increase from 67 to 118 (Newsham and Thomas, 2009). Most rainfall projection models also show reasonable agreement in a signal of decreasing precipitation over most of Namibia over the next century (Dirkx et al.m 2008; Davies et al., 2018). Barnes et al. (2012) concur that Namibia is expected to have as much as a 5 % - 20 % decrease in rainfall by 2080. These past trends and future projections have and will continue to negatively affect crop production in northern Namibia. Impacts of climate variability and climate change directly and indirectly affect crop production through flood damage and soil erosion, drying out of crops, increased pests and decreased soil fertility ultimately decreasing food security (Reid et al., 2008; Kalra et al., 2007; Newsham and Thomas, 2009; IPCC, 2012). Ziervogel and Erikson (2010) highlight that other components of food security such as the access, stability and utilization of food will also be indirectly impacted by climate change leading to outcomes such as malnutrition which further increase vulnerability (inability to cope) to climate change.

A study by Angula and Kaundjua (2016) on the north-central region of Namibia indicated that crop producers in the area are inherently vulnerable to climate change. This vulnerability stems from the especially high dependence on rainfed agriculture, high level of poverty (limited income to strengthen the farming system), limited capacity to diversify livelihoods away from agriculture and eroded agro-ecological indigenous knowledge. Furthermore, the current farming practices used are not sufficient to cope with future changes in the climate and farmers are not managing these risks by planning for change (Angula and Kaunjua, 2016, Angula et al., 2016).

Frequent droughts in the Onesi Constituency over the past 15 years have diminished food production to the extent that farmers have repeatedly had insufficient supplies of *mahangu* (pearl millet) to last them through the dry season (Hegga et al., 2016; Spear et al., 2016). This is particularly problematic for farmers who have historically grown their own food. As 39 % of subsistence farmers in Namibia are in a state of poverty (monthly income is less than N$ 378) and money is not always available to purchase food, many families have had to rely on food relief from the government and other donors (UNDP, 2017; NSA, 2012). Dry land regions in sub-Saharan Africa are especially vulnerable to climate change due to their sensitivity to projected changes and their low adaptive capacity (Fraser et al., 2011, IPCC, 2014b). Reid et al. (2008) state that subsistence rainfed cropping in Namibia, will be the worst affected by climate change in the future due to exacerbated dry conditions as well as flood damage and erosion from rainfall bursts of great intensity. In both a best and worst case scenario, there will be a large agricultural decline across Namibia, reductions in crop production are expected to be between 40 % - 80 % nationwide (Reid et al., 2008, IPCC, 2014b). The extent to which subsistence agriculture can feed a growing population will depend on the ability of local people to adapt to climate change (Reid et al., 2008).
Although, an effort has been made to reduce this vulnerability in north-central Namibia, it is believed that there has been relatively limited uptake of viable crop

production adaptation options (Hegga et al., 2016). Hegga et al. (2016) found that in the past when new farming practices and technologies were introduced to Onesi by the government there was a lack of ownership of these methods by the local people. Local people favoured traditional practices and traditional varieties of Mahangu when improved seeds were provided by the government (Hegga et al., 2016). Farmers in northern Namibia have a strong cultural connection to traditional ways of farming as well as to the appearance and taste of certain crop varieties (Davies et al., 2018; Fisher et al., 2015) Another study in Ondangwa by Von Hase (2013) indicated that the limited uptake of the ripper furrow practice was due to a lack of governmental support with land preparation, funding and information. These fall under the commonly referenced barriers to climate change adaptation: finance, information, technology, institutional and social (Shackleton et al., 2015; Eisenack et al., 2014; Biesbroek et al., 2013 Gruère and Wreford, 2017).

There are however many other populations in arid and semi-arid areas across the globe who have had to continuously adjust their livelihoods to short and long-term climate variations in the past and who have managed to enhance their food security and resilience to climate change through adaptive practices and planning for the future (Twomlow et al., 2008; Abid et al., 2015; Alam, et al., 2017). Since temperature, rainfall and soil are vital components of farming and highly sensitive to climate change, low cost adaptation requires the enhancement of water harvesting and soil fertility. For example, the practice of planting pits (crops are planted in holes and filled with compost or mulch) as a method of infield water harvesting, improving infiltration and enhancing soil quality has been used extensively across West Africa with successful yield increases and as a buffer against droughts and floods (Garrity et al., 2010; Adimassu et al., 2016). Despite the distance between these communities they share similarities in their livelihood experiences and vulnerability to climate change. McNamara and Buggy (2017) explain that agro-ecological knowledge and low input practices have been invaluable to adaptation for many rural communities across the world that are already experiencing impacts of climate change. By studying adaptation strategies of semi-arid communities, we may find valuable information on adaptation that can be shared with other similar groups.

Henceforth, there is an acute need for crop producing farmers in semi-arid regions, such as Onesi, to adapt their farming practices in order to reduce their vulnerability to climate change and enhance their food security. It is first necessary to examine the scientific base of the impacts of climate change on crop production in Northern Namibia (Newsham and Thomas., 2009; Dirkx et al., 2008; Republic of Namibia, 2015b). This paper will then attempt to understand local perceptions on vulnerability to climate change, in terms of impacts currently experienced and the possible future impacts, because perceptions govern adaptive behaviour and farmers will not change their practices if they do not perceive a risk (Balama et al., Burnham and Ma, 2017; 2016; Sing et al., 2016). Acquiring new ecological and farming knowledge, such as by word of mouth or learning through experimenting is inevitably slow in remote dryland areas like northern Namibia (Von Hase, 2013). In light of this, identifying and sharing effective agricultural adaptation practices adopted by farmers in different regions who have similar environmental and traditional contexts may offer an innovative approach of reducing their vulnerability. Lastly, this study aims to investigate the barriers that inhibit the uptake of new practices and the enablers that enhance their uptake (Eisenack et al., 2014; Biesbroek et al., 2013; Gicheru, 2016). Identifying and aiming to strengthen enablers of adopting new crop production practices is of central importance to this project. This brings us to the following overarching objectives and associated research questions, which will contribute to the literature on this topic.

1.1. Objectives and research questions:

To understand crop farmers' perceptions of climate change vulnerability.

1. To what extent does the farming community perceive the area to be vulnerable to climate change?
2. Are farmers planning for change?

To identify interventions that could reduce vulnerability to loss of crop yields.

1. What adaptation practices are employed in other semi-arid regions?
2. Are there any climate smart practices already promoted in north-

central Namibia?

3. Which new practices are suitable for the study villages in the Onesi constituency?

To assess the barriers and enablers of adopting practices from other semi-arid regions.

1. Are farmers willing to adopt new practices?
2. What are the barriers and enablers of adopting new practices in the study villages?

This research will feed into the Adaptation at Scale in Semi-Arid Regions (ASSAR) research project. The aim of ASSAR is to study vulnerability and adaptation to climate change, with a specific focus on the barriers and enablers of adaptation strategies in semi-arid regions. ASSAR are conducting research across seven countries: India, Kenya, Ethiopia, Ghana, Mali, Botswana and Namibia over a five-year span from 2014 - 2018.

Chapter Two: Literature Review

Image: Piles of *mahangu* (left) and sorghum (right), photo taken during fieldwork by Angela Chappel.

2.1. Climate change verse climate variability

Climate change is defined by IPCC (2012; 2014a) as: a change in the state of the climate that can be identified - using statistical tests- by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate variability, however, refers to variations in the mean state and other statistics - such as standard deviations - of the climate at all spatial and temporal scales beyond that of individual weather events (IPCC, 2012; 2014a). Variability may be due to natural internal processes within the climate system (internal variability), or variations in natural or anthropogenic external forcing (external variability) (IPCC, 2012; 2014a). One of the key differences between climate change and climate variability is that climate variability considers changes that occur over smaller timeframes, i.e. months, seasons and years whereas climate change considers changes that occur over a longer period of time (decades or longer) (WMO, 2017). It must also be noted that different parts of the world experience different degrees of variability. For example in one region variability may be weak which would mean that there is not much difference in the climatic conditions within a given time period. Namibia, however, has strong climate variability which means that conditions vary across a wide range (from very cold to very warm and very dry to very wet) (IPCC, 2012; ASSAR, 2015; Newsham and Thomas, 2009). In regions with strong variability it is inevitably more challenging to identify and attribute climatic events or conditions to climate change. WMO (2017) explain that variability is often understood and accepted, instinctively, by the people in a region, what is normal in one area may be totally abnormal in another. It has been argued that climate change will in fact cause even stronger climate variability in many regions including Namibia (ASSAR, 2015; Newsham and Thomas, 2009; Mubaya et al., 2012). In both the case of climate variability and climate change, climate risks are posed. Climate risk refers to the potential (the outcome is often uncertain) of adverse consequences on humans and ecosystems (IPCC, 2012).

2.2. Causes of climate change

Climate change is a complex issue with far reaching consequences, which has unsurprisingly been deemed the greatest challenge of our time (UNDP, 2015). Anthropogenic greenhouse gas (GHG) emissions, predominantly carbon dioxide (CO_2) methane (CH_4), nitrous oxide (N_2O) and chlorofluorocarbons (CFCs) are the leading contributors to climate change (IPCC, 2014b). These emissions come from actions such as burning fossil fuels, livestock production and deforestation, which have all increased since the industrial era due to economic and population growth (Brown, 2009; IPCC, 2014b). GHGs trap heat in the atmosphere, which causes the earth to warm up leading to a state of global warming. The conundrum implicit in this research is that Namibia is one of the least contributing countries to climate change; in 2010, for instance they contributed only 0.059 % to global emissions, yet they are highly vulnerable to the harmful impacts of climate change (Republic of Namibia, 2015a).

2.3. Impacts of climate change on crop production in Namibia

Climate change includes gradual changes in temperature, rainfall, the El Nino Southern Oscillation (ENSO) and CO_2 concentrations as well as sudden/abrupt changes causing extreme weather events. These impacts reduce the water availability, fertility and stability of the already degraded topsoil of northern Namibia, which has a direct impact on the ability to grow crops (GEF, 2006). It must be mentioned that in some instances the impacts of climate variability and climate change may have positive effects on the community. For example, annual floods that come from Angola fill the floodplains (locally know as *shanas*) in Northern Namibia. These floods bring fish and ensure water reserves for dry periods (Global Issues, 2011).

2.3.1. Temperature

In climate change terms, the IPCC, (2012; 2014a) define 'warm day's as days, were maximum temperatures or nights where minimum temperatures, exceed the 90th percentile, the respective temperature distributions relate to the 1961-1990 reference period. Similarly, 'cold days' refer to days, where the maximum temperature or nights where the minimum temperature, falls below the 10th percentile, again the respective temperature distributions relate to the 1961-1990 reference period (IPCC, 2012; IPCC, 2014a).

MET (2011) posit that over the past 40 years, globally, the annual number of days exceeding 35^0C has increased whilst the number of days with temperatures below 5^0C has decreased, suggesting a warming trend. Globally, extreme temperature events are projected to become even more intense, more frequent and last for a longer duration than what is currently observed. The results of 25 years of data from seven climate stations across Namibia show increases in the maximum temperatures of warm days as well as the frequency of warm days (Newsham and Thomas, 2009). According to the averages of 21 Intergovernmental Panel on Climate Change Fourth Assessment Report (IPCC AR4) models, there will be an increase in annual mean temperature of between 3°C and 4°C in Namibia by 2080 (Barnes et al., 2012). According to data from a downscaled Commonwealth Scientific and Industrial Research Organisation (CSIRO) model for north-central Namibia, the number of days exceeding 34^0 C per year between 2046 – 2065 is expected to increase from 67 to 118 (Newsham and Thomas, 2009). The Figures (1a and 1b) below show a time series of winter (JJA) and summer (DJF) precipitation and temperature over the period 1891 – 2100 for Namibia and the Omusati region. Figure 1a indicates an increasing trend in average winter temperatures of approximately 3°C – 5°C over the 240 year period for

Namibia (with a slightly higher temperature increase for Omusati in both the RCP 8.5 and RCP 4.5 models). Figure 1b indicates an increasing trend in average summer temperatures of approximately 4°C – 6°C. For the summer temperature the increase for Omusati is slightly less in both the RCP 8.5 and RCP 4.5 models Reid et al. (2008) further point out that increased temperatures will cause higher evaporation rates in Namibia; 1°C of warming is approximately equal to an increase of 5 % in evaporation. If this holds true there will be many negative impacts on crop production and food security. Increased temperature affects the optimum growing range of crops which decreases yield output (Kalra et al., 2007). Newsham and Thomas (2009) explain that even crops that are adapted to hot and dry climates, such as sorghum and *mahangu* will struggle to survive in such conditions

2.3.2. Decreased rainfall

By 2020, it is projected that approximately 250 million people across Africa will be exposed to increased water stress as a result of climate change, which will lead to a 50 % reduction in rain-fed agricultural yields (Arku, 2013; IPCC, 2014b). Barnes et al. (2012) posit that Namibia is expected to have a 5 % - 20 % decrease in rainfall by 2080. Davis (2011) used data from six downscaled global circulation models (GCMs) over the period 2036 – 2065, which show a decrease in annual rainfall totals across the country. With reference to the Figures below, Figure 1a indicates decreasing average winter precipitation across Namibia over the 240 year period. The average winter rainfall across Namibia is projected to decrease by about 6 mm by mid-century and 7 to 9 mm by the end of the century. Figure 1b indicates that average summer rainfall is projected to decrease by about 17 to 23 mm by mid-century and 19 to 40 mm by the end of the century (noting that rainfall is almost entirely experienced in the summer season in Namibia and that Omusati receives substantially more rainfall than Namibia's average). Reid et al. (2008) and IPCC (2014b) support this finding, by explaining that the southern African monsoon is predicted to weaken which would have a impact on northern Namibia by leading to less rainy days and less annual rainfall.

Decreased rainfall affects runoff and groundwater recharge rates, which consequently decreases the water available for crops (Kalra et al., 2007). A later onset and earlier cessation of rains as predicted as well as longer intervals between rainfall events will have a direct impact on crop growth and survival (Republic of Namibia, 2015b, Dirkx et al., 2008). This is especially true for smallholder farmers in northern Namibia, the majority of whom are reliant on rainfed agriculture (Newsham and Thomas, 2009). Increased rainfall variability is also challenging as it means that crop farmers cannot predict and plan when to plant their crops.

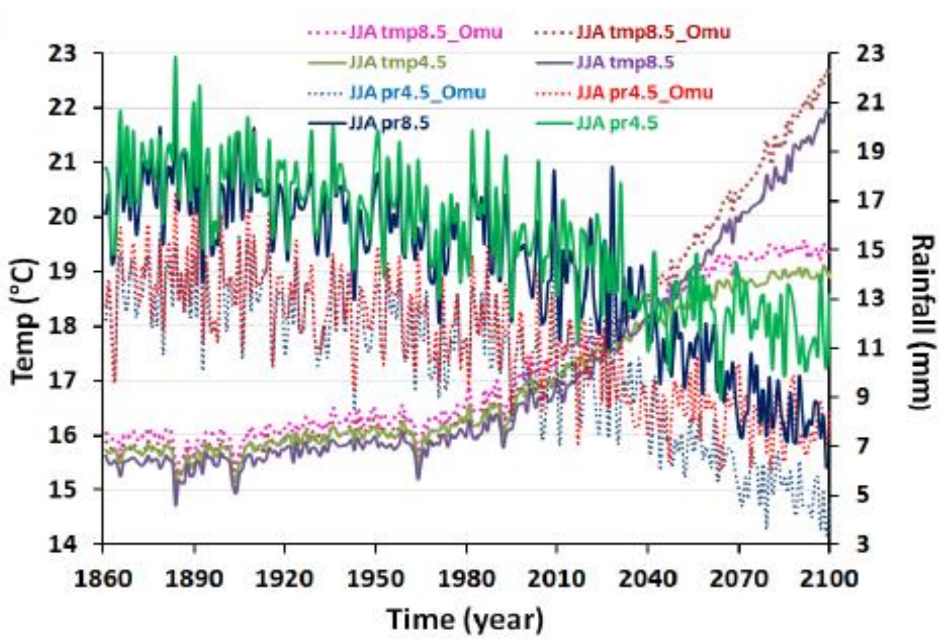


Figure 1a. Time series of winter precipitation (pr) shown as a dotted line and temperature (tmp) shown as a continuous line for Namibia and Omusati (Omu) from 1861 to 2100. This model is from the CMIP5 multi-model mean average using the RCP 8.5 (39 models) and RCP 4.5 (42 models) representative concentration pathways (RCPs). (Taken from Spear et al., 2018, created from KNMI Climate Explorer, 2018).

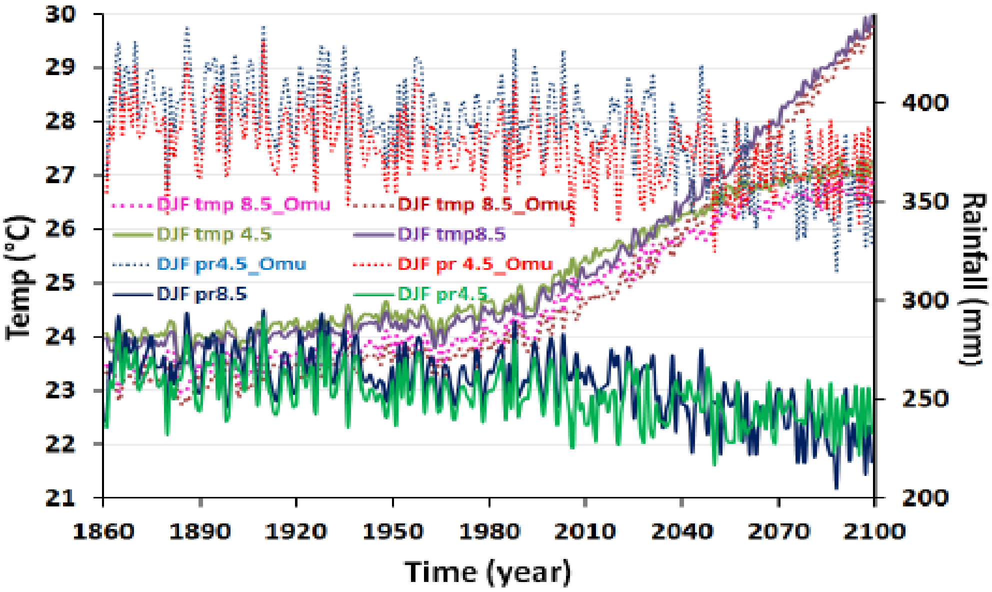


Figure 1b. Time series of summer precipitation (pr) shown as a dotted line and temperature (tmp) shown as a continuous line for Namibia and Omusati (Omu) from 1861 to 2100. This model is from the CMIP5 multi-model mean average using the RCP8.5 (39 models) and 4.5 (42 models) representative concentration pathways (RCPs). (Taken from Spear et al., 2018, downloaded from KNMI Climate Explorer, 2018)

2.3.3. ENSO

ENSO influences the rainfall over the north-eastern, eastern and southern parts of Africa in varying ways; Namibia is especially sensitive to these interactions (Camberlin et al., 2001; Reid et al., 2008). Dirkx et al. (2008) explains that prior to 1970, El Niño events (hotter and drier than La Nina) occurred at intervals of approximately three to seven years over southern Africa, however over the period 1976 – 1995 there were nine El Nino events (which means they occurred on average every two years). The severe droughts experienced in Namibia over the past few decades have been attributed, by meteorologists, to the disturbance and shifts in the global circulation patterns and the El Nino effect (Dahlberg et al., 2008; Republic of Namibia, 2015b). Although there is great uncertainty surrounding this, climate change is expected to cause disruptions to the amplitude and timing of the oscillation, which will cause more El Nino events for Namibia in the future and will affect the rainfall and hence agriculture (Yu et al., 2012). Stige et al. (2006) state that maize would be the worst affected by high El Nino conditions with a possible crop productivity reduction of 11.7 % compared to a normal year. Sorghum, millet and groundnuts would be less affected, as they are adapted to drier conditions, nonetheless, a reduction in all yields would be experienced (Stige et al., 2006)

2.3.4. Pests and diseases

Although there is great uncertainty surrounding the implication of climate change on pests and diseases there is ongoing research, which suggests correlations between the two (Gornall et al., 2010; Sun et al., 2011). As Kalra et al. (2007) point out, increased CO_2 concentrations generally help plants to grow faster by increasing the rate of photosynthesis. However, increased CO_2 in the atmosphere causes a variety of cascading effects that disrupt the natural balance of the agro-ecosystem (Sun et al., 2011). It is posited that increased CO_2 alters the phenotype of plants by inducing changes in the distribution of carbon and nitrogen which reduces the level of proteins and minerals in crops and ultimately the nutritional value of food crops (Sun et al., 2011; Adams et al., 1998). Loladze (2014) explain that this impact of climate change may exacerbate the problem of 'hidden hunger', which is the phenomenon in which although enough calories are consumed, the food is deficient in minerals leading to malnutrition. This is concerning for farmers in northern Namibia because their diets are based solely on a few crops which they rely on to obtain all of their nutrients.

Studies by Sun et al. (2011) in China found that CO_2 induced changes in host plants affected the intensity and frequency of pest outbreaks. Although CO_2 initially affects crop plants it subsequently perturbs higher trophic levels through the food chain to encompass pests, their natural enemies, pathogens and underground nematodes (Sun et al. 2011). Gornall et al. (2010) and Newman (2004) explain that pests, such as aphids respond positively to increased CO_2 and increased temperature combined For example, increased CO_2 prolonged the development of cotton bollworm and increased the population size of cotton and wheat aphids (Gornall et al., 2010). It is also postulated that warmer winter temperatures decrease aphid mortality (Newman, 2004). Hatfield et al. (2008) concur that there are many pests and weeds that grow more prolifically under warmer temperatures and increased CO_2 levels. Evidence further suggests that the migration patterns of locusts in sub-Saharan Africa may be influenced by rainfall patterns (Gornal et al., 2010).

Pests may be able to survive in new areas, live for longer and produce more offspring, which could cause extensive damage to crops. There are also human health implications and costs related to increased pesticide use to combat the greater prevalence of pests. An extreme outbreak of armyworms and an outbreak of locusts across northern Namibia were recorded in 2017, which caused extensive crop damage to maize and pearl millet and economic losses (MAWF, 2017, Africa Independent, 2017). There is also documentation of farmers in northern regions reporting increases of pests (mostly locusts and armyworms) on their land over time (Von Hase, 2013; Hasheela, 2010). These kinds of outbreaks are expected to increase in frequency and intensity in the future.

2.3.5. Extreme weather events

An increase in the frequency and intensity of extreme weather events such as droughts, floods and natural disasters can markedly damage crops and farmland. According to Reid et al. (2007) it is believed that as a result of climate change, when rainfall does occur in northern Namibia it will be in short lived intense falls, which will cause erosion and flood damage to the crops. Newsham and Thomas (2009) refer to the flood event experienced in northern Namibia in 2008 as an example of the kind of damage that could be caused by climate change related natural disasters in the future (Newsham and Thomas, 2009).

2.4. Short-term coping and long-term adaptation strategies to climate variability and climate change[1]

In climate change terms, coping implies the use of existing resources during and immediately after climatic shocks in an attempt to mitigate harm as quickly as possible and implies a short-term vision (Balama et al., 2016). Adaptation refers to long-term strategies used primarily to enhance resilience and reduce vulnerability, but can also lead to other social or environmental benefits (Balama et al., 2016). It is irrefutable at this point in time that even with the most ambitious efforts to reduce greenhouse gas emissions, the impacts of climate [1]change are already experienced globally. This will continue to worsen in the future which makes adaptation imperative.

Although some authors argue that short-term coping responses to climate variability

[1] The literature about adaptation practices used in other semi-arid regions can be found in the results section (chapter five) as this is a separate systematic literature review for Objective Two.

can facilitate long-term adaptation to climate change, others believe the inverse (Bryan et al., 2009). Ziervogel et al. (2008) point out that coping responses can sometimes actually increase vulnerability to long-term climate change and make adaptation in the future more challenging, in other words lead to maladaptation. This is because coping strategies are an unplanned use of available resources whereas adaptation is ideally a planned and sustainable use of resources (Muller and Shackleton, 2014). Paavola (2008) cites a study in Tanzania where agricultural households coped with climate change and other stressors through extending the duration of cultivation and intensifying their agricultural practices. These responses degraded the forest, soil and water resources that usually act as a safety net for vulnerable groups during times of stress. Degradation of these resources undermines the ability to adapt to climate change in the future. Hence, adaptation efforts need to involve suitable governance and sensitive use of natural resources to ensure their long-term sustainability (Paavola, 2008; Ziervogel et al., 2008).

In 2008 and 2009 floods affected northern Namibia and southern Angola which killed 112 people, led to a 50 % reduction in cultivated land and overall impacted up to 276 000 people in Namibia alone (Newsham and Thomas, 2009). The government and the Red Cross Society provided flood relief camps and food aid to help subsistence farmers to survive this major setback. In a similarly challenging instance, there was a severe drought in Namibia, over the 2015/2016 cropping season, according to FAO (2016) this was the worst drought in 80 years. This necessitated the distribution of 607 tonnes of fertilizer, 20 tonnes of cowpea seeds, 82 tonnes of maize and 123 tonnes of *mahangu* seeds as well as ploughing services by the government across the country in order to reduce the vulnerability of subsistence farmers to this event (Republic of Namibia, 2016). This is in addition to multiple other food relief programs which provide food for parts of the country annually (Republic of Namibia, 2016).

The government's response is an understandable crucial short-term coping strategy to climate variability but does not offer long-term resilience to future climate risks. It could be argued that strategies like this make people more vulnerable to climate change because they create a sense of dependency on the government and may lead to inertia for farmers to adapt their practices to a changing climate (Twomlow et al., 2008). Maru et al. (2014) concur that dependence on governmental aid reduces self-reliance and the capacity to adapt to future disturbances. Planning for change through the use of adaptation practices allows farmers to be prepared and resilient to gradual and sudden climatic changes.

2.4.1. Perceptions, vulnerability and responses to climatic changes

Perceptions, the way in which information is processed and understood, is an important influence on vulnerability and adaptation to climate change (Balama et al., 2016). Perceptions of climate change are shaped by belief systems, personal experiences of climatic events and perceived responsibility of the problem (Becken et al., 2013; Moyo et al., 2012). Trope and Liberman (2010) discuss the "Psychological Distance Theory" which suggests that events that are spatially, socially or temporally perceived to be closer are more salient and have a greater influence on individual's decisions. Hence, if the effects of climate change are perceived to be imminent, farmers will take appropriate adaptation action which will in turn mitigate their vulnerability and enhance the resilience of the agro-ecological system to climate change (Alam et al., 2017). Likewise, if climatic risks are not perceived and farmers are not aware that they are vulnerable, they are less likely to respond which increases their vulnerability even more (Silva-rosa et al., 2014). Becken et al. (2013) and Simelton et al. (2013) highlight that regardless of the scientific estimation of the actual risk associated with climate change, it is the perception of risk that governs people's response and behaviour. Grothman and Patt (2005) add that perceived ability to effect real adaptation is also an important determinant governing behaviour. The potential for adaptation ultimately hinges on how local people perceive and rationalise climatic changes and the associated risks such as changes in their yields.

Several studies in African countries have indicated different communities perceptions of past and current changes in their local climate in terms of rainfall and temperature and the ways in which they have responded in preparation for future changes (Ayanlade et al., 2016, Mongi et al., 2010; Ogalleh et al., 2012). In a Tanzanian study by Mongi et al. (2010) local people perceived climatic changes in terms of increasing temperatures and decreasing rainfall (almost 100 % of farmers and extension officers perceived rainfall to be declining for the last ten years). The interviewed farmers also stated that agriculturally unproductive years are becoming more frequent resulting in widespread food shortages (Mongi et al., 2010). Farmers responded to these change through a variety of adaptations such as changing to drought resistant crops and expanding the area under cultivation (by reducing the fallowed area) to compensate for yield reductions (Mongi et al., 2010). A similar study in Laikipia, Kenya by Ogalleh et al. (2012) showed that the perception of decreased rainfall and increased temperature led smallholder farmers to respond by planting early maturing crops and mulching to reduce water loss. However, farmers do not always respond to perceived changes. For example, a study in South Africa showed that 95 % of farmers perceived changes in temperature and 97 % perceived changes in rainfall yet 62 % of the farmers did not adapt their farming practices in any way to changes in temperature or rainfall (Bryan et al., 2009). This suggests that other factors including short-term climate variability, characteristics of the household (ie. size) as well as the economic and institutional environment influence decision making (Bryan et al., 2009, Ayanlade et al., 2016).

Hitayezu et al. (2017) highlight that the gradual nature of climate change makes it difficult to differentiate from the natural variability of local climates. Since farmers in semi-arid regions, such as northern Namibia, have always experienced variability, it can be difficult for farmers to detect trends in the weather amid short-term fluctuations (Shackleton et al., 2015). Moreover, in some cases perceptions of temperature and rainfall trends do not match the meteorological recorded data (Mubaya et al., 2010). For example, a study in the Eastern Cape province of South Africa where meteorological records indicated an increase in rainfall since 1990 yet a majority of the farmers perceived a decrease in rainfall (Muller and Shackleton, 2014). Muller and Shackleton (2014) and Moyo et al. (2012) suggest that the discrepancy between perceptions and actual trends may be because perceptions are shaped by recent climatic stimuli (possibly a recent drought) rather than long- term trends and because farmers may generalise the weather based on what they remember. Simelton et al. (2013) suggest that another explanation for the differences between farmer perceptions and meteorological evidence is that rainfall changes may be confused with changes in farming system sensitivity. This indicates that, although perceptions govern behaviour they are not necessarily an accurate representation of climatic conditions and should be compared to meteorological data. Since farmer's perceptions govern their responses rather than the scientific estimation, misrepresentation of trends as well as an underestimation of the severity of climatic changes may lead to maladaptation (Becken et al., 2013). The following response continuum (Figure 2) indicates how different responses to climatic stress may lead either to more vulnerable or more resilient systems.

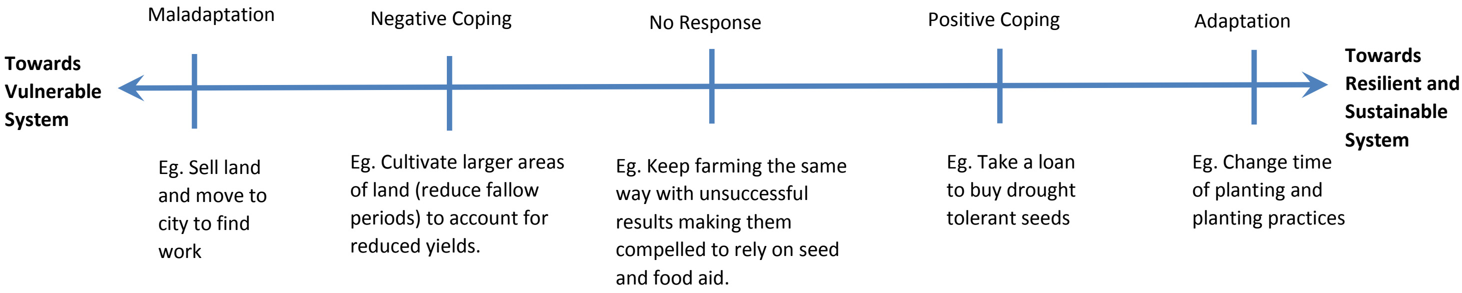


Figure 2. Farming response strategies to climatic stress conceptualised along a continuum, adapted from Singh et al. (2016)

2.5. Barriers to adopting new crop production practices

In this study of northern Namibia, barriers to the ability or willingness of farmers to adopt climate change adaptation practices are defined as configurations of tangible and perceived factors that emerge from an individual actor, governance system or the system of concern and reduce the effectiveness of adaptation strategies (Biesbroek et al., 2013). Barriers form at many different stages of adaptation and can overlap and interact across different spatial or temporal scales which create complex adaptation challenges (Shackleton et al., 2015). The research for this project is based on the premise that barriers can be overcome, decreased or avoided through creative and unique management (Eisenack et al., 2014). This is as opposed to limits to adaptation; a limit implies a point which cannot be overcome and hence prevents adaptation from taking place altogether (Barnett et al., 2015). Eisenack et al. (2014) refer to the notion of an 'adaptation deficit' whereby the implementation of adaptation strategies is not able to keep up with the pace of change. Adaptation barriers are an increasingly critical concern as developing countries (such as Namibia) fall further into an adaptation deficit.

It must be noted that the underlying poverty, weak institutional capacity and climate variability in northern Namibia creates a meager starting point for adaptation to climate change (Angula and Kaundjua, 2016). Barriers that prevent people from making changes to their farming practices may be categorised in many different ways, the following Figure 3 and descriptions indicate the broad barriers to crop production adaptation and some of the interactions of these barriers but this is by no means an exhaustive list.

2.5.1. Information

Information barriers refer to low levels of awareness about climate change or uncertainty about climatic projections; this is frequently cited as the main barrier to adopting new practices in Namibia and in other semi-arid countries (Bryan et al., 2009; Nena, 2015). For example, scientific information is crucial in helping small-scale farmers to establish early warning systems and change the time of planting (Antwi-Agyei et al., 2015). Trust of climate information is also important and can act as a barrier if the information is not relayed timeously or by a reputable source (Gruère and Wreford, 2017). Gruère and Wreford (2017) give a nuanced example of how farmers who are sceptical about climate change would be less likely to adopt climate friendly practices. However, if the practices are framed rather as a means of addressing weather variability, farmers may be more open to trying them. Information is linked to education because lower levels of education often correlate to a lack of awareness and understanding of climate change (Gbetibouo, 2009). In the Muller and Shackleton (2014) study in the Eastern Cape, education was the major differentiating variable between farmers who adapted to climate change and those who did not.

2.5.2. Social

Social barriers can be either cognitive relating to individual thought processes (this is where perceptions influence behaviour) or normative implying cultural values and norms including tradition and religion (Biesbroek et al., 2013). Farmers make sense of environmental processes based on their specific socio-cultural frame, which can impede or enhance their response, thus the social setting is essential to adaptation (Shackleton et al., 2015; Adger et al., 2009). Social barriers are highly subjective and adaptation is variable according to aspects such as gender, class and culture, which can give rise to different barriers in the same region (Shackleton et al., 2015). For example, in some regions women are limited in their adaptive capacity due to lack of access to land or credit (Shackleton et al., 2015). Thomalla et al. (2015) go so far as to claim that culture is at the root of all behaviour and culture is what deems which new farming practices will be taken up or rejected.

In northern Namibia, culture is a central component of Oshiwambo people's lives and farming traditions (Von Hase, 2013). Culture can act as a barrier to adaptation when those who prescribe to it are bound to the cultural practices which have been passed down over many generations and are unwilling to deviate from what is known and trusted (Gruère and Wreford 2017).

2.5.3. Institutional

Institutional barriers can refer to a lack of formal support from government extension services and NGOs or informal institutions, which act as shared social governance (this links to normative barriers) (Biesbroek et al., 2013). Biesbroek et al. (2013) highlight that adaptation to climate change is a low priority in low to middle income developing countries (such as Namibia) owing to the presence of many other pressing societal issues. This results in low levels of institutional support and funding for adaptation policies and practices. Furthermore, government driven top down approaches to adaptation are often unsatisfactory to local communities who require bottom up and integrated policies (Biesbroek et al., 2013). Eriksen and Lind (2009) further explain that institutional barriers form when external support disregards the local understanding of vulnerability and adaptation, which leads to inappropriate policies and strategies.

2.5.4. Financial

Financial barriers refer to the adoption costs and lack of credit facility services to pay for equipment, resources, land or labour to work on the land. This is commonly cited as a barrier, especially in poorer regions such as northern Namibia (Von Hase, 2013; Gruère and Wreford 2017). For example, the cost of purchasing drought resistant varieties of groundnuts in Ghana prevented farmers from using improved seeds to adapt to decreasing rainfall (Peterson, 2013). Financial barriers can also impact the size of land that is purchased or rented, if the size of land is small relative to the number of people it must support, there is pressure on the productivity of the land

(Masud et al., 2017, Nena, 2015). The actual or perceived lack of financial benefits that will accrue from adopting a new practice may also act as a barrier if they are not seen as worth the capital input (Gruère and Wreford 2017).

2.5.5. Technology

Technological barriers are linked to financial and institutional barriers which are particularly prominent in remote dryland regions and prevent households from engaging in more advanced adaptation strategies (Antwi-Agyie et al., 2015). Technological access and expertise in crop production adaptation refer to the development of early warning systems, new crop varieties and water harvesting technology, all of which build resilience to climate change (Antwi-Agyie et al., 2015). The UNFCCC (2006) highlights that technological barriers to adaptation tend to occur because adaptive technologies that are appropriate in one area do not successfully translate to other regions.

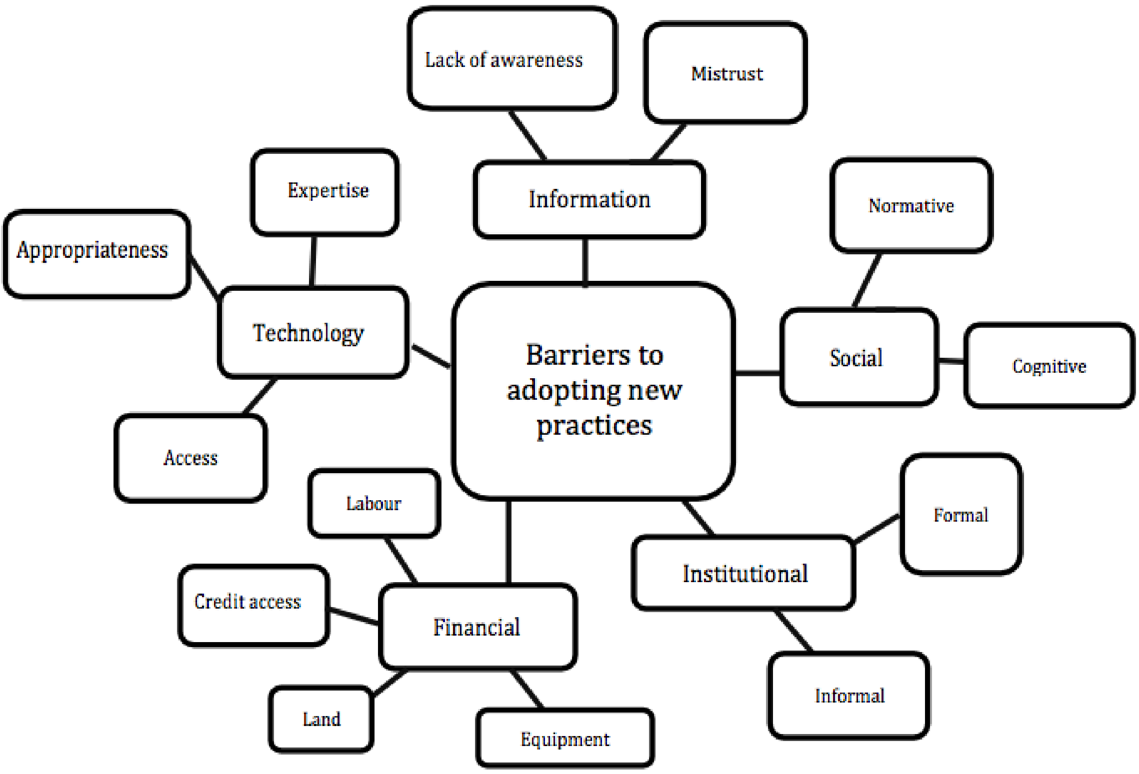


Figure 3. Barriers to the adoption of new farming practices developed by the researcher derived from the literature

2.6. Enablers of adopting new crop production practices [2]

An enabler is a condition or facility that assists an individual or group of people to make the necessary adaptations to climate change. Enablers in this instance can be viewed as the inverse of the barriers: information, institutional, financial, technological and social. The dissemination of context specific climate information is fundamental for marginal dryland communities since they are not afforded the benefit of ease of access to information like many people in the developed world. The role of institutions, from a national to local scale, in supporting individual and collective willingness to enhance adaptive capacity is widely acknowledged (FAO, 2018, Ziervogel and Erikson, 2010, Gruère and Wreford 2017). Financial and technological enablers that stem from institutional support are also pertinent to low income rural communities.

Although the cost of climate change adaptation is often initially high, it has been demonstrated time and again that the cost-benefit of adaptation in farming is overwhelmingly positive, with benefits in yield increases, improved livelihoods and ensuring food security for the future (which hosts additional psychological benefits) (Parry et al., 2009; OECD, 2014; Rouillard et al., 2016; FAO, 2018). Finally, social enablers can promote the sharing of adaptive ideas and solutions (Bryan et al., 2009). McNamara and Buggy (2017) outline the importance of viewing community-based adaptation as a learning-by-doing process with emphasis on participation and local ownership of the problem. This is necessary because of the local contextual knowledge and buy in required for adaptation to be successful. Hence, creating an enabling environment for communities to adopt new adaptation practices involves empowering local people to enhance their own resilience rather than providing external short-term solutions.

[2] The specific enablers to the uptake of new practices will be elaborated on in the results section (chapter six), as this is also a separate systematic literature review that forms part of Objective Three.

Chapter Three: Context and Methodology

This chapter will outline the study site, methodology for each of the objectives and information about the respondents' livelihoods in the study area.

Image: Our fieldwork team from left Efaishe Kavela (translator); Angela Chappel; Nivedita Joshi (researchers) and Hileni Shivolo (translator).

3.1. Study site:

3.1. 1. Namibia

Namibia has a population of approximately 2.2 million people, which makes it one of the most sparsely populated countries in Africa (Republic of Namibia, 2016; Odendaal, 2011). It is also one of the most unequal societies in the world in terms of wealth distribution, with a Gini coefficient of 0.57 in 2017 (UNDP, 2017). As previously mentioned, more than half of the Namibian population live in rural areas where subsistence agriculture is their primary livelihood; however, agriculture is greatly strained by harsh environmental and climatic conditions (Crawford and Terton, 2016). The soil in Namibia (dominated by sands of the Kalahari and the Namib

Desert) is characterized as having very low water retention with only 1 % of annual rainfall believed to recharge groundwater reservoirs as well as having a low fertility status (Crawford and Terton, 2016; Shiningayamwe, 2012). Soils in the semi-arid regions of sub-Saharan Africa are also inherently deficient in nitrogen and phosphorus (Odendaal, 2011).

The Namibian climate is controlled by a number of interacting systems. During winter the cold Benguela current flows north along the Namibian coast driven by the subtropical high-pressure zone (Dirkx et al., 2008). This cold dry air suppresses rainfall causing a dry season across Namibia. However, during summer in Namibia there is a rainy season from November – April. This is due to the low pressure from the southerly position of the Inter Tropical Convergence Zone (ITCZ) which brings moisture and rainfall from the tropics over northern and eastern Namibia, this can be seen in Figure 4 below (Mendelsohn et al., 2002; Dirkx et al., 2008). The temperate zone also moves northwards during the winter, which results in winter rainfall in the far southwest of Namibia (Republic of Namibia, 2015b)

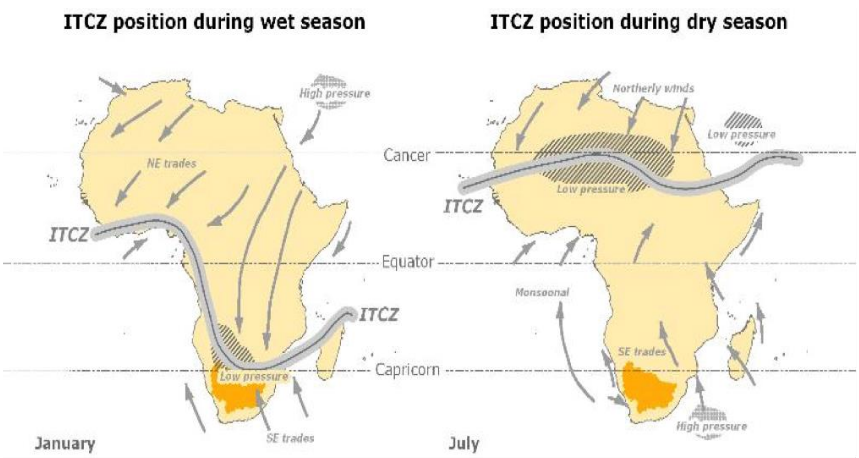


Figure 4. The position of the ITCZ in the wet (summer) season and dry (winter) season (IDRC, 1978).

Rainfall is variable across the country, ranging from 50 mm per annum in some regions to 700 mm in others (MET, 2011). Figure 5a, 5b and 5c, 5d below indicate the temperature and precipitation variability experienced across the country in summer and winter. There are five perennial rivers along the borders with neighboring countries but all other rivers are ephemeral which means they only flow after heavy rainfall events (Froystad et al., 2008)

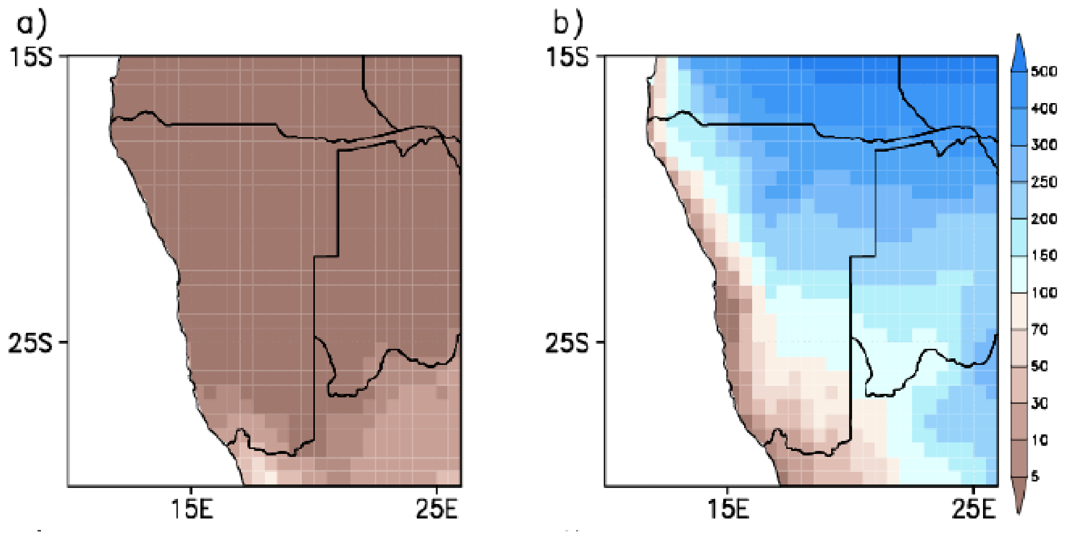


Figure 5a and 5b. Spatial maps of mean precipitation across Namibia, measured in mm over the period 1963 - 2012 a) winter precipitation b) summer precipitation (maps taken from (Spear et al., 2018) data derived from CRU TS3.22 dataset).

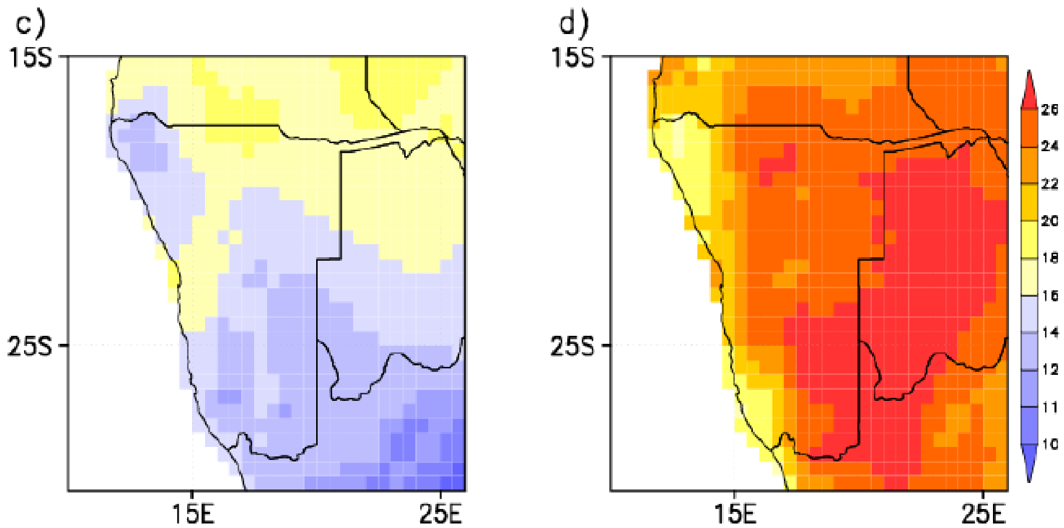


Figure 5c and 5d. Spatial maps of mean temperature in °C across Namibia over the period 1963 – 2012, c) winter temperature d) summer temperature (maps taken from (Spear et al., 2018) data derived from CRU TS3.22 dataset)

3.1.2. Ovamboland

Newsham and Thomas (2009) explain that the north-central region of Namibia (Omusati, Oshana, Ohangwena and Oshikoto) commonly referred to, as Ovamboland is unique to the rest of the country in a number of ways. One of the reasons for this is that the north-central region received less colonial domination by German and South African powers and hence the local Ovambo people were not subjected to the same extent of oppression as people in other parts of the country (Newsham and Thomas, 2009). Ovamboland, has become a flat landscape over the past 70 million years as a result of water and wind cycles depositing sediments from higher to lower ground (Newsham and Thomas, 2009). Ovamboland is also the wettest and most highly populated part of the country (Newsham and Thomas, 2009). The FAO (2009) explains that as a result of increased human population density and overstocking by livestock farmers, soil in the north-central region of Namibia has been overgrazed and is in poor condition. This means that microorganisms, essential for maintaining healthy soil, cannot survive and the water and nutrient holding capacity declines rendering poor quality soil so that even if fertilizer is applied it is leached out by the rain (FAO, 2009). Furthermore, organic matter and nitrogen content is extremely low in the topsoil of Ovamboland (Republic of Namibia, 2006). The population of Namibia is projected to increase from the present 2.2 million to 3 million by 2031, with majority located in the north-central region; this would increase pressure on agricultural land which would further decrease farm sizes and agricultural production per household (Republic of Namibia, 2017).

3.1.3. Onesi constituency

The Onesi Constituency (14^0 41’ 16, 6” E 17^0 34’ 14” S) is one of 12 electoral constituencies within the Omusati region, with a population of roughly 13 000 inhabitants (NSA, 2011). Rainfall in Onesi is approximately 400 mm per annum, which falls in summer between December and March (Republic of Namibia, 2006).

This research is focused on three villages within the Onesi constituency namely: Okathitukeengombe, Oshihau and Omaenene (Figure 6). Okathitukeengombe is the smallest village and also the furthest from an urban area. Houses in this village are mostly built out of stones, mud and stick and are very far apart. Oshihau is closest to the Onesi traditional authority and more of these houses are built out of bricks. Omaenene is the biggest of the three villages; it is right next to the C46 main road (between Outapi and Ruacanna) and very close to the Angolan border. These houses are closer together and most of them are built out of bricks or corrugated iron sheets.

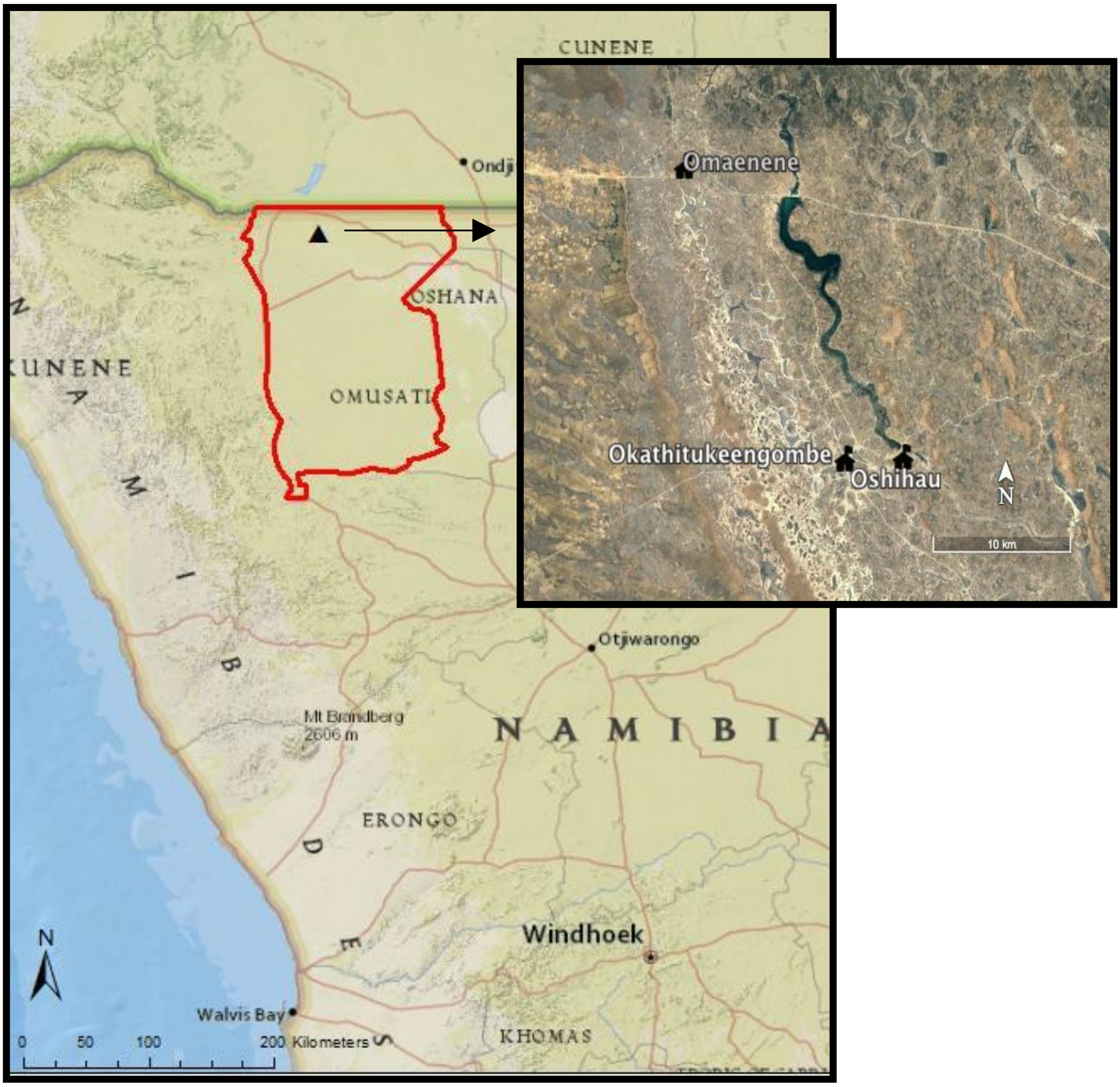


Figure 6. Study site map, three villages in the Onesi Constituency within Omusati Region, northern Namibia (Arc GIS, 2016).

3.2. Methods

The present study used predominantly qualitative data in the form of structured interviews as well as a systematic literature review. Fieldwork was conducted in Okathitukeengombe, Oshihau and Omaenene, in the Onesi constituency, Omusati region during the period 4 July – 15 July 2017.

3.2.1. Approval and consent

A brief proposal which included an explanation of the proposed methodology was submitted to the research ethics committee at UCT (UCT, 2012). This was approved prior to data collection. In the field, a meeting was set up with each headman with help from a member of the traditional authority centre in the Onesi Constituency. Each headman granted permission for the researcher to interview members of their respective village. Consent forms were prepared and translated into Oshiwambo; these were signed by each respondent before the interview was conducted (Appendix B). Confidentiality of the identity of each of the respondents was assured and maintained throughout the project.

3.2.2. Objective One: To understand crop farmers' perceptions of climate change vulnerability.

3.2.2.1. Data collection

To answer this objective and the associated key questions, 31 interviews, were conducted across the three study site villages (ten interviews per village in Okathitukeengombe and Oshihau and 11 interviews in Omaenene) (Appendix C). The headman of each village identified a few initial interviewees, after the first one to two interviews were conducted per village; snowball sampling was used to locate other candidates.

A translator assisted in asking farmers, in the local language of Oshiwambo, about whether they think their yields have decreased over time, if they think there will be future changes in their yield output and if they are worried about their future food supply. The term 'climate change' was not explicitly mentioned until the last question of each interview: "Have you heard about climate change before? From what source?" Interviews were purposefully structured this way so that respondents weren't prompted to mention climate change because they felt that this was the correct answer. During the interviews, the translator loosely translated each answer given by the respondent. This allowed the researcher to understand the essence of the interview and to ask further questions where necessary for clarification, the researcher wrote down these notes during the interview. A dictaphone was used to record the interviews.

3.2.2.2. Data analysis

After the interviews, the researcher and translator listened to the recordings and transcribed each interview into English so that all information was captured and quotes could be recorded word for word. The answers to each question were transferred into an excel spreadsheet. The interview data was then analysed by coding themes. Common themes were identified and the number of respondents who mentioned each theme for the relevant questions was noted. Quotes from the interviews were selected to illustrate the themes.

3.2.3. Objective Two: To identify interventions that could reduce vulnerability to loss of crop yields.

3.2.3.1. Systematic literature review

To locate information on adaptation practices used in other semi-arid regions a systematic literature review was conducted using Web of Science. The following procedure was followed:

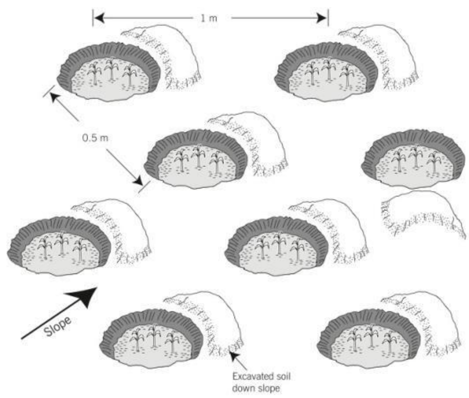
- The ‘advanced search’ setting was selected and ‘all databases’ were searched.
- The following phrases were searched: “adaptation farming”; “sustainable farming”; “water harvesting”; “soil conservation”; “climate smart agriculture”; "conservation agriculture"; "in field water harvesting"; “erosion control"; "organic amendment".
- The Boolean operator “OR” was used between these terms to locate literature containing any of the terms.
- Each of the nine semi-arid countries (Botswana, Uganda, Kenya, Mali, Niger, Burkina Faso, India, Ghana and Ethiopia) was searched separately. These countries were chosen, as they are comparable to Namibia because they all contain arid or semi-arid regions, they are developing countries and many of them are ASSAR study sites.
- The Boolean operator “AND” was used to combine the adaptation farming practice phrases with each country to find literature containing any of these practices used in each of these countries.
- Articles were ranked by relevance and the top 50 articles were considered. The abstract was read and if found to be appropriate the full

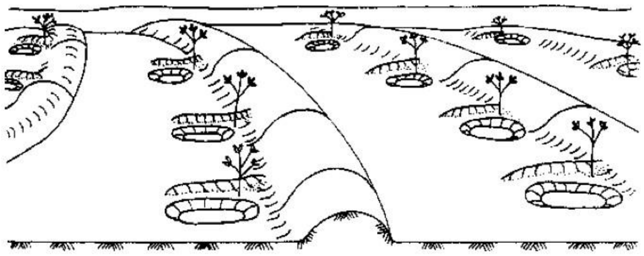
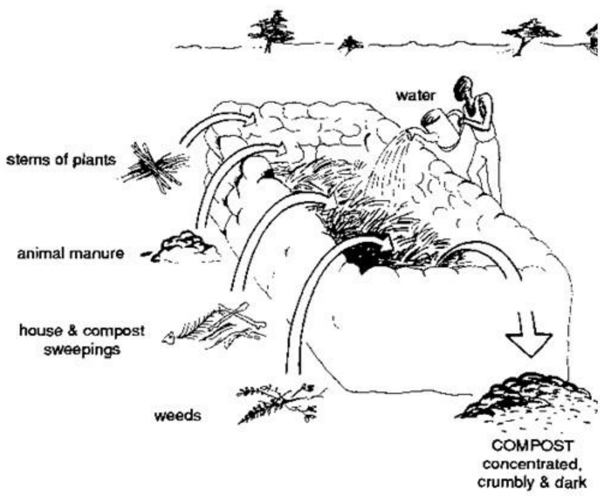
article was read to identify which adaptation farming practices are used in each country and evidence of their success, which was tabulated.

3.2.3.2. Use of the systematic review literature

The results of this search informed the selection of three appropriate farming practices that could be used to reduce vulnerability through conserving the limited water and enhancing soil structure and fertility. The selected techniques, planting pits, bunds and composting were explained to the respondents with the help of pictures (Table 1). After the interviews, a copy of the instructions of each of these techniques, translated into Oshiwambo, along with illustrative pictures was provided to each of the village headmen. This was to offer supportive information to any village members who wanted to try out the practices.

Table 1. Crop production adaptation to climate change techniques appropriate for Onesi

Technique	**Process**
Planting pits (UNEP, 2012; FAO, 2010; SSWM, 2012)	1. 30 cm^2 holes are dug approximately 50 cm apart. 2. Crops are planted inside the holes. 3. When crops are approximately knee height the hole can be filled with mulch/compost to enhance plant growth further.  (Image source: SSWM, 2012)

Bunds (FAO, 2010; SSWM,2012)	1. Soil or stones are used to create contour bunds along slopes and semi-circular bunds are used on flatter ground levels. 2. The bund walls are built with soil, sticks or rocks to a height of 20 - 30cm. 3. Crops are planted upslope of the bunds to catch the water.  (Image source: FAO, 2010)
Composting (Critchley and Graham, 1991)	Can be compiled in a hole or a heap 1. All organic waste can be collected, including crop residue, ash (from wood fires), vegetable peelings, animal manure, and household sweepings. 2. The compost must be turned every couple of weeks and if available water must be added (this can be soapy water from washing dishes/clothes). 3. After a few months, once this compost is dark and crumbly it can be spread over the fields.  (Image Source: FAO, 2010)

3.2.4. Objective Three: To assess the barriers and enablers of adopting practices from other semi-arid regions.3

3.2.4.1. Systematic literature review

To find literature on what enabled the uptake of planting pits, bunds and composting in other semi-arid regions another systematic literature review was conducted using Web of Science through the following procedure:

- The 'advanced search' setting was selected and 'all databases' were searched.
- The terms: "planting pit"; "zai pit"; "tassa"; "bund"; "compost" were searched to find all the literature on these farming practices (including different local names for the techniques).
- The Boolean operator "OR" was used between these terms to locate literature containing any of the terms.
- Each of the nine semi-arid countries previously mentioned was then searched separately.
- The Boolean operator "AND" was used to combine the planting practice terms with each country to find literature containing any of these practices used in each of these countries.
- Articles were ranked by relevance and the top 50 articles were considered. The abstract was read and if found to be appropriate the full paper was examined and enabling conditions for the uptake of each practice in each country were identified and tabulated.

Personal communication from a phone call and email discussion in December 2017 with a key informant, Professor Cecil Togarepi from the University of Namibia, was used to augment an understanding of aspects of the study area, practices used in the region and barriers to the uptake of new practices.

3.2.4.2. Data collection

The second half of the questions in the 31 interviews (Appendix B) conducted across the three study villages was used to identify the barriers to adopting new practices generally and specifically of adopting planting pits, bunds and composting in Onesi. Participants were asked about their willingness to use new practices and crops as well as what they think is preventing them from changing their practices. The participants were then asked whether they had heard about each technique before, whether they thought it would enhance their crop yields and whether or not they would be willing to use it.

3.2.4.3. Data analysis

This data was also translated, transcribed, copied into excel and coded to identify and count the number of respondents who mentioned different themes which showed the barriers and enablers to adopting each new practice.

3.2.4.4. Fieldwork limitations

During some of the interviews, responses were shorter than expected and did not provide comprehensive insight. This may have been because the respondents were apprehensive to open up or because they couldn't fully relate to the questions. A longer fieldwork trip would have allowed for more interviews and hence more responses to draw information from. Spending a longer time in each village may have also increased the rapport between the village members and the researcher which may have encouraged respondents to speak more comfortably and offer more in depth insight on their farming activities and beliefs.

Due to the remoteness of the study site, another fieldwork challenge was the distance between the researcher's accommodation and the study villages as well as the distance between the homesteads in each village. This meant that there was substantial travel time between interviews and limited the number of possible interviews per day. Furthermore, this meant that the interviewees chosen through snowball sampling were largely identified based on proximity and recommendation from a previous interview, which may have resulted in bias (friends of the previous interviewee) and limited the diversity of respondents. There is also no guarantee about the representativeness of the sample. In this study a literature search was used in combination with interviews to determine barriers and enablers to the adoption of new practices.

3.3. Respondent livelihoods

The following table shows a breakdown of the population of the Onesi constituency and the predominant sources of income (Table 2). It is interesting to note that farming is a relatively small source of income (11 %). However a household survey by Musingarabwi (2015) found that 80% of households were involved in subsistence cropping, which may explain this, since subsistence farming means that it is not a source of income but money is saved because food does not need to be bought.

Table 2. Onesi constituency census data, (NSA, 2011)

Area		602 km^2
Population	Male	5 979
	Female	7 170
	Total	13 149
	Density per km^2	21.8
Head of Household	Female	55 %
	Male	45 %
Income	Farming	11 %
	Wages and Salary	42 %
	Cash remittances	4 %
	Business	9 %
	Pension	30 %
	Disability	6 %

During interviews with the 31 respondents (ten men and 21 women) it was noted that generally when a family owned livestock, men were responsible for the livestock and women were responsible for crop production. If the family did not own livestock, crop production responsibilities tended to be shared. This distribution of farming responsibilities was in agreement across the literature (Singh et al., 2016; Bryan et al., 2009; Mongi et al., 2010).

In terms of the use of yield: 20 respondents used their crops for subsistence only and 11 sold certain of their crops or homemade sorghum beer when they had adequately supplied their own family and had an excess of yields. Cowpeas (n=30) and *mahangu* (n=30) were the most frequently grown crops followed by sorghum (n=27) (Figure 7). This corresponds with the literature, which suggests that these are the most commonly grown crops in northern Namibia (Republic of Namibia, 2016; 2013, Uno, 2005).

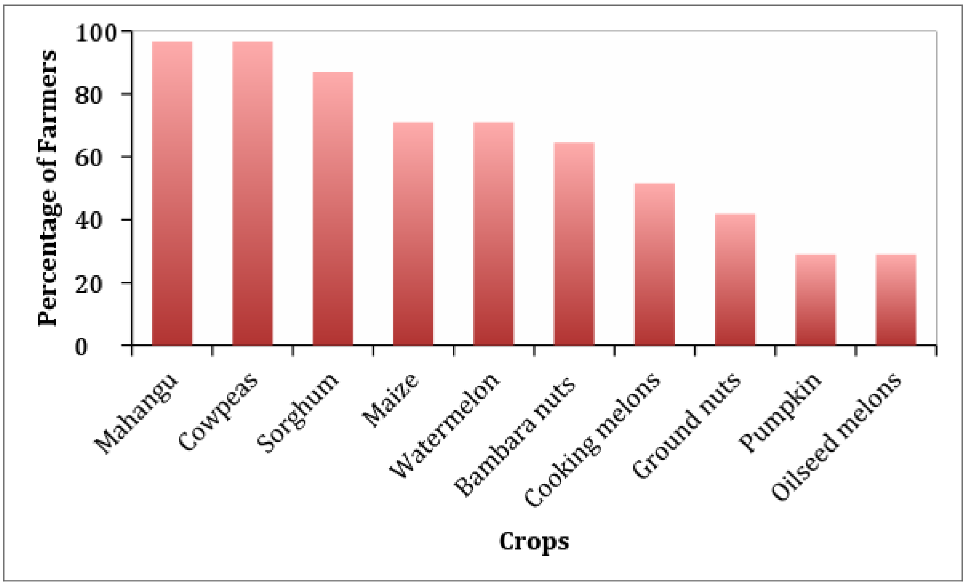


Figure 7. Percentage of farmers who grow each type of crop in Okathitukeengombe, Oshihau and Omaenene (n=31)

Pearl millet (Pennisetum glaucum) locally known as *mahangu* followed by sorghum (sorghum bicolor) locally known as *oilyavala* and maize (Zea mays) locally known as *omapungu* are the main crops grown here which are adapted to low rainfall (Newsham and Thomas, 2009; Uno, 2005). *Mahangu* is the staple crop for over 50 % of Namibia and contains vitamin B, iron, magnesium, phosphorus, copper and manganese which are important for healthy body functioning (Namibian Agronomic Board, 2017). *Mahangu* is the preferred cereal in northern Namibia because it is relatively drought resistant, can withstand high temperatures and can grow successfully in sandy soils (Uno, 2005). *Mahangu* is often eaten as porridge or made into a drink locally known as *oshikundu* and forms an integral part of the Oshiwambo culture (Uno, 2005). Sorghum is also favoured because it has high photosynthetic ability, and efficient nitrogen and water use which makes it suitable for hot and dry climates (Reddy et al., 2010). Sorghum is consumed as bread, porridge, beer and also as a feed grain for livestock (Reddy et al., 2010).

In addition to these crops, some families had fruit trees either around their homestead or in the fields with their crops. The fruit trees grown across the study site are: lemon, mango, marula, guava, palm and custard apple. Fruit trees act as an extra source of food as well as providing a wind buffer and a microclimate for crops to grow (Hawken, 2017).

Chapter Four: Perceptions

This chapter will deal with the results and discussion of Objective One and the associated research questions.

Objective One: To understand crop farmers' perceptions of climate change vulnerability.

1. To what extent does the farming community perceive the area to be vulnerable to climate change?
2. Are farmers planning for change?

Image: Interviewee demonstrating the process of separating *mahangu* during fieldwork.

4.1. Perceptions about changes in the past

The interviewees were asked about whether they thought that the yields received from their land have changed over the time that they have been farming. In response to this, 29 participants (out of 31) stated that the quality of their land and the yields that they receive has decreased. One person had not noticed any change in their land and one person thought that the state of their land had improved.

The most commonly stated reason for observed changes in yields was that 'rainfall in the area has decreased' (n=14), observational trends suggest that there has been a decrease in annual rainfall over the past few decades as well as a later onset and early cessation of the rainy season in northern Namibia (Newsham and Thomas, 2011; UNDP, 2017; Dirkx et al., 2008). The next most frequently cited reason was the 'depletion of nutrients from the soil due to overuse' (n=11) and because rain washes away the nutrients (n=7) (Table 3). This observation is supported by the FAO (2009) which explains that increased human population density and overstocking by livestock farmers, in the north-central region of Namibia has resulted in soil that has been overgrazed and is in poor condition. This further decreases the water and nutrient holding capacity of the soil so that if fertilizer is applied it is leached out by the rain (FAO, 2009).

Seven respondents mentioned that temperature has increased, this correlates to Newsham and Thomas, (2009) the results of 25 years of data from seven climate stations across Namibia which show that there have been increases in the maximum temperatures of warm days as well as the frequency of warm days. It is surprising that only seven people mentioned this observation, however, this may be because Namibia has high climate variability and hence it is difficult to distinguish trends amongst short term fluctuations (Shackleton et al., 2015). Similar studies conducted at Oshikoto by Nena (2015) and Ndonga by Montle and Teweldemedhin, (2014) in Namibia revealed high levels of agreement by participants that rainfall has decreased and temperatures have increased. This is valuable because perceptions about changes and risks dictate whether people will take action to adapt their behaviour.

These observations are also interesting because there is more agreement on climatic projections about increasing temperatures than they are about decreasing rainfall.

Predictions around rainfall are less certain. i.e. scientists are quite sure that temperatures are going to increase in future but are less certain about what is going to happen with rainfall. It is likely to become more variable but different models don't agree on whether there will be more or less rainfall.

In the current study, a further five respondents mentioned that crickets have recently come to the area and caused extensive crop damage (Table 3). The other respondents were not asked about their experience with crickets and none of the respondents speculated the cause of the outbreak. This corresponds with the newspaper articles and press release, which describe the major outbreak of pests (namely crickets and armyworms) in Namibia in 2017 (MAWF, 2017, Africa Independent, 2017; Club of Mozambique, 2017). There is no conclusive reason for the outbreak of pests but there is speculation that drought conditions precipitate armyworm invasions, and the migration patterns of locusts in sub-Saharan Africa are influenced by rainfall patterns (Gornall et al., 2010; MAWF, 2017, Africa Independent, 2017). In this specific case the El Nino triggered drought in 2016 is highlighted as a possible cause of the outbreak (Club of Mozambique, 2017; Biowatch, 2017). Hatfield et al. (2008) and Sun et al. (2011) discuss how climate change can lead to an increase in pests.

Additionally, three people mentioned that tractors bring bad soil to the surface; another person remarked that good soil is deep under the ground and ploughing brings this better soil to the surface (Table 3). The negative association with tractor ploughing may refer to the theory behind conservation agriculture, which follows that when fields are tilled, the soil structure is damaged. Water in the soil evaporates, organic and plant nutrients are lost and erosion is accelerated, this is especially pronounced in rain stressed environments (Sharma et al., 2014; Hawken, 2017). The Von Hase (2013) study concurs that traditional ploughing techniques (such as the use of a disc or mouldboard plough) pulverise the physical structure of soil, which reduces soil carbon content and leads to soil erosion. This is different to the climate smart practice of ripper furrowing where the sub-surface pan is broken with a ripper to allow deep rooting and rainfall is harvested in the furrow (Appendix A)

Table 3. Reasons farmers mentioned for observed changes in yields (n= 31)

Themes	Number	Illustrative Quotation
Rain has decreased	14	*"It has changed because of rain, because sometimes you will plough your field and sow seeds but the rain won't come or when it comes it is just not enough for the crops, and these results in dry land which leads to poor yield."*
Nutrients in the soil are depleted from overuse	11	*"The whole field used to give a good crop yield. Now there are lots of spaces where crops do not grow or the yield is very poor. Sometimes we sow seeds but when they germinate they just dry out. I think that this is because it is very dry and the soil is depleted of nutrients because people have been farming in the same place for many years."*
Rain washes away nutrients	7	*"We used to get better yields than we get now. The land lost nutrients because the rain washed it away"* *"My family has been living here for more than 50 years and the texture of the soil is changing, nutrients are decreasing. Poor rain or too much rain changes the soil. The nutrients wash away and get lost."*
Temperature has increased	7	*"The weather has changed, it has become hotter and drier"*
Crickets have damaged the crops	5	*"The crickets came this year and decreased my yield"*
Tractors bring bad soil to the surface	3	*"The tractors change our land, because it brings the bad soil on top and takes the good top soil underground. When it rains the soil from underground dries out being unsuitable for crops"*

4.2. Current and past coping strategies

In the study villages, of the 21 farmers who had changed their practices in response to poor yield output, 13 explained that they moved certain crops from areas of the field where they were not supplying sufficient yields to different locations.

> *"If mahangu or another crop doesn't do well because there is not enough rain then we rotate the crops and put a different one in that place"*.

This is a sort of crop rotation technique, although it is a reactionary approach rather than the precautionary approach of changing crops every season to ensure that the soil has time to regenerate and nutrient availability can be increased (Shiningayamwe, 2012). Another noteworthy coping strategy mentioned by many of the respondents is the use of 'portions'. This entails planting different crops in separate portions based on the soil and climate and what they believe will grow well. It is assumed that this refers to the indigenous agro-ecological land unit system, whereby farmers classify features of the environment such as soil, vegetation and landform according to their agricultural utility (Newsham and Thomas, 2009; Verlinden and Dayot, 2005). For example, a land unit characterised by a depression in the landscape (known as *ehenene*) may be used for growing *mahangu* during a dry season whereas an elevated area (known as *ehenge)* may be used during a wet season (Newsham and Thomas, 2009). This practice has historically enabled the population to deal with climatic variability. Von Hase (2013) and FAO (2009) argue that the land unit system is outdated and ineffective as a measure of long-term climate change adaptation. However, this valuable understanding of the soil must not be disregarded as there may be a role for knowledge co-production whereby farmers' existing agro-ecological knowledge can be integrated with agricultural science towards implementing adaptive strategies (Newsham et al., 2011).

Seven people mentioned applying manure to enhance their soil quality in an effort to cope with yield decreases. Manure application is believed to be a traditional soil fertility practice in Namibia that has been passed on for many generations and is used when yield output is low (Nena, 2015). A further ten people changed the variety of *mahangu* that they grow in order to improve their yield output. In terms of the *mahangu* varieties in the study site: kavango and ongonga were described to be slow-maturing and were changed to kangara and okashana #2. The rationale behind planting okashana #2 is that the crops reach maturity quickly and thus are large enough to withstand destruction by pests (such as crickets) and heavy rainfall.

> *"I have changed the mahangu I usually grow ongonga to kangara and okashana #2. Ongonga takes long to mature, so it requires the rain to start early but now rain starts very late, while kangara and okashana mature faster, if the rain comes late, we will be able to get a better yield."*

However, one person explained that when there is too much rain they prefer to use kangara as it can withstand waterlogging better than okashana #2.

> "*When there is too much rainfall I change the variety from okashana #2 to kangara. When there is too much rainfall kangara is better because it can withstand the water better and okashana falls. But the problem is that kangara does not mature fast enough so this year while we were waiting for it to grow the crickets came and killed the crops*".

Okashana #1 was introduced in 1990 as an early maturing millet, within 75 – 90 days compared to 120 days for the local variety, and it has a higher grain yield (Mallet and Du Plesis, 2001). Okashana #2 and Kangara were then introduced in 1998 as part of a crop improvement program, all of these varieties are believed to withstand drought and heat better than the previously used landrace cultivars (Uno, 2005; Matanyaire and Gupta, 1996). However, it is believed that even these varieties will struggle to grow in a hotter, drier future (Government of Namibia, 2017).

4.3. Perceptions about changes in the future

In order to ascertain perceptions about changes in crop production in the future and thus vulnerability to climate change, the respondents were asked if they think their yield output will change in any way. The most frequent response was that 'yields will decrease' (n=12) followed by the sentiment that 'yields depend on the rain' (n=12) (Table 4). In line with this, when asked about climate change, 16 respondents stated that they had heard about climate change either from the radio, by word of mouth or from school. Most of the respondents believed that climate change is connected to the rain and this is what will cause decreased rainfall in the future.

Table 4. Perception of yield changes in the future (n=31)

Themes	**Number**	**Illustrative Quotation**
Yields will decrease	12	*"I think the yields will get worse because of the crickets" "I think there will be low rainfall in the future and crop yields will be low. If there is low rainfall, hunger will come"*
Yields depend on the rain	11	*"It depends on rain. If there is good rain there will be good yields, if there is bad rain there will be bad yields."*
Yields will improve	5	*"I think the yields will improve because we put manure everywhere. If it rains the soil quality will improve and we will get better yields"*
It depends on God	3	*"If anybody says the yields in the future will be high or low that person must be lying. Nobody can predict the future, only God knows." "Maybe it is Gods will, maybe God is angry because of the things people are doing, that is why we don't get enough rainfall"*

4.4. Adaptation strategies for the future

Although many of the interviewees perceived that their crop output would in fact decrease in the future, bar one, all respondents said that they would continue farming in the same way without adaptation. Additionally, when the farmers were asked whether they were worried about their food supply in the future, 24 responded that they were indeed worried because of the uncertainty of what may happen and because they do not have alternatives.

> "*I am worried because if the crops don't do well there is nothing we can do. We can't move to better land, we are stuck on this land."*

> *"I am very worried, in the past we could predict rainfall, we can't predict it anymore. Now even if you predict rainfall you will be surprised that you don't get it."*

However, the other seven participants responded that they were not worried about the future. This was predominantly attributed to faith that God will provide sufficient rain or that the government will provide assistance.

> *"I am not worried because we don't know what God has in store for us. He is the creator, he will provide."*
>
> *"Maybe I will get enough food for my family but if I don't, the government will assist us"*

Findings from a similar study in India by Singh et al. (2016) suggest that perceived adaptive capacity and efficacy to carry out adaptive actions are factors that mould farmer's adaptive responses. Although the perception of risk in the future is believed to promote action to reduce vulnerability, in the current study, it appears that the farmers do not have confidence in their adaptive capacity for current or future changes (Becken et al., 2013). Grothmann and Patt (2005) suggest that in cases such as this, farmers may not believe that their actions can actually protect themselves from harm. The farmers did not believe that they had the necessary information or capacity to change their practices. Hence although the farmers think that their yields will decrease in the future they are still not planning for change. The specific barriers to changing farming practices will be elaborated on in chapter six.

With regards to the perception that God or the government will provide solutions, this perspective may lull people into a sense of safety and inertia to respond. These farmers have resigned themselves to fate and given up responsibility. In both cases, those who are worried (negative perspective about the future) and those who are not worried because god or the government will solve the problem (positive perspective about the future), are vulnerable to the impacts of climate change because they are not planning for change. There is a need for farmers to understand that even with the little resources they have, they can adapt and cope with climate variability.

There was only one exception to this sort of response that represented an example of proactive adaptive thinking: one of the headmen who had recently attended a climate change ASSAR workshop wanted to help his village prepare for impending changes. He was of the belief that the people in his village are willing to try new practices; they just need information and support. He also explained that he was planning to make a community garden in the village where everyone can share the workload and the output for times when the village members' individual pieces of land are unable to supply enough food.

> *"I have heard about climate change and I know that it affects agriculture. The trees and crops are not doing well anymore because of climate change. It has even caused the animals that live underground to come to the surface, which never used to happen. I think they are looking for water. Also our livestock are dying because they don't have enough food to eat. I have spoken to the people in the village about making a garden together; we are going to divide into groups maybe 20 each to grow different things so that we can all have food to eat. They were very happy. I have targeted one place where we can cultivate the land. I am going to buy wire so we can put it around the field and divide it up. We can collect manure for it."*

This is a positive instance of how information can be transmitted and spread from village leaders to communities. A community garden could also act as a demonstration site to showcase the use of new practices.

4.5. Conclusion to Objective One: To understand crop farmers' perceptions of climate change vulnerability.

The results for Objective One indicate that the local people of Onesi perceive that they have experienced a decrease in rainfall, increase in temperatures, increase in pests and an overall reduction in yield output. They have coped with these changes by adopting coping strategies such as:

i) Changing where they plant their crops to ensure the correct location for each type of crop;

ii) Growing new varieties of *mahangu* to enhance resilience against adverse weather and pests;

iii) Applying manure on the field to enhance the soil quality.

The manner in which communities currently cope with exposure to climate variability and shock can offer insight into their adaptive capacity to future impacts of climate change. The above-mentioned coping strategies are not substantial enough to buffer against future climatic changes. Several respondents (n=12) mentioned that they believe that their yields will decrease further in the future, and many respondents (n=24) are fearful of what may happen but they do not know how they will adapt to these changes. Some of the respondents (n=7) are not concerned because they believe God or the government will provide assistance if they do not have enough food. These perceptions of climate risks are supported by the historical climatic trends and future projections, previously discussed which point to decreasing rainfall, increasing temperatures and ultimately decreasing crop productivity in the region. There is a general lack of awareness about climate risks, which would ostensibly affect the implementation of adaptation efforts. This demonstrates vulnerability and the need for education and awareness about climate risks as well as the introduction of adaptation information and practices so that subsistence farmers are empowered to increase their own resilience. The proposed practices, in the next chapter, stem from traditional practices and hence it is not to say that traditional coping practices should be disregarded but rather they can be integrated with other practices and with climate change information.

Chapter Five: Practices used in other Regions

This chapter will reveal the results and discussion of Objective Two and the associated key questions.

Objective Two: To identify interventions that could reduce vulnerability to loss of crop yields.

1. What adaptation practices are employed in other semi-arid regions?
2. Are there any climate smart practices already promoted in north-central Namibia?
3. Which new practices are suitable for Onesi?

Image: Millet grown in planting pits in Burkina Faso (Motis et al., 2013).

5.1. Practices used in other semi-arid regions

Many climate change adaptation practices stem from indigenous knowledge systems, which have been constantly evolving to combat climate and soil variability (Douxchamps et al., 2015). Since people in remote dryland regions have demonstrated significant resilience to local climate and environmental adversity in the past, it is believed that they have the potential to adapt to future climate change (Maru et al., 2014). Semi-arid developing regions hence provide an appropriate *locus* for identifying potential adaptation solutions. However, it must be cautioned that although these countries share many similarities they also have many differences in their food production as well as their social customs. Hence, careful consideration must be practiced in transferring these adaptation practices. Climate change impacts the water availability, fertility and stability of soil, which directly affects the ability to grow crops. Hence, a literature review of practices directed at infield water harvesting, soil conservation and organic amendment used in the other nine semi-arid regions was conducted (Table 5). All of these practices improve the quality of the soil, which can rehabilitate already degraded land, sustainably increase crop production and enhance the resilience of the land to climatic changes.

Bunds were the most commonly cited practice in the literature search with short-term benefits of retaining runoff and sediment which improves the water balance and reduces erosion, in the long term as crops become well established, the slope angle is reduced, soil is further stabilised and nutrient availability is increased (Gebremichael et al., 2005; Maatman et al., 1997). It is hence assumed that these characteristics will be beneficial in reducing the effects of climate change on crop production, namely reduced water availability, fertility and stability of soil. As a result of the wide range of variables relating to location, crops grown, resources available and techniques used, the results reported in the literature indicate a wide range of potential yield increases. Examples of techniques which resulted in substantially increased yields include: 142 % yield increase owing to compost combined with grass strips in Ethiopia; up to 283 % yield increase from crop residue mulching in Niger and 153 % and 196 % increase in millet and sorghum output respectively under agroforestry in Niger (Table 5). The improved yield output in many of these examples led to additional benefits, which augmented the adaptive capacity of farmers. For example, in cases where crops are sold, income is increased, where crops are used for subsistence, money is saved, in both cases this 'extra' money can be used for other means of enhancing adaptive capacity (Garrity et al., 2010; Maatman et al., 1997 Hengsdijk et al., 2005).

Table 5. Farming practices employed in other semi-arid regions

Technique (refer to Appendix A for description)	**Categorisation**	**Evidence of success**
Bunds	Infield water harvesting Soil conservation	● Tigray, Ethiopia: stone bunds led to a 68 % reduction in annual soil loss (Gebremichael et al., 2005). ● Tigray, Ethiopia: stone bunds led to a 7 % yield increase (Vancampenhout et al., 2006). ● Tigray, Ethiopia: soil loss by sheet and rill erosion was decreased by 68 %, water infiltration was enhanced and crop yields were improved (Nyssen et al., 2007). ● Ethiopia: Considering a four year average, soil bunds reduced the loss of soil organic matter by up to 52 %, total nitrogen up to 48 %, and phosphorus up 41 %. Soil bunds combined with elephant grass reduced soil loss by 63 % and runoff by 40 % compared to the control plot (Amare et al., 2014). ● Burkina Faso: Yields on fields with stone bunds are on average 12.5 % higher than yields on the control fields without rock bunds (Maatman et al., 1997).
Planting pit	Infield water harvesting Soil conservation	● Niger: Planting pits improved crop nutrient uptake of approximately 53 % for nitrogen, 68 % for phosphorous and 62 % for potassium as well as doubling the efficiency of water use (Fatondji et al., 2006). ● Niger: planting pits led to an estimated average increase in cereal production of 400 kg/ha, a percentage increase of between 40 % and 100

		% which is an annual increase of 80,000 tonnes of grain, and could provide for 500,000 people (Garrity et al., 2010). ● Burkina Faso: planting pits combined with rock bunds led to an increase in sorghum and millet crop production of 19 % for a bad rain scenario, 18 % for average rain and 16 % for good rain compared to the control plot (Maatman et al., 1997).
Tied ridges	Infield water harvesting Soil conservation	● Botswana: Tied ridges improved soil water storage by 26 mm (18 %) (Moroke et al., 2017). ● Mali: Tied ridges decreased soil erosion by approximately 72 % and increased net farm income and production (Kablan et al., 2008). ● Kenya: tied ridging led to a runoff reduction of 52 % during long rains and 51 % during short rains in 2011 (Okeyo et al., 2014).
Closely spaced terraces	Infield water harvesting Soil conservation	● Mali: The mean infiltration rate increased by 67 % on treated areas compared to the control (Kablan et al., 2008).
Contour farming	Infield water harvesting Soil conservation	● India: The rainwater runoff decreased from 54 % to 40 % where contour farming was used. Sorghum yield increased by 66 % compared with up-and-down slope cultivation (Bhattacharyya et al., 2016).
Manure	Organic amendment	● Niger: Increasing the rate of cattle manure application from 1 to 3 tons per hectare led to a yield increase of 115 % (Fatondji et al., 2006).
Compost	Organic amendment Soil	Burkina Faso: application of compost increased sorghum yield by 107 % compared to the control plot (Zougmore et al., 2004).

	conservation	• Burkina Faso: Providing compost or manure in combination with stone rows or grass strips increased sorghum grain yield by as much as 142 % (Zougmore et al., 2003). • Ethiopia: Application of compost increased the maize yield by 13 %.
Mulching	Organic amendment Soil conservation	• Kenya: Mulching led to a runoff reduction of 49 % during long rains and 30 % during short rains in 2011 (Okeyo et al., 2014). • Niger: crop residue used as a mulch protected the young plants from sand erosion and burial and increased the nutrient uptake of nitrogen and potassium. The total dry matter of millet at harvest in mulched areas increased from 35 % in 1992, 108 % in 1993 to 283 % in 1994 compared with the control (Buerkert and Lamers, 1999).

5.2. Climate smart practices that are already promoted in the region

Climate smart agriculture (CSA) is defined by FAO (2018) as an approach focused on transforming agricultural systems to support development and ensure food security in a changing climate. This approach aims to sustainably increase productivity, build resilience to climate change and reduce greenhouse gas emissions (FAO, 2018; MAWF, 2017). CSA is promoted in Namibia by the Ministry of Agriculture, Water and Fisheries (MAWF) through training extension staff and hosting demonstration workshops in all of the regions in the country (MAWF, 2017). Togarepi (personal communication, December 2017) explained that some of the climate smart practices encouraged are ripper-furrowing, crop rotation using stover (crop residue) as mulch, drip irrigation and a technique of planting rice in low lying flood prone areas and millet on higher ground (see Appendix A for descriptions).

There is extensive research by the University of Namibia into drought tolerant crop varieties, which is endorsed by the government (Republic of Namibia 2016). There are also two relatively new organisations which assist rural farmers in north-central Namibia to reduce their vulnerability, namely: Learning and Information Sharing for Agriculture

(LISA) and Climate Resilient Agriculture in Vulnerable Extreme northern crop-growing regions (CRAVE). LISA, supported by MAWF, NNFU, FAO and the EU, is a website and SMS line where farmers can communicate with extension workers and agricultural experts to learn information about climate forecasts and ask for advice (MAWF, 2017). CRAVE is sponsored by the Green Climate Fund. It offers monetary support and plans to establish a centre where pilot studies can be conducted and farming resources can be obtained (Green Climate Fund, 2016). This indicates that the government and other organisations are taking steps to assist farmers in northern Namibia to reduce their vulnerability to climate change although both organisations are in their infancy and it may take a while before the benefits are experienced in Onesi.

5.3. Practices that are suitable for Onesi

Some of the practices from the literature review have been used by the interviewed farmers in the three villages, namely: crop rotation (n=21); planting pit (n=8); manure application (n=5); bunds (n=1); compost (n=1) and mulching (n=1). This may indicate that more farmers could use them if the right information and monetary or technological support is offered. Many of the practices would be appropriate for Onesi considering that they have been used successfully in similar semi-arid regions in other developing countries to enhance the resilience of crop producing farmers to climate risks.Bunds, pits and compost (Table 6) have been proposed for the purposes of this project in Onesi for a number of practical reasons.

These three practices are beneficial for adaptation in the study villages because they enhance the stability, fertility, water harvesting and the water holding capacity of the soil, all of which improves the ability of crop production especially in times of droughts, heat stress and floods which – currently and will continue to – affect Onesi. These three practices are suitable for the current status of equipment, labour, water and soil that exists at the study villages (Table 6). They are also appropriate for the staple crops, sorghum, mahangu and maize that are grown at the study villages. Furthermore these practices are simple to explain and understand for purposes of the researcher relaying them to the interviewees as well as by word of mouth beyond the scope of this project ie from the headmen to the villagers and amongst the village members.

Table 6. Relevance of the chosen practices for Onesi

		Equipment	Labour	Water	Soil	Other information
Onesi Context		Spades and hoes generally available. Sometimes animal draft is available.	Labour is limited as many individuals of working age have migrated to urban areas to find work.	Semi-arid area (higher evaporation than precipitation). 400 mm mean rainfall per annum.	Mostly sandy, fragile, porous, low fertility. Interviewees mentioned that rain washes nutrients out of the soil.	Sorghum, millet and maize are the predominant crops grown. Terrain is mostly flat with some gentle slopes.
Planting Practices	**Bunds**	Spade (Animal draft or a wheelbarrow would help to move rocks and sticks.)	Fairly labour intense in the first year thereafter-marginal maintenance. No specific skills required.	Slows and catches water to increase infiltration.	Prevents erosion of the fragile soil and helps to retain nutrients in the soil.	Soil and rocks or sticks to build bunds are easily available. Can be used on flat or sloped land. Reduces the need for irrigation.
	Pits	Spade or hoe	Labour intense but yields are significantly increased (output exceeds input (Amede al., 2011)). Pits can be used for two to three years. No skills required.	Water is channeled and concentrated around crops. Pits are suitable for areas receiving 300-800 mm annual rainfall (Danjuma and Mohammed, 2015).	Enhances infiltration of the porous soil. Increases carbon content which enhances water holding and cation exchange capacity. Reduces nutrient leaching.	Allows resources (manure, mulch, compost) to be concentrated around crops so that nothing is wasted hence improving the soil structure with minimal resources. Pits regulate temperature and protect crops from wind. Sorghum, millet, maize are appropriate crops for pits (SSWM, 2012).
	Compost	Spade or stick to turn pile.	Minimal labour and no specific skills required.	Household wastewater can be used on compost.	Enhances soil fertility (reducing the need for fertilizers). Increases water holding capacity of the soil. Increases stability of the soil making it less susceptible to erosion.	Can be implemented by a few households as a community compost pile. Utilizes agricultural and domestic waste as a free resource.

Aklilu (2006) and Stroosnijder (2009) posit that families who are resource poor have short time horizons for utilising their resources. Returns on water conservation practices are experienced faster and hence prioritised over soil conservation approaches. Since water conservation and soil conservation are both highly valuable to adapting to climate variability and climate change in the Onesi context, it is recommended that adaptation practices combine water conservation with soil conservation to ensure maximum output. Planting pits, bunds and compost can all be used in combination for this purpose. A bund can be formed downslope of the pit and compost can be used to fill the pit.

It is relevant at this point to note that existing indigenous knowledge in northern Namibia, such as the land unit system discussed in chapter four can be integrated with the practices proposed by the researcher. It is arguable that these practices were developed through a similar experiential understanding as the land unit system and then supported by scientific research (Fatondji et al., 2006; Maatman, 2006; Kablan et al., 2008). The indigenous understanding of how soil on different parts of the land affects crop growth, can aid in conceptualising the scientific reasons why the infiltration, holding capacity and fertility of soil can be improved through the use of compost, planting pits and bunds as well as when to use these techniques to enhance the resilience of the land to climate change (Hillyer et al., 2006).

Science tends to focus on the biophysical components of farming whereas indigenous knowledge includes the lived experiences and learning-by-doing interactions of farmers with their land (Mafongoya and Ajayi, 2017). Since both aspects are important for climate change adaptation there is a role for knowledge co-production which can encourage mutual learning and developing appropriate adaptation strategies.

5.4. Conclusion to Objective Two: To identify interventions that could reduce vulnerability to loss of crop yields.

CSA can help farmers in northern Namibia and elsewhere to be more resilient to climate variability and increase their productivity, which will help them to cope with impending climatic risks. The Namibian government aims to expand CSA through extension services that conduct workshops across the country. There are also a few private organisations in the area that are assisting subsistence farmers, with information, monetary and technological support, to adapt to climatic changes. This indicates the recognition of the vulnerability of north-central Namibian farmers to climate risks and a hopeful institutional response, although these responses are still too recent for the benefits to be fully experienced.

It is conceivable that many of the reviewed farming practices would be beneficial to Onesi. However, planting pits, bunds and composting are contextually appropriate and were thus chosen by the researcher as examples of low input adaptation practices that could be implemented in the study villages. Since these practices stem from indigenous knowledge systems in other regions they can be understood through a similar lens and hence may be easily assimilated. These practices could also be used as a combination for water and soil harvesting, increasing soil fertility and ultimately to sustainably enhance yield production and reduce vulnerability to climate change.

Chapter Six: Barriers and Enablers to the uptake of the proposed practices

This chapter will show the findings of Objective Three and the associated research questions:

Objective Three: To assess the barriers and enablers of adopting practices from other semi-arid regions.

1. Are farmers willing to adopt new practices?
2. What are the barriers and enablers of adopting new practices in the study villages?

Image: Field of maize crop residue from one of the study villages. Taken by Angela Chappel during fieldwork.

6.1. Willingness to adopt new practices in Onesi

When asked about willingness to try new farming practices, 29 people responded that they were willing to adopt new practices and only two people stated that they were not willing, due to their old age.

> "*I am not willing to use new practices because I am old and maybe I won't carry them out correctly.*"

With regard to the chosen practices for Onesi: everyone (n=31) was willing to try composting followed by bunds (n=29) and then planting pits (n=27). Compost was the preferred practice by 15 people; ten people preferred planting pits and three people preferred bunds. After the practices were explained to the interviewees, the practices were acknowledged as effective because they are easy to use, will increase nutrients in the soil and don't require extensive new equipment.

> "*Planting pits are a good method that will increase my yields, because the fertilizer will stay close to the plants so that I don't waste any fertilizer.*"
> "*Compost is good because we don't have any fertilizer and all the materials are already available.*"
> "*Bunds will stop the water from running away and washing away the nutrients.*"

Compost was particularly well received, a few people explained that they already keep their organic matter in a pile but they hadn't realised that it is a valuable source of nutrients for the soil.

> *"We keep our compost in a hole, didn't know you could put it back on the field."*

Some people described how they put their household sweepings onto the soil and another person mentioned that they mix leaves with the soil to improve the soil texture and fertility. Hence, the idea of using organic waste as a low input means of improving the soil was highly desirable. These responses show an understanding of the benefits of the practices, which suggests that the new information was accurately received and interpreted. Similarly, 29 people were willing to grow new crops, one person believed the crops grown on their farm are fine and do not need to be changed and one person believed it would be too difficult to learn to grow new crops. The Hegga et al. (2016) report on Omusati suggests that although there has been limited acceptance of new agricultural practices in the past, this may be changing as farmers become more receptive to new practices. This general sentiment of willingness to take up new practices is promising because if a farmer is willing, barriers can be addressed and enablers can be enhanced however if he/she is not willing, barriers and enablers may be irrelevant.

6.2. Barriers to adopting new practices in Onesi

Following this, respondents were asked what they believe is inhibiting them from trying new practices and growing new types of crops (Table 7). 'Information' about new ways to practice farming and grow new crops was the greatest barrier identified (n=14). This corresponds with the Omusati report by Hegga et al. (2016) in which inadequate information was cited as the primary reason preventing farmers from changing their practices. This is because other than the radio there are limited avenues for new information to enter the relatively isolated villages. The next most frequently mentioned barriers are: 'the belief that current practices are the only or best method' (n=9) and 'fear that a new practice won't work' (n=6). This also corresponds with the Hegga et al. (2016) assessment where local farmers, especially older generations, were reluctant to change practices that are steeped in culture and tradition. Togarepi (personal communication, December 2017) explained that farming practices are central to the Oshiwambo culture, to the point that it would be taboo if a farmer did not farm their field annually even if it was because they knew that there were poor rains that year. In other words, it is actually better to farm a field and have it fail than not to farm it at all. This is in contrast to the economics of production[3] and places a greater emphasis on the cultural and social value of farming.

These barriers link to the theme of path dependency explained by Barnett et al. (2015). Path dependency is the continued use of a practice based on historical and cultural preference, which creates a state of inflexibility and a resistance to change, even if the practice is maladaptive (Pike et al., 2010; Barnett et al., 2015). Barnett et al. (2015) elaborate that path changes are possible under the right conditions. However, if the

[3] The aim of production is to make a profit; hence the value of the output should be greater than the value of the input.

necessary path change does not commence for an extended period of time or the change occurs at a rate slower than the climatic change (creating an adaptation deficit) there is a danger that path dependency will become a definitive limit rather than a barrier to adaptation. Ultimately, path dependency could lead to increased vulnerability to the impacts of climate change.

Table 7. General barriers to using new practices (n=31), type of barrier based on Figure 3 categorisation

Barriers	**Type of Barrier**	**Number**	**Illustrative Quotation**
Information	Information (Lack awareness)	14	*"We just have to continue farming in the same way because we don't have any other information on other methods that we could use and our animals have died in the drought so we have to continue using the tractor." "We don't have any information about other practices" "We are not educated there is lack of information."*
Belief that current practice is the only or best way	Social (Normative)	9	*"We are used to farming in the same way"* *"I haven't changed my method because the method I am currently using is the best one, I think"* *"I know where each crop does well in the field and don't want to change it"*
Fear that a new practice won't work	Social (Cognitive)	6	*"I fear new practices won't work and my yield will be even worse"* *"I am scared to use new practices in case we don't get a good yield"* *"Because the nutrients in the soil is already depleted I am scared to use other methods because I know crop rotation already works."*

Insufficient water	Resource[4]	6	*"We have a water shortage"* *"I have a problem of palm trees in my field, their roots take up nutrients and water for my crops; and I can't use other farming practices."*
Money	Financial (Credit access)	3	*"I don't have money to buy or rent equipment to work on my land"* *"Sometimes I want to buy fertilizer for my field but I don't have money because I don't work"*
Tools and materials	Financial (Equipment	3	*"Availability of equipment and materials"*
Time consuming	Social (Cognitive)	3	*"We don't know if it will really help or it will just waste time."* *"I want to use new practices but other practices are time consuming and I don't want to try things that I don't know if I will get a good yield or nothing."*
Labour	Financial/ Social	3	*"The field is big and I don't have any help"*
Culture	Social (Normative)	3	*"Also cultural beliefs because we always use mahangu and don't trust new practices."* *"We must grow mahangu because it is part of our culture."* *"We will keep farming in the same way because in the Oshiwambo culture we don't like to change tradition."*

4 This is not included in the Figure 3 categorisation of barriers because scarce water is a circumstance that requires adaptation rather than a barrier to adaptation

Old age	Social (Cognitive)	2	*"I am old and maybe I won't carry them out correctly, I won't catch up to them. I farm alone because the kids go to school and I am by myself most of the time"*

6.3. Barriers to adopting planting pits, bunds and composting

As in the previous section, Figure 8 indicates that 'information' was the major barrier to the uptake of each of these three practices (planting pits = 11; bunds = 17; compost = 12). 'Time consuming' and 'labour' were the next two most frequently cited barriers. Due to the low and declining productivity of farming in marginal arid regions, such as Namibia, there are diminishing marginal returns on labour which means that the land is unable to provide sufficient income and food (Shackleton et al., 2015). This encourages people to move to urban areas to find work and further decreases available labour in farming areas. Many similar studies from rural areas in Namibia indicate that household labour is limited due to the increased migration of household members to urban areas for work and school (Nena, 2015; Von Hase, 2013; Montle and Teweldemedhin, 2014). HIV also poses a growing challenge to the agricultural labour force because the productive members of society (aged 16 – 25) tend to be the most infected by the disease (Spear et al., in press; Shackleton et al., 2015). It is estimated to take approximately 40 person days (roughly based on 8 hours per day) per hectare to dig planting pits and 32 person days per hectare for bunds, which indicates that substantial time and labour is required (Danjuma and Mohammed, 2015; SSWM, 2012). However, a study in Ethiopia by Amede et al. (2011) showed that farmers earned 20 times more income from their crops grown in pits than the cost of the labour required to dig the pits, hence the profit was worth the effort.

Overall, compost has the least barriers, which corresponds with it being the preferred choice as an adaptation practice. These practices were identified as suitable for the region because they require minimal tools and money; therefore these were seldom mentioned as barriers.

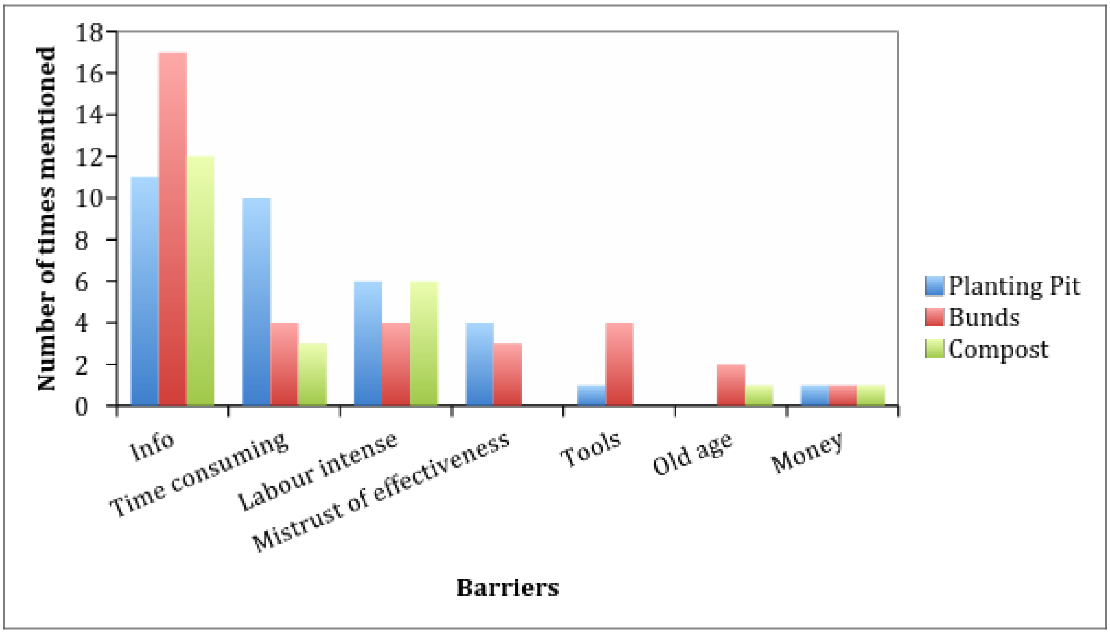


Figure 8. Barriers to the uptake of planting pits, bunds and compost

6.4. Enablers to the uptake of practices in other semi-arid regions

The systematic literature search indicated that support from NGOs, the government and extension services are important enablers, particularly for planting pits and bunds, which require instructions and a sense of affirmation that the practices will be effective (Table 8). The Garrity et al. (2010) study showed that the combination of the recognition of the benefits of agroforestry by the government and key donors led to investment in research and strengthening extension services which has expanded agroforestry training across Zambia and ultimately enhanced food security and resilience to climate change. A study by Jona and Terblanche (2015) which assessed the extent and perceptions of extension services in Oshikoto Namibia, concluded that more than half of the interviewed farmers had not had any contact with agricultural support services in over a year and overall extension services were largely inefficient. Although the Ministry of Agriculture (2015) report claims that there has been an effort to increase the dissemination of information and support of extension services in Namibia, neither the interviewees in this study nor the Oshikoto Nena (2015) and Jona and Terblanche (2015) study experienced this support. This is not unique to Namibia as according to Agriculture for Impact (2018) there is roughly one agricultural extension worker per 4 000 farmers in Africa, which is far below the FAO recommended rate of one officer to 400 farmers, hence agricultural extension services across Africa need to be drastically upgraded.

Limited access to information is a commonly mentioned barrier and consequently enhancing access to information is an enabler to successful adaptation. According to a household survey in Onesi by Musingarabwi (2015), when households were asked about the different sources of climate information (for example weather forecasts to assist in agricultural planning) that they used, 80 % of respondents used the radio, 49.5 % used information from village leaders and traditional authorities and 21 % used information from the government. The other sources of information were negligible: television 4 %, NGOs 3 % and extension officers 2 %. The NSA (2011) confirmed that 62 % of households in Onesi have access to a radio. Hence, radio, village leaders and traditional authorities are an important source of information; these communication pathways should therefore be used and enhanced in Onesi to share information about climatic changes and adaptive practices.

Moreover, there is growing literature that suggests the benefit of engaging with culture, tradition and religion in an effort to promote adaptation rather than conceptualising adaptation as a totally separate or even opposing entity (Davies et al., in press (b); Nyasimi et al., 2017). This entails framing adaptation information in the appropriate context and enlisting traditional and religious leaders to explain the impacts of climate change and encourage adaptation. This is also useful because there is greater trust in leaders from within the community (Nyasimi et al., 2017).

Other noteworthy enabling conditions which were mentioned for more than one of the practices are: a perception of the severity of the state of the land as well as a perception of the benefit of the practice, witnessing the success of a practice on another farm, demonstration sites and sufficient labour (Table 8). In a study on the uptake of rice farming practices in Kenya, Gicheru (2016) found that the adoption of new practice was directly correlated to the perception of degradation of the land, which highlights that farmers will be more willing to adopt new practices if they perceive low functionality of the land. In the Ouédraogo et al. (2001) study in Burkina Faso, although farmers were aware of the benefits of compost, 26 % of the farmers in the study area only adopted the practice after witnessing the success of compost on another farm which implies that this has a strong psychological effect on the adoption of a new practice. Witnessing the success on another farm links to the idea of climate change champions as discussed in the literature on enhancing awareness and adaptation (Davies et al., in press (b); Meijerink and Stiller, 2013). Climate change champions are eager individuals who demonstrate successful climate change adaptation strategies and are revered by their community. This in turn promotes the spread of adaptation practices. Similarly, the effectiveness of demonstration sites as an enabler to promote the adoption of planting pits is clear in the Danjuma and Mohammed, (2015) study on Burkina Faso. In this example, a field of planting pits was dug at a site next to a popular road, as the crops grew; villagers visited the site and received advice on digging pits on their own fields (Danjuma and Mohammed, 2015). Labour from a sufficiently endowed household or from self-help groups, in which farmers organise themselves to take turns working on each other's farms, were cited as necessary enablers for the uptake of all of these practices (Table 8). The Sidibé (2005) study in Ethiopia highlights how self-help labour groups (which allow work to be completed faster) are empowering and enable the adoption of practices that may otherwise have been far-fetched for individual households. Labour groups also offer the benefit of enhancing social networks and learning from each other.

Many of the cited barriers and enablers can be classified as institutional and social. Sietz and Van Dijk, (2015) and Bryan et al. (2009) emphasize the importance of social networks in the uptake of soil and water conservation practices as an important means of sharing information, brainstorming ideas and as an informal source of credit. Rural development policies that promote the formation of formal or informal farmer associations can strengthen this form of farmer-to-farmer interaction (Nganga et al., 2016; Nkegbe et al., 2011).

Table 8. Enablers of the selected farming approaches to adaptation

Planting practice	Enabler	Type of enabler	Country and reference
Planting pit	Support from NGOs and the extension service.	Institutional	Burkina Faso (Garrity et al., 2010) Niger (Reij and
	Support from rural grass root associations	Institutional	Burkina Faso (Schuler et al., 2016)
	Access to information	Information	Ethiopia (Tesfaye and Brouwer, 2012) Burkina Faso (Sidibé, 2005) Burkina Faso (Schuler et al., 2016)
	Education	Information	Burkina Faso (Sidibé, 2005)
	Self-help labour (farming groups)	Institutional	Burkina Faso (Ouédraogo et al., 2001)
	Demonstration sites	Information	Burkina Faso (Danjuma and Mohammed, 2015)
	Livestock for manure	Resources	Burkina Faso (Slingerland and Stork, 2000)
	Livestock for draft	Equipment	Burkina Faso (Slingerland and Stork, 2000)
	Mechanical transport	Equipment	Burkina Faso (Slingerland and Stork, 2000)
	Perception of severity of soil degradation	Social	Burkina Faso (Sidibé, 2005)
	Witnessing the success on another farm	Social	Niger (Reij and Smaling, 2008)
Bunds	Support from extension service	Institutional	Ghana (Nkegbe et al., 2011)

	Support from local government	Institutional	Ethiopia (Amare et al., 2014)
	Education	Information	Ethiopia (Hassam and Yirga, 2006)
	Land use certification (Secure land tenure)	Institutional	Ethiopia (Herweg and Ludi, 1999) Ethiopia (Tesfaye and Brouwer, 2012)
	Perception of severity of soil degradation	Social	Ethiopia (Hassam and Yirga, 2006)
	Trust in Authorities	Social	Ethiopia (Tesfaye and Brouwer, 2012)
	Membership in a farmer's organization (access to training, information, inputs, credit and equipment)	Institutional	Burkina Faso (Sidibé, 2005)
Composting	Access to information	Information	Ethiopia (Kassie et al., 2009)
	Sufficient labour (large household size)	Social	Uganda (Bevis et al., 2017) India (de Graaf et al., 2008) Ghana (Nkegbe et al., 2011) Ethiopia (Kassie et al., 2009) Kenya (Onduru et al., 2002)
	Living in densely populated areas (land is too valuable to leave	Social	Mali (Bodnár and de Graaf, 2003)

	Livestock for draft	Resources	Burkina Faso (Somda et al., 2002; Traoré and Stroosnijder, 2005) Ghana (Bellwood-Howard, 2012)
	Witnessing the success on another farm	Social	Burkina Faso (Ouédraogo et al., 2001)
	Self-reliance (failure of fertilizer delivery)	Social	Ethiopia (UN, 2007)
	Perceived benefit to yield	Social	Burkina Faso (Somda et al., 2002)

6.5. Interaction of barriers and enablers

Barriers and enablers overlay and interact in many ways. Firstly there are often multiple barriers which interact and are self reinforcing which inhibit the ability to adapt, for example one farmer stated that: "Sometimes I want to buy fertilizer for my field but I don't have money because I don't work, and we are not educated there is lack of information." In this case a lack of resources is due to a lack of finance which is due to a lack of information and education. Another farmer claimed that they don't use other practices because of "a lack of information/awareness. Also cultural beliefs because we always use Mahangu and don't trust new practices. We don't know if it will really help or it will just waste time." In this case education and social (cognitive and normative) barriers are imposed. The overlay between cognitive, normative barriers is also apparent since how we perceive things (information about climatic changes and trust in new practices) is influenced by the formal and informal institutional and cultural context within which we exist. These barriers could possibly be overcome through interacting enabling conditions such as access to education and information, support from government or extension services and building trust in these authorities which provide new information.

6.6. Conclusion to Objective Three: To assess the barriers and enablers of adopting practices from other semi-arid regions.

The findings of Objective Three indicate that almost everyone is willing to try new practices, which is a positive affirmatory response. However, the respondent's willingness to take up new practices is currently inhibited by:

i) A lack of information;
ii) The belief that there are no alternatives;
iii) The fear that a new practice won't work;
iv) A lack of time and labour.

Many of the barriers and the corresponding enablers can be classified as social or institutional which indicates that these aspects need to be targeted. Some of the social and institutional enablers that could promote the uptake of these practices and hence reduce vulnerability are:

i) Support from local authorities and possibly enlisting the help of religious and traditional leaders (including building trust within these networks);
ii) Enhancing information access (especially through the radio);
iii) Explaining the severity of climate change and the value of adaptation practices;
iv) Establishing self-help labour groups;
v) The creation of demonstrations sites.

Chapter Seven: Overarching Conclusion and Recommendations

Image: Sunset in Onesi during fieldwork, photo taken by Nivedita Joshi.

7.1. Conclusion

This study assessed local perceptions on past and future changes in productivity of the land and how these changes affect food security. It also identified planting practices that are used in other semi-arid regions that are appropriate for reducing vulnerability to climate change in Onesi and the barriers and enablers to the uptake of these practices. The interviewed farmers are experiencing decreased rainfall and higher rainfall variability, increased temperatures and a recent outbreak of crickets. This corresponds with the records of climatic trends in northern Namibia and further afield (Newsham and Thomas, 2009; IPCC, 2014b). Furthermore, it is projected that by 2050, the temperature will increase by between 1°– 4° and rainfall variability will be further exaggerated across southern Africa as a result of climate change (ASSAR, 2015).

Many farmers are worried about their food supply in the future as they do not believe that they can enhance their resilience because they do not have access to information or resources, such as farming equipment or sufficient labour (chapter four). Some farmers are not worried because they believe that climate interactions are God's will and solutions will be provided or that the government will provide assistance if they do not have sufficient food (chapter four). In some cases, tradition was also a central determinant of action and prevented farmers from wanting to make changes from what they know and trust. In all of these cases, farmers are vulnerable to future food insecurity because they are not actively adapting their farming practices to climatic changes.

The recommended practices: compost, bunds and planting pits, along with the climate smart agricultural practices that are already promoted in the area, such as mulching, agroforestry, crop rotation and minimum tillage, offer a practical means of reducing vulnerability to climate change (chapter five). These practices can enhance the quality and resilience of the soil to climatic stress by catching runoff water, increasing infiltration, regulating heat, reducing pests and increasing the fertility of the soil. These practices are relevant to the study site because of the inherent sandy, porous, low fertile soil present. These low input practices are appropriate for the grossly under resourced setting (chapter four). However, in order for the uptake of these practices to be successful, the reported barriers - namely a lack of information, mistrust, time and labour - must be overcome. None of the obstacles identified by the participants were limiting, in other words too great to be overcome or avoided. The enabling conditions: institutional support, access to information (including an understanding of the severity of the land and climate), self-help labour groups and demonstration sites must be enhanced. Gruere and Wreford (2017) differentiate between soft approaches such as demonstration sites and hard approaches such as policy interventions, both of which must be enhanced to affect real change.

7.2. Recommendations for policy

The Namibian government is a signatory of the UNFCCC and is committed to mitigation and adaptation as specified in the Intended Nationally Determined Contributions (Republic of Namibia, 2015a). It is believed that the government is striving towards an integrative and collaborative approach of adaptation including through mainstreaming adaptation into various governance levels (Republic of Namibia, 2015a; Davies et al., in press (a)). There are a few government and private projects in place aimed at reducing vulnerability to climate change in northern Namibia; however, they have not been implemented at a substantial scale or pace (chapter four). Although the government and other donors have provided food aid, low cost seeds and sometimes fertilizer, it is evident from the literature and the interviewee responses that people in north-central Namibia have not received sufficient information about climate change adaptive options to date (Nena, 2015; Von Hase, 2013; Montle and Teweldemedhin, 2014).

Upgrading the quantity and quality of extension services is an imperative for agriculture across Africa since this form of institutional support has great potential but is grossly ill-equipped to deal with agriculture in a changing climate (Agriculture for Impact, 2018). Trust in the government and extension services is another important enabler in the literature. If a reliable relationship is created between subsistence farmers and authorities, farmers may trust new information and may be willing to try new practices (Tesfaye and Brouwer, 2012). Institutional support must involve empowering people to enhance their own resilience to climate change rather than providing aid which promotes dependency (Maru et al., 2014). The traditional and religious influence over perceptions of climate change implies that scientists, governments and other related institutions need to consider the cultural and traditional beliefs of farmers when designing adaptation practices (Ndamani and Watanabe, 2015).

7.3. Recommendations for practice

7.3.1. Information sharing

The majority of the farmers explained that they did not have information about new practices that would enhance their resilience to changing temperature and rainfall (chapter six). Therefore, information sharing is a necessary enabler to assist the uptake of new practices (Sidibé, 2005; Kassie et al., 2009). In the remote landscape of Onesi, the primary source of information about the climate and farming practices is the radio and instructions from village leaders or traditional authorities. Since Onesi is a cultural and religious community, the narrative through which climate change and adaptation information is delivered should be explained through this appropriate frame (chapter six). If information can be delivered to these community leaders, they can host workshops, meetings or even religious gatherings in their own villages, to transmit further context appropriate information (Nyasimi et al., 2017).
In line with information sharing, an important enabler is an understanding of the severity of the land (Hassam and Yirga, 2006). A few of the farmers had heard about climate change before but only had a vague understanding of how it would affect their farming (chapter

four). It may be helpful to educate village leaders and community members about the impacts of climate change and how they will get worse in the future, to encourage forward planning in combination with information about adaptive techniques. The LISA SMS line, where farmers can communicate with extension officers, is also an innovative platform for information sharing which could be promoted through advertising and announcements on the radio (chapter five) (MAWF, 2017).

7.3.2. Demonstration sites

Demonstration sites where adaptive practices are being used successfully can encourage people to try the practices in their own spaces (Danjuma and Mohammed, 2015). For example, the headman from one of the study villages who had recently attended an ASSAR workshop about climate change was eager to establish a community garden (chapter four). This space could act as a demonstration site for new practices to be tested and displayed. Witnessing the success of a practice on another farm is a similar enabler (Reij and Smaling, 2008). If targeted individual village members test practices on their own farms, they will be witnessed by other village members and in this way new adaptive farming practices can be spread.

7.3.3. Labour groups

Labour was cited as a barrier to the uptake of new practices, often because household members in rural areas move to urban areas for school and work (chapter six). Labour sharing groups can be formal as in farmer associations or informal groups of neighbouring farmers who share labour and equipment. The establishment of self-help labour groups would empower village members to help each other and achieve more on their farms than if they work individually, this has been proven to increase the adoption of new practices (Nkegebe et al., 2011; Sidibé, 2005; Critchley and Graham, 1991). Labour groups also promote the sharing of information, brainstorming solutions for farming challenges and enhancing social networks, which act as a safety net for times of shock.

7.4. Recommendations for future research

The harsh farming conditions and severe vulnerability to climate risks of north-central Namibia make it a relevant and important research site. It is important as an example of how climate change will affect many areas and populations across the globe as well as for considering adaptive strategies for people who have such limited resources.

To follow on to this research it would be helpful to assess the success of the uptake of the recommended practices using the proposed enablers. An example would be using the community garden mentioned by one of the headmen as a demonstration site to show how planting pits, bunds and compost can be used. After witnessing the success of the practices, the uptake of each practice by village members could be observed over time. This would indicate whether demonstration sites are in fact an effective enabler of the uptake of new practices in Onesi.

Another component of this research that calls for greater research is information sharing. This was frequently cited as a barrier and speaks to the isolation of the study villages. Research could include an inquiry into the preferred avenues of information for locals in Onesi and ways in which these could be augmented as well as establishing new information sharing channels.

Reference List

Abid, M., Scheffran, J., Schneider, U. A. and Ashfaq, M. 2015. Farmers' perceptions of and adaptation strategies to climate change and their determinants: the case of Punjab province, Pakistan. *Earth System Dynamics,* (6): 225-243.

Adams, R. M., Hurd, B. H., Lenhart, S. and Leary, N. 1998. Effects of global climate change on agriculture and interpretative review. *Climate Research*, (11): 19-30.

Adger, W. N., Dessai, S., Goulden, M., Hulme, M., Lorenzoni, I., Nelson, D. R., Naess, L., Wolf, J. and Wreford, A. 2009. Are there social limits to adaptation to climate change? Climatic Change, 93, (3): 335–354.

African Independent. 2018. Amid armyworm outbreak, red locusts emerge. Available online: https://www.africanindy.com/news/amid-armyworm-outbreak-red-locusts-emerge-7784925

Agriculture for Impact. 2018. Agriculture for Impact Growing Opportunities for Africa's Development. Available online: https://ag4impact.org/sid/socio-economic-intensification/building-human-capital/agricultural-extension/

Adimassu, Z., Langan, S., Johnston, R., Mekuria, W. and Amede, T. 2016. Impacts of soil and water conservation practices on crop yield, run-off, soil loss and nutrient loss in Ethiopia: review and synthesis. *Environmental Management,* 59(1): 87-101.

Alam, G. M. M., Alam, K. and Mushtaq, S. 2017. Climate change perceptions and local adaptation strategies of hazard-prone rural households in Bangladesh. *Climate Risk Management*, 17, 52-63.

Amare, T., Zegeye, A. D., Yitaferu, B., Steenhuis, T. S., Hurni, H. and Zeleke, G. 2014. Combined effect of soil bund with biological soil and water conservation measures in the northwestern Ethiopian highlands. *Ecohydrology and Hydrobiology,* 14(3):192-199.

Amede, T., S. Tarawali, and D. Peden. 2011. Zai improves nutrient and water productivity in the Ethiopian highlands. Special Issue: Improving water productivity of crop-livestock systems in drought-prone regions. *Experimental Agriculture*, 47 (1): 7-20.

Angula, M., Ntombela, K. Samuels, M., Swarts, M., Cupido, C., Haimbili, N., Menjono-Katjizeu, M. and Hoabes, M. 2016. Understanding pastoralist's knowledge of climate change and variability in arid Namibia and South Africa. Proceedings of

Centenary Conference of the Society of South African Geographers, 252-266.

Angula, M.N. and Kaundjua, M.B., 2016, 'The changing climate and human vulnerability in north-central Namibia', Jàmbá: Journal of Disaster Risk Studies 8(2): 7 pp.

Antwi-Agyei, P., Dougill, A. J. and Stringer, L. C. 2015. Barriers to climate change adaptation: evidence from northeast Ghana in the context of a systematic literature review. *Climate and Development,* 7(4): 297-309.

ASSAR. 2015. Adaptation at Scale in Semi-Arid Regions: Southern Africa regional diagnostic study. Report Summary. 5 pp.

Arku, F. 2013. Local creativity for adapting to climate change among rural farmers in the semi-arid region of Ghana. *International Journal of Climate Change Strategies and Management*, 5(4): 418-430.

Ayanlade, A., Radney, M. and Morton, J. 2016. Comparing farmers perception of climate change with meteorological data: A case study from southwestern Nigeria. *Weather and Climate Extreme*, 1-10.

Balama, C., Augustino, S., Eriksen, S. and Makonda, F. B. S. 2016. Forest adjacent households' voices on their perceptions and adaptation strategies to climate change in Kilombero District, Tanzania. *Springer Plus,* 5(792): 22 pp.

Barnes, J. I., MacGregor, J. and Alberts, M. 2012. Expected climate change impacts on land and natural resource use in Namibia: exploring economically efficient responses. *Pastoralism Journal.* (2): 23 pp.

Barnett, J., Evans, L. S., Gross, C., Kiem, A. S., Kingsford, R. T., Palutikof, J. P., Pickering, C. M. and Smithers, S. G. 2015. From barriers to limits to climate change adaptation: path dependency and the speed of change. *Ecology and Society,* 20(3): 11 pp.

Bayu, W., Rethman, N. and Hammes, P. 2004. The role of animal manure in sustainable soil fertility management in sub-Saharan Africa: a review. *Journal of Sustainable Agriculture*. 25(2): 1540-7578.

Becken, S., Lama, A. K. and Espiner, S. 2013. The cultural context of climate change impacts: Perceptions among community members in the Annapurna Conservation Area, Nepal. *Environmental Development,* (8): 22-37.

Bellwood-Howard, I. 2012. Donkeys and bicycles: capital interactions facilitating timely compost application in northern Ghana. International Journal of Agricultural Sustainability, 10(4): 315-327.

Bhattacharyya, R., Nath Ghosh, B., Dogra, P., Kumar Mishra, P., Santra, P., Kumar, S., Fullen, M. A., Mandal, U. K., Anil, K. S., Lalitha, M., Sarkar, D., Mukhopadhyay, D., Das, K., Pal, M., Yadav, R., Chaudhary, V. P. and Parmar, B. 2016. Soil conservation issues in India. *Sustainability*, 8(565): 37 pp.

Biesbroek, G. R., Klostermann, J. E. M., Termeer, C. J. A. M. and Kabat, P. 2013. On the nature of barriers to climate change adaptation. *Regional Environmental Change,* 13(5): 1119-1129.

Bodnár, F. and De Graaff, J. 2003. Factors influencing adoption of soil and water conservation measures in southern Mali. *Land Degradation and Development*, 14(6): 515-525.

Brown, L. 2009. The economic impact of climate change on commercial agriculture in Namibia. University of York, *MSc dissertation,* 37 pp.

Bryan, E., Deressa, T. T., Gbetibouo, G. A. and Ringler, C. 2009. Adaptation to climate change in Ethiopia and South Africa: options and constraints. *Environmental Science and Policy.* 12: 413-426.

Buerkert, A. and Lamers, J.P.A., 1999. Soil erosion and deposition effects on surface characteristics and pearl millet growth in the West African Sahel. *Plant Soil.* (215): 239–253.

Burnham, M., and Z. Ma, 2017: Climate change adaptation: factors influencing Chinese smallholder farmers' perceived self-efficacy and adaptation intent. *Regional Environmental Change,* 17, 171–186.

Camberlin, P., Janicot, S. and Poccard, I. 2001. Seasonality and atmospheric dynamics of the teleconnection between African rainfall and tropical sea surface temperature: Atlantic vs. ENSO, *International Journal of Climatology,* (21): 973-1005.

Club of Mozambique. 2017. SA confirms presence of invasive pest that infests maize / Outbreak has spread to Mozambique, Namibia,. Available online: http://clubofmozambique.com/news/south-africa-confirms-presence-invasive-pest-infests-maize-outbreak-spread-mozambique-namibia-says-fao/ [Accessed 19 Sep. 2018].

Crawford, A. and Terton, A. 2016. Review of current and planned adaptation action in Namibia. CARIAA Working Paper no. 12. International Development Research

Centre, Ottawa, Canada and UK Aid, London, United Kingdom. 54 pp.

Critchley, W. and Graham, O. 1991. Looking after our land: soil and water conservation in dryland Africa. *Oxfam Publishing*, London, United Kingdom 88pp.

Dahlberg, E., and Wingqvist, G.O. 2008, Environmental and Climate Change Policy Brief, Sida INEC, Stockholm, 25 pp.

Danjuma, M. N. and Mohammed, S. 2015. Zai Pits System: a catalyst for restoration in the dry lands. *Journal of Agriculture and Veterinary Science,* 8(2):1-4.

Davies, J.; Spear, D.; Ziervogel, G.; Hegga, S.; Angula, M; and Kunamwene, I. In press (a) Barriers to Climate Change Adaptation in Namibia. 14 pp.

Davies, J.; Spear, D.; Chappel, A.; Joshi, N.; Togarepi, C.; Kunamwene, I. In press (b). Considering religion and tradition in Climate Smart Agriculture: insights from Namibia. In The Climate-Smart Agriculture Papers: Investigating the Business of a Productive, Resilient and Low Emission Future; Rosenstock, T., Nowak, A. & Girvetz, E., Eds.; Springer International Publishing: Basel, Switzerland.

Davis, C.L. 2011. Climate risk and vulnerability: a handbook for Southern Africa. Council for Scientific and Industrial Research, Pretoria, South Africa, 92pp.

de Graaff, J., Amsalu, A., Bodnár, F., Kessler, A., Posthumus, H. and Tenge, A. 2008. Factors influencing adoption and continued use of long-term soil and water conservation measures in five developing countries. *Applied Geography,* 28(4): 271-280.

Dirkx E, Hager C, Tadross M, Bethune S and Curtis B. 2008. Climate change vulnerability and adaptation assessment: Namibia. Desert Research Foundation of Namibia and Climate Systems Analysis Group for the Ministry of Environment and Tourism, Windhoek, 149pp.

Eisenack, K., Moser, S., Hoffmann, E., Klein, R. J. T., Oberlack, C., Pechan, A., Rotter, M. and Termeer, C. J. A. M. 2014. Explaining and overcoming barriers to climate change adaptation. *Nature Climate Change*, 4(10): 867-872.

Eriksen, S. H. and Lind, J. 2009. Adaptation as a Political Process: Adjusting to Drought and Conflict in Kenya's Drylands. *Environmental Management,* 43(5): 817-835.

FAO. 2009. Food and Agriculture Organisation of the United Nations. Special Report FAO/WFP crop, livestock and food security assessment mission to Namibia. Washington, Food and Agriculture Organization. 92 pp.

FAO. 2010. Food and Agriculture Organisation of the United Nations. Water Harvesting. FAO Corporate document repository. Available online: www.fao.org/docrep

FAO. 2016. Food and Agriculture Organisation of the United Nations. Southern Africa Situation Report. 7 pp.

FAO. 2018. Food and Agriculture Organisation of the United Nations. Climate Smart Agriculture Handbook. Available online: http://www.fao.org/climate-smart-agriculture-sourcebook/enabling-frameworks/module-c5-finance/c5-overview/en/

Fatondji, D., Martius, C., Bielders, C. L., Vlek, P. L. G., Bationo, A. and Gerard, B. 2006. Effect of planting technique and amendment type on pearl millet yield, nutrient uptake, and water use on degraded land in Niger. *Nutrient Cycling in Agroecosystems,* 76(2-3): 203-217.

Fisher, M., Abate, T., Lunduka, R. W., Asnake, W., Alemayehu, Y., and Madulu, R. B. 2015. Drought tolerant maize for farmer adaptation to drought in sub-Saharan Africa: Determinants of adoption in eastern and southern Africa. *Climatic Change*, 133(2), 283–299.

Fischler, M. and Wortmann, C. S. 1999. Green manures for maize–bean systems in eastern Uganda: Agronomic performance and farmers' perceptions. Agroforestry Systems, (47): 123–138.

Fraser, E. D. G., Dougil, A. J., Hubacek, K., Quinn, C. H., Sendzimir, J and Termansen, M. 2011. Assessing vulnerability to climate change in dryland livelihood systems: conceptual challenges and interdisciplinary solutions. *Ecology and Society* 16(3): 13 pp.

Froystad, M., Hoffmann, J. and Schade, K. 2008. Agriculture: Future Scenarios for Southern Africa Country Briefing – Namibia. Prepared for Trade Knowledge Network Southern Africa, *The Namibian Economic Policy Research Unit*, Working Paper No. 113. 19 pp.

Garrity, D. P., Akinnifesi, F. K., Ajayi, O. C., Weldesemayat, S. G., Mowo, J. G., Kalinganire, A., Larwanou, M. and Bayala, J. 2010. Evergreen Agriculture: a robust approach to sustainable food security in Africa. Food Security, 2(3): 197-214.

Gbetibouo, G. A. 2009. Understanding Farmers' Perceptions and Adaptations to Climate

Change and Variability: The Case of the Limpopo Basin, South Africa. Environment and Production Technology Division Discussion Paper 00849. International Food Policy Research Institute: Washington, DC, United States of America, 52 pp.

Gebremichael, D., Nyssen, J., Poesen, J., Deckers, J., Haile, M., Govers, G. and Moeyersons, J. 2005. Effectiveness of stone bunds in controlling soil erosion on cropland in the Tigray Highlands, northern Ethiopia. *Soil Use and Management,* 21(3): 287-297.

GEF. 2006. Global Environment Facility, CPP Namibia: Adapting to Climate Change through the Improvement of Traditional Crops and Livestock Farming (CCA). Focal area: climate change. *GEFSEC project*, 100 pp.

Gicheru, M. 2016. Barriers and enablers to uptake and implementation of system of rice intensification. A case study of Mwea irrigation scheme in Kenya. Master's Degree in Science, *University of Cape Town, Cape Town* 79 pp.

Global Issues. 2011. Social, Political, Economic and Environmental Issues That Affect Us All. Heaviest Ever Floods in Northern Namibia, Inter Press Service, Friday, March 25, 2011. Available online: http://www.globalissues.org/news/2011/03/25/9041

Gornall, J. Betts, R., Burke, E., Clark, R., Camp, J., Willett, K and Wiltshire, A. 2010. Implications of climate change for agricultural productivity in the early twenty-first century, The Royal Society Publishing, 365: 2973-2989.

Government of Namibia. 2002. Initial National Communication to the United Nations Framework Convention on Climate Change, Report, 154 pp.

Government of Namibia. 2017. Ministry of Agriculture, Water and Forestry. Omahenene Project Available online: http://www.mawf.gov.na/omahenene-project

Green Climate Fund. 2016. Projects and Programs CRAVE. Available online: http://www.greenclimate.fund/-/climate-resilient-agriculture-in-three-of-the-vulnerable-extreme-northern-crop-growing-regions-crave-

Grothmann, T., and Patt, A. 2005: Adaptive capacity and human cognition: The process of individual adaptation to climate change. *Global Environmental Change*, 15, 199–213.

Gruère, G. and Wreford, A. 2017. Overcoming barriers to the adoption of climate-friendly practices in agriculture, OECD Food, Agriculture and Fisheries Papers, No. 101, *OECD Publishing, Paris,* 40 pp.

Hasheela, R. 2010. Adaptation of Farmers to Climate Change in Ohangwena Region, Namibia. Masters. University of the Free State.

Hassam, R. and Yirga, C. 2006. Poverty and soil conservation efforts among small holder farmers in the central highlands of ethiopia'. *Department of Agricultural Economics University of Pretoria,* 9(2): 224-261.

Hatfield, J., Boote, P., Fay, L., Hahn, C., Izaurralde, B., Kimball, T., Mader, J. , Morgan, D., Ort, W., Polley, A., Thomson. and Wolfe, D. 2008. Agriculture: The effects of climate change on agriculture, land resources, water resources, and biodiversity in the United States. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. *Washington, DC., USA*, 362 pp

Hawken. 2017. Drawdown: The Most Comprehensive Plan Ever Proposed to Reverse Global Warming. *Penguin Books, New York*. 239 pp.

Hegga, S., Ziervogel, G., Angula, M., Spear, D., Nyamwanza, A., Ndeunyema1, E., Kunamwene, I., Togarepi, C. and Morchain, D. 2016. Vulnerability and Risk Assessment in the Omusati Region in Namibia: Fostering People-Centred Adaptation to Climate Change. Report. 61 pp.

Hengsdijk, H., Meijerink, G. W. and Mosugu, M. E. 2005. Modeling the effect of three soil and water conservation practices in Tigray, Ethiopia. *Ecosystems and Environment*, 105(1-2): 29-40.

Herweg, K. and Ludi, E. 1999. The performance of selected soil and water conservation measures—case studies from Ethiopia and Eritrea. *CATENA*, 36(1-2): 99-114.

Hillyer, A. E. M., McDonagh, J. F. and Verlinden, A. 2006. Land-use and legumes in northern Namibia - The value of a local classification system. Agriculture, Ecosystems and Environment, 117(4): 251-265.

Himanen, S., Mäkinen, H., Rimhanen, K. and Savikko, R. 2016. Engaging farmers in climate change adaptation planning: assessing intercropping as a means to support farm adaptive capacity. *Agriculture,* 6(34): 1 - 13.

Hitayezu, P., Wale, E. and Ortmann, G. F. 2017. Assessing farmers' perceptions about climate change: A double- hurdle approach. *Climate Risk Management,* 17: 123-138

IDRC (International Development Research Centre). Ker, A.D.R., Moorse, M.W., Watts, E.R. & Gill, B.N. 1978. ITCZ mean position information Available from: http://www.idrc.ca/books/focus/793/fig3.gif.

IPCC. 2001. International Panel on Climate Change. Climate change synthesis report summary for policymakers. Report. 40 pp.

IPCC. 2012. Glossary of terms. In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, Cambridge, UK, and New York, NY, USA, pp. 555-564.

IPCC. 2014a. Annex II: Glossary [Mach, K.J., S. Planton and C. von Stechow (eds.)]. In: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, pp. 117-130

IPCC. 2014b. International Panel on Climate Change. Climate change synthesis report summary for policymakers. Report. 32 pp.

Jona, C. N. and Terblanche, S. E. 2015. Farmers' perception on contact frequency, adequacy, relevance and quality of agriculture support services in Oshikoto region in Namibia. South African Journal of Agricultural Extension, 43(1):107-121.

Kablan, R., Yost, R. S., Brannan, K., Doumbia, M. D., Traoré, K., Yoroté, A., Toloba, Y., Sissoko, S., Samaké, O., Vaksman, M., Dioni, L. and Sissoko, M. 2008. "Aménagement en courbes de niveau," Increasing Rainfall Capture, Storage, and Drainage in Soils of Mali. *Arid Land Research and Management,* 22(1): 62-80.

Kalra, N. Chander, S. Aggarwal, P. Gupta, N., Sehgal, M. and Chakraborty, D. 2007. Impacts of climate change on agriculture. *Outlook on Agriculture,* 36 (2):109-118.

Kassie, M., Zikhali, P., Manjur, K. and Edwards, S. 2009. Adoption of organic farming technologies: evidence from a semi-arid region in Ethiopia. Climate change and food systems resilience in sub-Saharan Africa. *Environment for Development Initiative and Resources for the Future*, 26 pp.

Klintenberg, P. and Seely, M. 2004. Land Degradation Monitoring In Namibia: A First Approximation. Environmental Monitoring and Assessment, (99): 5–21.

KNMI. 2018. Climate Explorer, European Climate Assessment and Data, Available online: http://climexp.knmi.nl/start.cgi.

Kouyate, Z., Franzluebbers, K., Juo, A. S. R. and Hossner, L. R. 2000. Tillage, crop residue, legume rotation, and green manure effects on sorghum and millet yields in the semiarid tropics of Mali. Plant and Soil, (225):141–151.

Loladxe, I. 2014. Hidden shift of the ionome of plants exposed to elevated CO_2 depletes minerals at the base of human nutrition. *eLife*, (3): 1

Maatman, A., Sawadogo, H., Schweigman, C. and Ouedraogo, A. 1997. Application of zaï and rock bunds in the northwest region of Burkina Faso; Study of its impact on household level by using a stochastic linear programming model. *University of Groningen, Netherlands*, 10 pp.

Mafongoya, P. L. and Ajayi, O. C. 2017, Indigenous Knowledge Systems and Climate Change Management in Africa, CTA, *Wageningen, The Netherlands*, 316 pp.

Mallet, M. and du Plessis, P. 2001. Mahangu post-harvest systems a summary of current knowledge about pearl millet postharvest issues in Namibia. Research report prepared for Ministry of Agriculture, Water and Rural Development Directorate of Planning and Namibian Agronomic Board. 63 pp.

Maru, Y. T., Smith, M. S., Sparrow, A., Pinho, P. F. and Dube, O. P. 2014. A linked vulnerability and resilience framework for adaptation pathways in remote disadvantaged communities. *Global Environmental Change.* 14 pp.

Masud, M. M., Azam, M. N., Mohiuddin, M., Banna, H., Akhtar, R., Alam, A. S. A. F. and Begum, H. 2017. Adaptation barriers and strategies towards climate change: Challenges in the agricultural sector. Journal of Cleaner Production, (156): 698-706.

Matambo, S. and Seely, M. 2012. World Resources Report Case Study. Namibia: Combating Desertification with Tools for Local Level Decision Making. World Resources Report, *Washington DC.* Available online: http://www.worldresourcesreport.org

Matanyaire, C. M. and Gupta, S. C., 1996. On-farm evaluation of improved pearl millet varieties in Namibia. Pages 59-6 3 in Drought-tolerant crops for southern Africa: proceedings of the SADC/ICRISA T Regional Sorghum an d Pearl Millet Workshop, 1994, Gaborone, Botswana. International Crops Research Institute for the Semi-Arid Tropics.

McNamara, K. E. and Buggy, L. 2017. Community-based climate change adaptation: a review of academic literature. *Local Environment,* 22(4): 443-460.

MAWF. 2017. Ministry of Agriculture, Water and Forestry, Learning and Information Sharing for Agriculture. Available online: http://www.lisa.com.na/admin/

MET. 2011. Ministry of Environment and Tourism: Namibia second national communication to the United Nations Framework Convention on Climate Change. Windhoek: Government of Namibia, 128 pp.

Mendelsohn, J., Jarvis, A., Roberts, C. and Robertson, T. 2002. Atlas of Namibia. A Portrait of the Land and its People - Cape Town (David Philip Publishers; New Africa Books (Pty) Ltd.

Mongi, H., Majule, A. E. and Lyimo, J. G. 2010. Vulnerability and adaptation of rainfed agriculture to climate change and variability in semi-arid Tanzania. *African journal of Environmental Science and Technology.* 4 (6): 371-381.

Moroke, T. S., Pule-Muelenberg, F., Mzuku, M., Patrick, C. and Kashe, K. 2017. Water Harvesting and Conservation Techniques for Dryland Crop Production in Botswana: *A Review. Agricultural Mechanization in Africa, Asia and Latin America,* 41(3): 9 - 16.

Motis, T., Aiuto, C. and Lingbeek, B. 2013. Zai Pit System. Technical Note # 78, Echo. 12 pp.

Montle, B. P. and Teweldemedhin, M. Y. 2014. Assessment of farmers' perceptions and the economic impact of climate change in Namibia: Case study on small-scale irrigation farmers (SSIFs) of Ndonga Linena irrigation project, Journal of Development and Agricultural Economics, 6(11): 443-454.

Moyo, M., Mvumi, B. M., Kunzekweguta, M., Mazvimavi, K., Craufurd, P. and Dorward, P. 2012. Farmer perceptions on climate change and variability in semi-arid Zimbabwe in relation to climatology evidence. *African Crop science Journal,* 20: 317-335.

Mubaya, C. P., Njuki, E. P. Mutswangwa, F. T. Mugabe and Nanja, D. 2012. Climate variability and change or multiple stressors? Farmers perceptions regarding threats to livelihoods in Zimbabwe and Zambia. *Environmental Management,* 102: 9-17.

Muller, C. and Shackleton, S. 2014. Perceptions of climate change and barriers to adaptation amongst commonage and commercial livestock farmers in the semi-arid Eastern Cape Karoo. African Journal of Range and Forage Science. 31 (1): 1-12.

Musingarabwi, S.2015. ASSAR Onesi household pilot survey. Unpublished data.

Namibian Agronomic Board. 2017. Mahangu. Available online: http://www.nab.com.na/controlledcrops/grain/mahangu/

NSA 2011. National Statistics Agency, Omusati Regional Profile, Population and Housing Census, 182 pp

NSA. 2012. National Statistics Agency, Poverty dynamics in Namibia: A comparative study using the 1993/94, 2003/04 and the 2009/10 NHIES surveys. Report, 45 pp.

Ndamani, F. and Watanabe, T. 2015. Farmers' Perceptions about Adaptation Practices to Climate Change and Barriers to Adaptation: A Micro-Level Study in Ghana, Water (Switzerland), 7: 4594 – 4604. Nena, P. 2015. Factors affecting subsistence farmers' adoption of sustainable land management practices in Oshikoto region, Namibia. Masters Thesis. Agricultural University of Iceland, 25 pp.

Newman, J. A. 2004. Climate change and cereal aphids: the relative effects of increasing CO_2 and temperature on aphid population dynamics. Global Change Biology. 10, 5–15.

Newsham, A, J. and Thomas, D. 2009. Agricultural adaptation, local knowledge and livelihoods diversification in North-Central Namibia. *Tyndall centre for climate change research.* (140): 64 pp.

Newsham, A. J. and Thomas, D. 2011. Knowing, farming and climate change adaptation in North-Central Namibia. Global Environmental Change. (21): 761-770.

Newsham, A. J., Naess, L. and Guthinga, P. 2011. Farmers' Knowledge and Climate Change Adaptation: Insights from Policy Processes in Kenya and Namibia. Policy Brief. *Future Agricultures Consortium,* 12 pp.

Nganga, S. K., Van Wijk, M. T., Rufino, M. C., and Giller, K. E. 2016. Adaptation of agriculture to climate change in semi-arid Borena, Ethiopia. *Regional Environmental Change,* 16(8): 2317- 2330.

Nkegbe, P. K., Shankar, B. and Ceddia, G. 2011. Smallholder Adoption of Soil and Water Conservation Practices in northern Ghana. Paper prepared for presentation at the EAAE 2011 Congress Change and Uncertainty Challenges for Agriculture, *Food and Natural Resources*, Zurich Switzerland, 30 August to 2 September 2011, 13 pp.

Nyasimi, M., Kimeli, P., Sayula, G., Radeny, M., Kinyangi, J. and Mungai, C. 2017. Adoption and Dissemination Pathways for Climate-Smart Agriculture Technologies and Practices for Climate-Resilient Livelihoods in Lushoto, Northeast Tanzania. *Climate,* 5(3): 63 pp.

Nyssen, J., Poesen, J., Gebremichael, D., Vancampenhout, K., D'aes, M., Yihdego, G., Govers, G., Leirs, H., Moeyersons, J., Naudts, J., Haregeweyn, N., Haile, M. and Deckers, J. 2007. Interdisciplinary on-site evaluation of stone bunds to control soil erosion on cropland in northern Ethiopia. *Soil and Tillage Research*, 94(1): 151-163.

Odendaal, W. 2011. Land grabbing in Namiba: A case study from the Omusati region, northern Namiba. Report. 26 pp.

OECD (Organisation for Economic Co-operation and Development). 2014. Financing Climate Change Action, Policy Perspectives, 20 pp.

Ogalleh, S. A., Vogl, C. R., Eitzinger, J. and Hauser, M. 2012. Local Perceptions and Responses to Climate Change and Variability: The Case of Laikipia District, Kenya. Sustainability (4): 3302-3325.

Onduru, D., Diop, J. M., Van der Werf, E and De Jager, A. 2002. Participatory On-Farm Comparative Assessment of Organic and Conventional Farmers' Practices in Kenya, Biological Agriculture and Horticulture, 19 (4): 295-314.

Ouédraogo, E., Mando, A. and Zombré, N. P. 2001. Use of compost to improve soil properties and crop productivity under low input agricultural system in West Africa. *Agriculture, Ecosystems and Environment,* 84(3): 259-266.

Paavola, J. 2008 Livelihoods, vulnerability and adaptation to climate change in Morogoro, Tanzania. *Environnmental Science.* (11): 642–654.

Parry, M., Arnell, N., Berry, P., Dodman, D., Fankhauser, S., Hope, C., Kovats, S., Nocholls, R. Satterthwaite, D., Tiffin, R. and Wheeler, T. 2009. Assessing the costs of adaptation to climate change: A review of the UNFCCC and other recent estimates. *International Institute for Environment and Development and Grantham Institute for Climate Change, London,* 116 pp.

Peterson, C. 2013. Fast-growing groundnuts keep Ghana's farmers afloat amid climate shifts. Available online: http://www.trust.org/item/20130709095148

Pike, A., Dawley, S. and Tomaney, J. 2010. Resilience, adaptation and adaptability, Cambridge Journal of Regions, *Economy and Society*, 3 (1): 59–70.

Reddy, B. V. S., Kumar, A. and Reddy, P. 2010. Recent Advances in Sorghum Improvement Research at ICRISAT. *Natural Science,* (44): 499 – 506.

Reid, H., Sahlén, L., Stage, J. and MacGregor, J. 2007. The economic impact of climate change in Namibia: How climate change will affect the contribution of Namibia's natural resources to its economy. *International Institute for Environment and Development* (IIED). Discussion Paper. 54pp.

Reid, H., Sahlen, L., Stage, J. and MacGregor, J. 2008. Climate change impacts on Namibia's natural resources and economy, *Climate Policy,* 8(5): 452-466,

Reij, C. P. and Smaling, E. M. A. 2008. Analyzing successes in agriculture and land management in sub-Saharan Africa: Is macro-level gloom obscuring positive micro-level change? *Land Use Policy,* 25(3): 410-420.

Republic of Namibia. 2006. Regional Development Plan 2001/2002-2005/2006. Omusati region, Omusati region development council, 176 pp.

Republic of Namibia. 2015a. Intended nationally determined contributions of the Republic of Namibia to the United Nations framework convention on climate change. Ministry of Environment and Tourism: *Windhoek, Namibia,* 21 pp.

Republic of Namibia. 2015b. Third National Communication to the United Nations Framework Convention on Climate Change. Ministry of Environment and Tourism: *Windhoek, Namibia,* 173 pp.

Republic of Namibia. 2016. Namibia Zero Hunger Newsletter. *National Planning Commision.(*1): 24 pp.

Republic of Namibia Ministry of Agriculture, Water and Forestry. 2017. Media Release Pest outbreak in North Central and North Eastern Regions. Available online: http://www.mawf.gov.na/documents/37726/84627/Insect+Pest+Outbreak+Arm yworm++2017+%281%29.pdf/c56790f9-6f49-4614-a806-0d1e7e5c2f19 .

Rouillard, J., Tröltzsch, J., Tarpey, J., Lago, M., Watkiss, P., Hunt, A. Bosello, F., Ermolieva, T., Goodess, C., Mechler, R., Parrado, R., Sainz de Murieta, E., Scussolini, P. 2016. The economic analysis of climate adaptation: Insights for policy-makers. ECONADAPT, 46 pp.

Shackleton, S., Ziervogel, G., Sallu, S., Gill, T. and Tschakert, P. 2015. Why is socially-just climate change adaptation in sub-Saharan Africa so challenging? A review of barriers identified from empirical cases. *Wiley Interdisciplinary Reviews: Climate Change*, 6(3), 321-344.

Schuler, J., Voss, A. K., Ndah, H. T., Traoré, K. and de Graaff, J. 2016. A socioeconomic analysis of the zaï farming practice in northern Burkina Faso. *Agroecology and Sustainable Food Systems*, 40(9): 988-1007.

Sharma, K. L., Grace, J. K., Chandrika, M. S., Vittal, K. P. R., Singh, S. P., Nema, A. K., Chauhan, S. P. S., Sankar, G. M., Mandal, U. K., Korwar, G. R., Venkateswarlu, B., Ramesh, G., Chary G. R., Madhavi, M., Gajbhiye, P. G.., Munna Lal, T., Kumar, S and Rani, K. U. 2014. Effects of Soil Management Practices on Key Soil Quality Indicators and Indices in Pearl Millet (Pennisetum americanum (L.) Leeke)–Based System in Hot Semi-arid Inceptisols, *Communications in Soil Science and Plant Analysis,* 45,(6):785-809.

Shiningayamwe, E. N. 2012. Crop rotation as a soil fertility improvement strategy using different legumes on a pearl millet field. *Agricola* (22): 40-44.

Sidibé, A. 2005. Farm-level adoption of soil and water conservation techniques in northern Burkina Faso. *Agricultural Water Management*, 71(3): 211-224.

Sietz, D. and Van Dijk, H. 2015. Land-based adaptation to global change: What drives soil and water conservation in western Africa? *Global Environmental Change,* 33:131-141.

Silva-rosa, T., Michelle Bonatti, M., Vanini, A. and Zuffo, C. 2014. Vulnerability and Climate Change Perceptions: A Case Study in Brazilian Biomes. *Environment and Pollution*, 3(1).

Simelton, E., Quinn, C. H., Batisani, N., Dougill, A. J., Dyer, J. C., Fraser, E. D. G., Mkwambisi, D., Sallu, S. and Stringer, L. C. 2013. Is rainfall really changing? Farmers' perceptions, meteorological data and policy implications, 5(2):123-138.

Singh, C. Dorward, P. and Osbahr, H. 2016. Developing a holistic approach to the analysis of farmer decision-making: Implications for adaptation policy and practice in developing countries. *Land Use Policy*,(59): 329-343.

Slingerland, M. A. and Stork, V. E. 2000. Determinants of the Practice of Zaï and Mulching in North Burkina Faso. *Journal of Sustainable Agriculture,* 16(2): 53-76.

Somda, J., Nianogo, A., Nassa, S. and Sanou, S. 2002. Soil fertility management and socio-economic factors in crop-livestock systems in Burkina Faso: a case study of composting technology. *Ecological Economics,* 43(2): 175-183.

Spear, D., Haimbili, E., Angula, M. N., Hegga, S., Zaroug, M. and Okeyo, A. 2016. Vulnerability and adaptation to climate change in semi-arid areas in southern Africa. CARIAA-ASSAR Working Paper. University of Cape Town, Cape Town, South Africa. 117pp. Available online at: www.assar.uct.ac.za.

Spear D., Zaroug M. A. H., Daron D.D., Ziervogel G., Angula M.N., Haimbili E.N., Hegga S.S., Baudoin M., New M., Kunamwene I., Togarepi C. and Davies J.E. 2018. Vulnerability and responses to climate change in drylands: The case of Namibia. CARIAA-ASSAR Working Paper. University of Cape Town, Cape Town, South Africa. Available online at: www.assar.uct.ac.za

Spear, D., Zaroug, M. A. H., Daron, D. D., Ziervogel, G., Angula, M. N., Haimbili, E. N., Hegga, S. S., Baudoin, M., New, M., Kunamwene, I. and Togarepi, C. In press. Sustaining the livelihoods of smallholder farmers under climate change in northern Namibia, 29pp.

Stige, L. C., Stave, J., Chan, K., Ciannelli, L., Pettorelli, N., Glantz, M., Herren, H. and Stenseth, 2006. The effect of climate variation on agro-pastoral production in Africa, PNAS. 103(9): 3049-3053.

Stroosnijder, L. 2009. Modifying land management in order to improve efficiency of rainwater use in the African highlands. *Soil and Tillage Research,* 103(2): 247-256.

Sun, Y., Yin, J., Chen, F., Wu, G. and Ge, F. 2011. How does atmospheric elevated C02 affect crop pests and their natural enemies? Insect Science. Instutute of Zoology, *Chinese Academy of Science.* (18): 394-400.

SSWM. 2012. Sustainable Sanitation and Water Management Toolbox. Available online:

http://www.sswm.info/content/planting-pits
Tesfaye, A. and Brouwer, R. 2012. Testing participation constraints in contract design for sustainable soil conservation in Ethiopia. Ecological Economics, (73):168-178.
The Namibian. 2004. Locusts plague Kavango Region. Available online: https://allafrica.com/stories/200411190026.html.
Thomalla, F., Smith, R. and Schipper, L. F. 2015. Cultural Aspects of Risk to Environmental Changes and Hazards: A Review of Perspectives, 16 pp.
Tilman, D., Cassman, K. G., Matson, P. A., Naylor, R. and Polasky, S. 2002. Agricultural sustainability and intensive production practices. *Nature,* 418(6898): 671-677.
Traoré, K. and Stroosnijder, L. 2005. Sorghum Quality, Organic Matter Amendments, and Health: Farmers' Perception in Burkina Faso, West Africa. Ecology of Food and Nutrition, 44(3): 225-245
Trope, Y and Liberman, N. 2010. Construal-Level Theory of Psychological Distance. Psychological Review, 117 (2): 440-463.
Twomlow, S., Mugabe, F. T., Mwale , M., Delve, R., Nanja, D., Carberry,P., Howden, M. 2008. Building adaptive capacity to cope with increasing vulnerability due to climatic change in Africa – A new approach. *Physics and Chemistry of the Earth,* (33): 780-787.
UCT. 2012. UCT research ethics code for research involving human participants. Report. 3 pp.
UNDP. 2015. Republic of Namibia National Planning Commission: Poverty and Deprivation in Namibia. Report. 16 pp.
UNDP. 2017. Namibia: African Economic Outlook, OECD. Report. 14 pp.
UNEP. 2012. United Nations Environment Programme, Planting Pits. Available online: www.unep.or.jp/iets/publications
UNFCCC. 2006. Technologies for adaptation to climate change, Climate Change Secretariat Bonn, Germany. Report, 40 pp
Uno, D. 2005. Farmer's selection of local and improved pearl millet varieties in Ovamboland, Northern Namibia. *African Study Monographs*, (30): 107-117.
Verlinden, A. and Dayot, B., 2005. A comparison between indigenous environmental knowledge and a conventional vegetation analysis in north-central Namibia.

*Journal of Arid Environments, (*62):143–175.

Von Hase, F. 2013. Facilitating Conservation Agriculture in Namibia through Understanding Farmers' Planned Behaviour and Decision Making, MSc thesis. *Swedish University of Agricultural Science.* 62 pp.

WFP. 2017. Namibia | WFP | United Nations World Food Programme - Fighting Hunger Worldwide. Available Online: http://www.wfp.org/node/3530

Wheeler, T. and Von Braun, J .2013. Climate Change Impacts on Global Food Security. *Science*, 341 (6145): 508-513.

WMO. 2017. World Meteorological Organisation, Weather Climate Water. Available online: http://www.wmo.int/pages/prog/wcp/ccl/faqs.php

Yu, B., Zwiers, F. W., Boer, G. J. and Ting, M. F. 2012. Structure and variances of equatorial zonal circulation in a multimodel ensemble, *Springer*, 1-17.

Vancampenhout, K., Nyssen, J., Gebremichael, D., Deckers, J., Poesen, J., Haile, M. and Moeyersons, J. 2006. Stone bunds for soil conservation in the northern Ethiopian highlands: Impacts on soil fertility and crop yield. *Soil and Tillage Research*, 90(1-2):1-15.

Ziervogel, G. and Ericksen, P. 2010. Adapting to climate change to sustain food security, WIRES Climate Change, (1):525–540.

Ziervogel G, Nyong A, Osman-Elasha B, Conde C, Cortés S and Downing, T. 2008. Household food security and climate change: comparisons from Nigeria, Sudan, South Africa and Mexico. In (Eds) Leary N, Conde C, Kulkarni J, Nyong A and Pulhin J. Climate Change and Vulnerability. Earthscan. 173-197.

Zougmore, R., Mando, A., Ringersma, J. and Stroosnijder, L. 2003. Effect of combined water and nutrient management on runoff and sorghum yield in semiarid Burkina Faso. *Soil Use and Management,* 19(3): 257-264.

Zougmore, R., Mando, A., Stroosnijder, L. and Ouodraogo, E. 2004. Economic benefits of combining soil and water conservation measures with nutrient management in semiarid Burkina Faso. *Nutrient Cycling in Agroecosystems,* 70(3):261-269.

Appendix A: Description of climate smart planting techniques

Technique	Description	Relevance to climate change/ benefit to soil and
Planting Pit	Crops are planted in pits dug approximately 30 cm deep by 30 cm wide and 50 cm apart. Once the crops are knee height, the pits are filled with mulch or compost (FAO, 2010).	• Stops surface runoff and conserves water • Prevents soil erosion caused by flash floods • Increases soil moisture • Protect seedlings from the
Bund (Similar to stone rows, ridges and terraces)	Soil or stones are used to create contour bunds along slopes and semi-circular bunds are used on flatter ground levels. Crops are planted upslope of the bunds (SSWM, 2012).	• Slows water flow • Prevents erosion caused by flash floods • Stores nutrients that may be lost through water flow
Compost	All organic waste can be collected in a hole or heap, including crop residue, (ash from wood fires), vegetable peelings, animal manure, and household sweepings. This must be turned every couple of weeks and water added if available. After a few months once it is dark and crumbly the compost can be spread over the fields.	• Improves soil fertility by providing a variety of nutrients and trace elements which enhance the soil stability, infiltration, water holding capacity and resistance to erosion.

Intercropping	The cultivation of two or more crops simultaneously in the same area (Himanen et al., 2016). Eg one row of legumes next to a row of maize.	• Pests and diseases are reduced because there is no single favoured host. • Soil quality is enhanced because crops exchange different nutrients with the soil. • Competition for resources is reduced.
Crop rotation	Changing the crops that are grown in each area every growing season (Tilman et al., 2002).	• Pests and diseases in the soil are reduced because the host plants change. • Nutrients in the soil can be replenished. • Soil erosion is reduced.
Animal manure	Animal manure can be applied to fields directly or mixed with mulch or other organic matter (Bayu et al., 2004).	• Improves soil fertility by providing a variety of nutrients and trace elements which enhance the soil stability, infiltration, water holding capacity and resistance to erosion.
Drip irrigation	Water is gradually delivered to plant roots through tubing (SSWM, 2012).	• Evaporation and runoff is greatly reduced which makes water use more efficient.

Ripper furrowing	The soil surface is broken: ridges and furrows are created. Crops are planted in the furrows and receive runoff water from the ridges, grains and legumes are intercropped and rotated each year (Von Hase, 2013).	• Water is used more efficiently • Diseases and pests are reduced by rotation and intercropping
Mulching	Organic material is spread over topsoil around the base of crops s (Himanen et al., 2016)	• Prevents water loss • Regulates the temperature • Reduce the growth of weeds • Enhances nitrogen in the soil
Contour farming	Farming along contours reduces erosion and gullies from forming and creates a water break.	• Reduces erosion • Enhances water infiltration (was can sink into the soil at a slower rate)
Agroforestry	Trees are intercropped or grown around the edges of crops (Hawken, 2017)	• Prevent erosion • Prevent flooding • Helps to recharge ground water • Creates a windbreak and micro-climate • Sequesters carbon (climate change mitigation)
Minimum tillage	A soil conservation system with minimal soil manipulation, the soil is not turned over like in conventional tilling which changes the soil structure, releases carbon and causes water loss (Hawken, 2017).	• Reduce erosion • Reduces water loss

Grass strips	Grass is planted in strips in or around crops.	• Slows water runoff • Prevents erosion
Green manure	Cover crops and other plants are grown and then ploughed back into the soil.	• Enhances water infiltration • Improves soil quality

Appendix B Consent form for Interviews

Project Title: Identifying Barriers and Enablers to the Adoption of New Practices to Improve Crop Production in the Semi-Arid Omusati region, Namibia

African Climate and Development Initiative

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Invitation to participate, and benefits: You are invited to participate in a research study conducted with crop farmers in the Omusati region. The aim of the study is to identify what may be preventing or what would promote adopting new farming practices.

Procedures: During this study, you will be asked some questions about the farming practices that you use and about your opinion on new farming practices.

Risks: There are no harmful risks related to your participation in this study.

Disclaimer/Withdrawal: Your participation is completely voluntary; you may refuse to participate, and you may withdraw at any time without having to state a reason and without any prejudice or penalty against you. Should you choose to withdraw, the researcher commits not to use any of the information you have provided without your signed consent. Note that the researcher may also withdraw you from the study at any time.

Confidentiality: All information collected in this study will be kept private in that you will not be identified by name or by affiliation to an institution. Please note that this interview will be recorded. Confidentiality and anonymity will be maintained as names will not be mentioned

What signing this form means:

By signing this consent form, you agree to participate in this research study. The aim, procedures to be used, as well as the potential risks and benefits of your participation has been explained verbally to you in detail. You agree to allow the interview/focus group discussion to be recorded using a dictaphone which will later be translated and transcribed. Refusal to participate in or withdrawal from this study at any time will have no effect on you in any way. You are free to contact me, to ask questions or request further information, at any time during this research.

I agree to participate in this research (tick one box) ☐ Yes ☐ No____(Initials)

______________________	______________________	________
Name of Participant	Signature of Participant	Date
______________________	______________________	________
Name of Researcher	Signature of Researcher	Date

Appendix C: Interview Template

Interview Date:

Name:

Age:

Village:

Interviewer:

Translator:

Objective One: To understand the perceptions of crop farmers on vulnerability to Climate change. (what crop production strategies are currently employed? Are farmers planning for change/ what may be preventing them from doing something different?)

1. What crops do you farm? How do you use your land? What farming practices do you use?
2. Do you sell your crops; use them for your family or both?
3. Has the land changed and the amount of yields that you receive from your farm changed in any way in the time that you have been farming here?
4. Can you describe these changes and why you think they have happened?
5. Have you changed the crops that you grow or planting techniques in response to the change in yields?
6. Do you think that the crop yields on your farm will change in the future? Why?
7. Do you plan on continuing to farm the way that you are currently farming?
8. If you continue to farm in the way that you are farming, do you think you will be able to supply food/ income for your family in the future?
    1. Can you explain this?
9. Are you worried about your food supply in the future?
10. Would you be willing to try new farming practices?
    1. If not, why not?

    Would you be willing to grow new crops?

    What is preventing you from using different farming practices?

Objective Three: Assessing barriers and enablers of adopting new farming practices (Are farmers willing? What other barriers and enabling conditions would affect taking up new farming practices)

Have you use used:

Intercropping		
Crop Rotation		
Mulching		
Drip Irrigation		
Diversifying crops		
Ripper-furrowing		

Show pictures and explain each technique:

Planting pit:

1. Have you heard about this farm practice?
2. What do you think about planting pits - do you think it can increase your crop yields?
3. Would you be willing to this farming practice? (If not why not?)
4. What would prevent you from trying this?

Bunds:

5. Have you heard about this farm practice?
6. What do you think about bunds - do you think it can increase your crop yields?
7. Would you be willing to try this farming practice? (If not why not?)
8. What would prevent you from trying this?

Compost:

1. Have you heard about this farm practice?
2. What do you think about compost - do you think it can increase your crop yields?
3. Would you be willing to try this farming practice? (If not why not?)
4. What would prevent you from trying this? Which of these do you prefer and why?

Have you heard about climate change before? From what source?

Any other questions/comments?