Selection and Implementation of Climate Smart Agricultural Technologies: Performance and Willingness for Adoption

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ABSTRACT

The role of subsistence and smallholder agriculture on peoples' livelihoods in the majority of rural African households is directly related to household food security. Subsistence and smallholder farming provides food at household level, it also acts as part of an income generating mix of strategies enabling households to purchase and exchange products at cheaper prices compared to formal markets prices. However, their vulnerability to climate related issues place a large burden upon their production, creating food shortfalls and insecurity for households. Integration of Climate Smart Agricultural Technologies (CSATs) with local indigenous knowledge may be critical towards improving rural farmers' food production for food and nutrition security. A mixed method approach was employed in conducting the study. In this method qualitative, quantitative and field trial research methods were employed. The study selected and implemented four appropriate CSATs namely, In-field Rainwater Harvesting (IRWH), Mechanized Basin (MB), Minimum Tillage (MT) an Conventional Tillage (CT) in two homestead plots (MaNxusa and Musa) and one school garden (Inyaninga Primary School) in KwaSwayimane, KwaZulu-Natal. These technologies were selected based on biophysical properties, climatic conditions and institutional arrangements that exist in selected study area. Maize crop was considered as a test crop across the treatments in two sites, plot one and plot two (MaNxusa and Musa) respectively, while beans, spinach and cabbage were planted in plot three for dietary requirements at start up level of the food value chain. The results in plot one showed that IRWH and MB outperformed MT and CT. These results revealed that IRWH and MB collected and stored more water in the soil to support plant growth and production since it captures water from runoff area and stores it in the basins, which was not the case for CT and MT. Similar trends were observed in plot 2 except that CT performed better which can be associated with farmer's management practice. The farmer in this site only treated CT with N-fertilizer while others did not receive the same treatment. The farmers' perceptions based on the results and information sharing days conducted during the course of the study considered IRWH as the best CSAT. The expressions to upscale the use of this technology by farmers were widely expressed due to better yield from demonstration sites which could improve household food security and sustainable livelihood. The study further found that farmers needed incentives in order to adopt certain technologies and partner with research process. The study concludes that IRWH is a good CSAT and that strong participatory engagement with farmers and stakeholders to foster adoption is important. The study

recommends strong farmer centered partnerships supported by other stakeholders including government and NGOs and market related stakeholders.

DECLARATION 1

I, Ntokozo Lucas Mazibuko, declare that:

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ii. This thesis has not been submitted for any degree or examination at any other university.

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As research supervisor, I agree to submission of this dissertation for examination:

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Dr. Joyce Chitja

DECLARATION 2: DRAFT MANUSCRIPT

Details of contribution to draft publication manuscript that form part and/or includes research presented in this dissertation.

Publication manuscript 1: (Journal being identified)

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Dr. Joyce Chitja

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BRU: BIO-RESOURCE UNIT

CSA: CLIMATE SMART AGRICULTURE

CSATs: CLIMATE SMART AGRICULTURAL TECHNOLOGIES

CT: CONVENTIONAL TILLAGE

FDGs: FOCUS GROUP DISCUSSIONS

IKS: INDIGENOUS KNOWLEDGE SYSTEM

IRWH: INFIELD RAINWATER HARVESTING

MB: MECHANISED BASINS

MDG: MILLENNIUM DEVELOPMENT GOALS

MT: MINIMUM TILLAGE

SDG: SUSTAINABLE DEVELOPMENT GOALS

SPSS: STATISTICAL PACKAGE FOR SOCIAL SCIENCES

CHAPTER 1: THE PROBLEM AND SETTING

1.1 Background Introduction

Climate change is defined as fluctuations in regional and global climatic patterns (Lineman, Do, Kim, & Joo, 2015), brought about largely by human actions and is one of the most critical environmental issues (Rahman, 2013). Climate change varies with regards to geographic area and region. It results in serious threats to vulnerable and underprivileged people worldwide (Neely, Bunning, & Wilkes, 2009). These geographic variations include topography, elevation or altitude and impacts climatic conditions including temperature, precipitation, moisture content, and many other climatic characteristics. Impact on those variables significantly affects crop yields, affecting food production for food and nutrition security in multiple parts of the world (Zhang, Zhang, & Chen, 2017). Consequently, this may result in varying water availability and soil suitability globally, allowing for different irrigation and soil management systems that can be suitable. Not only does climatic conditions guide available water and soil arability, but it also impacts on farmer's choice of plants to match hiking input demands to meet their food and nutrition security. This has resulted in farmers worldwide choosing crop choice driven by resource constraints and trade-offs across crop activities (Wineman & Crawford, 2017).

Water is one resource that plants and animals require on a daily basis. The threats brought upon by climate change has subjected it to numerous and competing demands between environmental uses, agriculture and human livelihoods (Hanak & Stryjewski, 2012). Due to water's vital nature to life, it is speculated that many countries including India and China are likely to experience conflicts and wars over it (Pak, 2016). These conditions are further strained when population pressure grows demand for an already depleted resource (Caretta, 2015). Considering water's scarcity, management and sustainability are critical issues that the whole world need to adopt towards preservation for a longer period. Water sustainability refers to the continuous supply of clean water for human uses and for other living organisms (Schnoor, 2010). Due to water being essential for living, water has found its way into the sustainable development goals which is goal number six. Such significance has brought major attention to develop strategies for mitigation and adaption worldwide. South Africa has recommended the National Climate Change Response Policy as a framework for an effective climate change response, and long-term mitigation strategy for a climate-resilient economy and society. Such development in SA are prioritizing fair and optimal use of resources for both development and transformational purposes, ensuring a careful balance between human needs and the needs of nature is maintained to ensure the availability and sustainability for the future. One way to achieve such balances includes implementation of climate smart water management strategies aiming at improving water use efficiency without decreasing yield (Abunnour, Hashim, & Jaafar, 2016). It is, therefore, critical that existing technologies and research on Climate Smart Agricultural Technologies (CSATs) that are water efficient get explored and practically implemented. CSATs are essential agricultural adaptation practices or methods of adapting to climate change, through provision and facilitation of information and knowledge flow.

With regards to the importance and scarcity of water, it is critical that techniques and technologies selected for water-use practices are climate smart and efficient. Given the rising temperatures and variation in rainfall patterns over climate change, there are higher possibilities to have serious consequences on water resources availability, which can immensely disturb agricultural practices (Sikka, Islam, & Rao, 2017). This includes both commercial and small scale agriculture. Consequently, this indicates that it is additionally significant for the development of farming adaptation strategies and policies guiding water resources planning and management (Dey & Mishra, 2017). This substantial challenge has called for development and implementation of CSATs including infield rainwater harvesting (IRWH) to prevent runoff water lost during rainfall while creating water banks that keeps the soil moist for longer periods after rainfall. This system seems to be modern and significant as it gives farmers information like soil moisture and plant water requirement with regards to their field (Markham, 2013). Implementation of such technologies which can be affordable for both commercial and struggling subsistence farmers can be vital in adapting to climate change challenges and improving food production for food security. This indicates that advanced irrigation practices can improve water efficiency, gaining an economic advantage while also reducing environmental burdens (Levidow et al., 2014).

Not only does changing in climatic conditions affect water, but also multiple threats over soil resources are some of the threats suffered worldwide. Soils are primarily the functions of all terrestrial ecosystems, food and fibre production (Paustian et al., 2016). Significant and proper management are amongst the most needed mechanisms to maintain and sustains its ability to continue supporting ecosystems processes and human life. Changes in rainfall along with projected changes in temperature, solar radiation, and atmospheric carbon dioxide concentrations, will have massive impacts on soil erosion rates (Nearing, Pruski, & O'neal, 2004). Agriculturally, this erosion and loss of the topsoil removes essential nutrients that are required to support plant growth, resulting in food and nutrition insecurities around other parts of the world. Failure to produces adequate and enough food exacerbates poverty, hunger and malnutrition in other parts of the world and even results in conflicts eruption where people fights for access over the limited availability of food.

Poverty has been at the top of the world devastating challenges over the past decades. Within the previous Millennium Development Goals (MDGs), it was in the top five to be achieved. It is also amongst the top five of the Sustainable Development Goals (SDGs). This raises the need and concerns to improve and innovates CSATs while on the other hand conserving and managing the same resources that the world provides. Improved irrigation scheduling and crop specific irrigation management are some of the strategies that can be followed, specifically by commercial farmers to preserve natural resources while achieving maximum food production (Abunnour *et al*., 2016). Food production in the form of small scale farming and household gardens are important in determining the state of the household food and nutrition security. Millions of smallholder agriculturalists in sub-Saharan Africa and South Asia benefit from affordable climate smart irrigation techniques, which also extensively boost smallholder incomes and food security (Giordano & de Fraiture, 2014).

Smallholder farmers have been managing risk through their farming operations. They possess technologies and strategies albeit poorly documented. Their indigenous knowledge and localized knowledge in climate smart technologies is important to investigate and discuss in order to improve and explore synergies of adoption of new technologies. Finding these synergies is essential to enhance the capacity of farmers to adopt such technologies and crop management techniques and to achieve higher rates of return on land (Rosegrant & Cline, 2003). Many rural households in the developing world rely on agriculture to a significant level, from ensuring food security to creating employment opportunities for most rural dwellers (Von Loeper, Musango, Brent, & Drimie, 2016). Household food and nutrition security incorporate many aspects of living. For a rural farming household to be secured, water and soil resources are amongst key required inputs. With the longing and continuing changes in climate, household food insecurity is likely to be more prevalent in most rural small-holder and subsistence farm households in sub-Saharan Africa (Tibesigwa

& Visser, 2016). Firstly, this will call for rural households to shift and adapt the expense of other households' investment in other aspects of human welfare, strengthening poverty traps (Eakin et al., 2016). Rural households will have to rely on low water qualities to meet their daily water needs. Not only will this impact their livelihoods, but also poor water quality is the major limitation that restrains the sustainable development of agriculture worldwide (Yang *et al.*, 2017). Crops attain some nutrients from water used for irrigation. From poor or no irrigation water, the transition of nutrients from crops to human will suffer, resulting in human malnutrition disease and death. Poor quality irrigation water for crop production can also cause detrimental impacts to the environment (Singh, 2015).

Climate smart agricultural technologies are amongst the key solutions towards minimizing challenges brought upon by climate changes and uplifting farmer's continuous food production for food and nutrition security. The main focus of these technologies includes a continuous increment of farm productivity, improved resilience and farmer's adaptation to climate change and variability. This may indirectly enable farmers to market their production, creating income for farmers to access other human needs for sustainable livelihoods. These technologies are critical in reducing the drivers of climate change (Sikka *et al.*, 2017). South African (SA) climatic conditions differ from one region to another. Based on rainfall distributions and variabilities, SA climate can be distinguished into three climate zones being eastern, central and western as well as the cape fold mountains (Tadross & Johnston, 2012). Such instances articulate the need for SA rural smallholder farmers to adopt different CSATs. Since different amounts of rainfall are received for different regions, farmers cope with climate change challenges differently. Some adaptation strategies are indigenous knowledge modified with modern technologies and such were findings from the study conducted by (Ncube & Lagardien, 2015). Water harvesting, animal manure and mulching are amongst adaptive technologies that rural farmers have adopted to manage a continuous crop production. Rodda, Carden, and Armitage (2010) emphasizes that promotion and decentralization of adaptation technologies such as greywater for irrigation in gardens and small-scale agriculture has the potential to improve food security in low income settlements. Such findings signify the essence of synergies between indigenous knowledge, CSATs and modern technologies towards advancing rural farmer's production skills and resilience to climate change. Incorporation of these technologies with farmers long earned agricultural knowledge can contributes significantly in improving food production. It is therefore critical that CSATs are innovated, implemented and their adoption be supported. In this study, the willingness and readiness of farmers to adopt selected CSATs is assessed among smallholder farmers in KwaZulu-Natal, Swayimane. Research questionnaire and Farmers' day presentation were key elements and processes used to assess and measure farmers' willingness and readiness towards adopting CSATs.

1.2 Importance of the study

Rural households' agricultural fields and gardens plays a crucial role in improving household food and nutrition security while also alleviating poverty. Food production at various scales including at the home gardens are a part of the agriculture and food production systems in many developing countries, widely used as a remedy to alleviate hunger and malnutrition in the face of a global food crisis (Galhena, Freed, & Maredia, 2013). Not only do rural farming household fields ensure food and nutrition security at household level, but also rural people usually share and sells surplus produces to the community, creating some little income to cover for other household needs. In other words, smallholder agriculture can be an essential method for low income rural households allowing them to make an additional income (Lupia & Pulighe, 2015). It is clear that with articulate CSATs and innovated local knowledge enhanced with nowadays technology, under current climatic conditions, households can be able to meet their food and nutrition security requirements. This can also be crucial in brightening the need from subsistence farmers to sustain natural resources and biodiversity for future uses. CSATs furthermore contributes to livelihood development through its direct and indirect benefits. Some of these direct benefits brought upon include high productivity, all year round farming and lower risk of crop failure (Beyan, Jema, & Adem, 2014).

Due to water scarcity and related problems over climate change, the ability of household gardens to sustain and produce continuously is significantly impaired, worsening food and nutrition insecurity of rural households. This has indicated a need for proper and efficient CSATs for small-scale farmers and gardeners at the beginning of the food value chain. For gardeners, land sizes are not of larger scales and therefore it requires schemes and techniques that are well efficient and climate suitable for the crops they produce. Suitability of an agricultural technique depends on a majority of factors including the climatic condition of an area and crop type to be planted in order to make difference in household food security (Brandt *et al.*, 2017). As different crops including maize, beans and vegetables are cultivated on household gardens, different management and climate smart agricultural techniques are applied depending on the water requirements and soil structural build ups of every single crop (Caretta, 2015). With proper and efficient climate smart agricultural techniques, multiple advantages and improvements can be achieved from household gardens. However, it is crucial that before a technique is selected, a proper analysis is done to eliminate chances of failure whilst improving productivity and enhancing food and nutrition security of the household.

Climate change has also resulted in soil issues ranging from structural disturbance, erosion and other challenges that subsistence farmers and gardeners have to deal with on their daily basis. Higher temperatures result into frequent soil moisture loss. According to Holsten, Vetter, Vohland, and Krysanova (2009) "Global warming impacts the water cycle not only by changing regional precipitation levels and temporal variability but also by affecting water flows and soil moisture dynamics". Dealing with water loss from the soil through evaporation is one of the challenges that farmers deal with using their indigenous skills and knowledge. Integrating those critics and skills with modern climate smart techniques and methods from other parts can be essential in improving food and nutrition security at household.

The combination of local climate farming adaptations and knowledge systems, climate smart and efficient agricultural techniques can result in a broader adaptation of farmers to climate change impacts. Integration of literature regarding soil management strategies can be crucial in improving the sustainability of soil resources, enabling farmers to continue food production for household security. The main importance of this study is to equip farmers with knowledge and variety of different CSATs that can be useful for their agricultural practices. By so doing, the success of CSATs can be critical towards enhancing a continuous food production for small scale and subsistence farmers improving household food security. It is believed that using sustainable soil and water management strategies with CSATs can bilateral benefits the farmers as it through improving resource management, while also enabling them to improve production, crop variety and resistance towards different climatic conditions.

Smallholder farming and household gardens has been amongst the oldest and most enduring practices of agriculture and such practices have been recognized as an imperative supplemental foundation contributing to food and nutritional security and livelihoods

(Galhena *et al.*, 2013). Economy segregation in SA is one crucial challenge faced by the country nowadays. There is a significant difference between higher and lower income classes. Given climate variations of the country, food insecurity cases are prone to increase for rural agricultural dependant dwellers, making this study essential towards enhancing and equipping rural farmer's resilience to climate change issues. Testing and adoption of CSATs by smallholder and gardeners farmers in SA rural households may bring significant improvement upon food production, conquering issues of food and nutrition insecurities.

1.3 Research Problem

Food availability is of the key pillars of food security and relies mostly on soil and water generosity. However, due to low and unreliable rainfall, smallholder farmers in many parts of South Africa are struggling to obtain maximum crop yields. This may result in the majority of households disregarding their agricultural activities due to water shortages. Research on CSATs to improve water management exists. However, not much has been published about the adoption of the appropriateness, implementation and uptake of these technologies among smallholder and subsistence farmers. In addition, the identification of such technologies that can be integrated with local indigenous knowledge is thin. This research study aims to assess the implementation of selected CSATs for small scale and subsistence farmers, monitor and compare plant growth under those implemented technologies. The farmer's willingness and readiness to adopt and implement technologies of their choice is further attended to.

1.4 Research Question

How can the Climate Smart Agricultural Technologies be adopted and improve food production and household food security for rural smallholder farmers?

1.5 Research Objectives

The main objective of this research is to select and implement selected climate smart agricultural technologies for small scale and subsistence farmers and monitor crops performance under different technologies. The second objective of this study is to assess willingness and readiness of farmers to adopt and implement technologies at their individual farmlands after observation from demonstration and farmers' day presentations.

1.6 Hypothesis

Adoption of Climate Smart Agricultural Technologies is related to the willingness and readiness of farmers in order to improve food production and household food security for rural smallholder farmers.

1.7 Limitations to the study

Some rural people assume a change is natural and they are likely to explain change as their luck regardless of whether the implementation quickened the rate of improvement or not. The research is focusing on exploring the impact of selected CSATs on production, but measuring the exact yield obtained under each technology may be challenging since cobs are the marketable product of farmers need to be sold. Commitment and stronger incentives for farmers to partner with the project may be costly and weaken day to day management of the field experiments.

1.8 Research Design and Methodology

A mixed research methodology will be guiding the project to gather different kinds of data to comprehensively answer the research question and objectives. A mixed method research is defined as an approach which includes both qualitative and quantitative data will be used to collect data (Terrell, 2012). Mixed method approach technique will be used in finding answers and understanding subsistence farmer's perceptions, perspectives and understanding of soil and water management practices and its significance towards sustainable household food and nutrition security. Readiness and willingness are some of the concepts that will be measured both qualitatively and quantitatively. This is a technique that combines the qualitative and quantitative approaches within different phases of the research process (Terrell, 2012). It involves scientific assumptions that guide the direction of the collection and analysis of data and the mixture of qualitative and quantitative data in a single study or series of studies (Cameron, 2011). During this study, subsistence farmers were sampled purposively to include farmers who have a long-standing farming experience, show an interest in to smart technologies and are willing to engage.

Focus Group Discussions (FDGs) technique was used to gain more insight in the willingness and readiness of farmers. FDG is an established research method used to gain an in-depth understanding of a phenomenon, and it aims to obtain data from a purposively selected group of individuals (O Nyumba, Wilson, Derrick, & Mukherjee, 2018). The FGDs was further used to explore farmer’s local knowledge on CSATs. This is a method where by people are gathered into groups, creating environmental conditions to be more conducive for more spontaneous expression of each one, and facilitating the interaction of everybody (Freitas et al, 1998). One of the main benefits of using FGDs is that the participants can become a forum of change through sharing of information and knowledge regarding soil and water management ideas from farmers which can be integrated with CSATs for the purpose of the project (Gibbs, 1997).

Field demonstrations of selected CSATs were be used. Field demonstrations are common research tool in agricultural field research and plays key responsibilities towards transitioning theory into practice and knowledge exchange (Wamae *et al.*, 2011). Furthermore, in participatory research and translational research, demonstrations are important to ensure farmers buy in and adopt CSATs as tools and implement upon their individuals’ fields.

1.9 Assumptions

Engagement of community through selected lead farmers, the research team and other formal stakeholders entered to, with regards to partnering with farmers will yield adequate commitment from lead farmers to co-manage the implementation sites.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Climate and environmental change processes alters biophysical support systems for human and animal life including terrestrial surface, water and soil resources (Iheke & Agodike, 2016). As a result, it is critical for invention and innovation of Climate Smart Agricultural Technologies (CSATs) to sustain the available natural resources without jeopardizing their existence for future generations to use. This indicates a need for transformation and exchange of agricultural knowledge and goals aimed at advancing food production for achieving food security, while also responding to climate change without the exhaustion of natural resources (Williams *et al.*, 2015). Climate smart agricultural production refers to an integration of different agricultural production knowledge and skills, whether it is indigenous or modern knowledge, to conquer the issues of climate change over production resources to meet food and nutrition security. The term climate smart agriculture is defined by Murray, Gebremedhin, Brychkova, and Spillane (2016) as "agriculture that sustainably increases productivity, enhances resilience (adaptation), reduces/removes greenhouse gases (mitigation), and enhances achievement of national food security and development goals". Subsequently, these technologies also need to integrate existing farmer's knowledge and experience which may enhance adoption and acceptability by rural farmers. This definition articulates that CSATs needs to be adoptable by rural farmers and also improves food production for food and nutrition security.

Natural resource availability determines food and nutrition security for smallholder farmers in many parts of the world that are agriculturally dependants, explicitly at a household level. Over the past decades, due to natural and human induced activities, climate change and variation has been one of the crucial outcomes that the planet is experiencing, which indirectly affects agricultural production and food security worldwide. Wheeler and Von Braun (2013) expands that it is extremely challenging to monitor accurately the current status of universal food security, however, it is possible that climate variability and change may aggravate food insecurity in areas presently vulnerable to hunger and malnutrition. As a result of this activities, there has been major alterations to hydrological cycle processes, causing change in spatial distribution of water availability (Dey & Mishra, 2017).

Consequently, soil structural disturbance has also been experienced in some parts of the world, disabling the maximum potential capacity of food production. Climate change effects create massive impacts over agriculture, resulting into production short falls, creating hunger and poverty over the world. The majority of crops (including staple crops like maize wheat and cassava) are under massive threats of harmful effects with an average yield reduction in the range of 11%–33% by 2050 (Awoye, Pollinger, Agbossou, & Paeth, 2017). Such challenges could interrupt progresses aimed at improving food production for food and nutrition security as well as achieving a world without hunger.

Food production for food security in Africa suffers greater impact over climate change. Results from a study by (Müller, Cramer, Hare, & Lotze-Campen, 2011) concluded that agriculture everywhere in Africa is at higher risk of being negatively affected by climate change and present farming systems and arrangement will have to be restructured and changed to adapt and meet future food demands. Another study by (Müller *et al.*, 2011) also found that unless effective adaptation measures and technologies are put in place, African crop production may obtain reduced productivity and suitability of stable crops such as maize and beans. As a result, regional and local rural farmers' food production may suffer greatly, worsening issues of food insecurity and malnutrition. Such challenges signify the need to enhance rural smallholder farmers' current knowledge through implementation of CSATs to enable better adaptation over climate change and improves food production for food and nutrition security. It is essential to consider farmer's input and current knowledge to advance and stimulates better adoption and acceptance of CSATs by farmers.

Water is one input natural resource that support and advocates for human life and survival on earth, but it is unevenly distributed. Surveys and research estimated that globally, plus or minus 1.1 billion people in the world lack access to improved water supplies and 2.6 billion people lack adequate sanitation (Moe & Rheingans, 2006). Amongst other goals that MDGs set to achieve by 2015 was reducing by half the proportion of people without sustainable access to safe drinking water and basic sanitation. Successfully, the MDGs goals achieved great outcomes in improving the access to safe and adequate drinking water for people. UNICEF and World Health Organization (WHO) report states that 2.6 billion people have gained access to an improved drinking water sources since 1990 which shows an improvement on global perspective (Organization & UNICEF., 2013). However, access to safe drinking water does not guarantees food production for rural smallholder farmers. One key aspects that needs to be incorporated with water is management and sustainability. Decentralization and adoption of water management skills and knowledge to farmers may be crucial towards improving their food production knowledge for household food and nutrition security. Therefore, sharing articulate CSATs concerned specifically to managing water resources may significantly help improves smallholder farmers' food production.

Without arable soils around the world, food production may suffer huge declines, exacerbating the deaths due to poverty, malnutrition and food insecurity. Climate change impacts over soil resources are major challenges that requires attention in trying to meet population's food and nutrition requirement worldwide. Literature indicates that there are concerns that the natural functions of soils are gradually threatened by alterations in the environmental context. These threats include decline in soil organic matter, erosion, soil sealing and plenty of other climate and human induced activity upon the resource (Blum, 2013). In trying to maintain food security for the growing population, a move from indigenous knowledge systems to artificial production has been practiced especially by commercial farmers. While it has shown greater effects on food production for a short term period, it has on the other side increased soil related issues that climate change is also exacerbating. Rural farmers and communities have been practicing soil and water management conservation techniques that are indigenous. According to Mulat (2013) "Indigenous knowledge in soil conservation practices is common in many indigenous peoples of the world, and it is common to see different forms of soil conservation practices across the various indigenous societies and peoples of Africa". This is evidently supported by the study by Engdawork and Bork (2014), which indicated a failure of artificial soil management system while there was a success of indigenous practices. Nonetheless, managing soil systems is the primary inputs to achieving food security and therefore innovation of current practices are key to minimising disturbances caused over soil resources.

Incorporation of local indigenous knowledge practices and enhanced CSATs adaptation may significantly improves food production for rural households. Undisputedly, rural farmers already use a vast array of climate change adaptation strategies which have been acquired from generation to generation. Such indigenous knowledge and techniques have been moulded and improved to survive nowadays soil and water stresses that climate change brings up. This knowledge and practices are key in natural resources management, while also are crucial in ensuring food and nutrition security. These practices are often characterized as livelihood strategies that have been advanced to decrease overall vulnerability to climate shocks and to manage their impacts (Morton, 2007). Agriculture is accountable for a huge percentage of employment more especially under developing countries (Von Loeper *et al.*, 2016), unless proper CSATs are implemented to smallholder farmers to improves their coping strategies, the world is vulnerable to food insecurity, conflicts and malnutrition. Hence it is essential for exploration of combining indigenous knowledge with modern CSATs which may greatly improves food production for food security at rural household levels.

2.2 Importance of Farming at Household Level

Farming has been the main food source worldwide for multiple decades. This includes taming and domestication of animals which has been occurring amongst hunter-gatherer populations some ten thousand years ago including during the ice age (Zvelebil & Pluciennik, 2011b). The definition of farming primarily includes cultivation of crops and animals alongside other aspects, all aimed at food provision for food and nutrition security. Nonetheless, it is a broader term including input suppliers to wholesalers and retailers and non-traditional agricultural sectors such as horse tracks, lawn and garden supplies (Hornbrook & Hoag, 1997). Such definitions clarify that the idea behind farming from centuries was to conquer hunger and poverty issues, resulting in food and nutrition security.

Climate change and rapid population increases around the globe are challenging farming and has resulted in massive necessity for improved farming techniques and ideas to meet food demands for global food security (Shivakoti, Pradhan, & Helmi, 2016). According to Ward and Pulido-Velazquez (2008) “Climate change, water supply limits, and continued population growth have intensified the search for measures to conserve water in irrigated agriculture, the world's largest water user”. Food demands have increased exponentially, calling for adoption of crop production techniques that are efficient, smart and environmentally friendly. In the face of changing and increasing non-food demand for agricultural production, declining growth in agricultural productivity due to uncertainties from changing weather patterns, feeding the world's population (9 billion by 2050) can be challenging without the use of innovative ideas and CSATs (Regmi & Meade, 2013).

Rural households in many African and Asian countries practice farming as their main strategy of meeting their household dietary food and nutrition security. Due to climate change, farmers face significant challenges that includes changes in the normal temperatures and the rainfall regime to an increased inconsistency of weather conditions and the frequency of extreme events (Sautier, Piquet, Duru, & Martin-Clouaire, 2017). Such changes results in destructive alteration of agricultural landscapes and majority of rural communities whom relies mainly on rain fed smallholder agriculture for their livelihood suffers tremendously (Nyasimi *et al.*, 2017). This climate change affects farming profitability as well as the potential of farming systems adaptations to suit the new climatic conditions (Thamo et al., 2017). Agriculture is the main food source especially in the African rural residences, climate change is a great challenge to food security at national and household levels. As a result, climate change on agriculture will lead to profitability loss, affecting job creation and food access for rural people. This also calls for collaboration on knowledge dissemination and implementation thereof to farmers on the mitigation of climate change.

Rural subsistence farmers understand food demand at household and threats that climate change brings upon their food production for household food and nutrition requirements. From the experience acquired through their forefathers, farmers possess indigenous and local knowledge that is critical for risk mitigation in order to continue producing adequate food for nutrition and security fulfilment. This is furthermore explained by (Lejju, Tolo, & Majule, 2014) that over the years, indigenous knowledge systems (IKS) have proven effective in promoting sustainable development particularly for those in subsistence agriculture. This indicates the commitment of subsistence farmers in ensuring that food demand at household level is met all the times. It is, therefore plausible that adoption of CSATs by rural farmers and integration with IKS and local knowledge may positively improve food production, creating adaptive skills towards climate change.

2.3 Water Access for Farmers in South Africa

Water access does not only guarantee human survival, but it also has a profound social and economic impact towards human life (Fogden & Wood, 2009). Water availability and access determines quality of human life, development of country and its success towards battling issues related to hunger, poverty and malnutrition. Access to water guarantees maximum food and industrial production, creating employment for skilled and unskilled labours. This may be vital in enabling people to conquer food insecurity challenges. Uneven distribution of such a precious resource in South Africa (SA) and exacerbated climate issues globally disabled maximum food production, resulting into many reports of poor production. Through proper and efficient use of water resources, farmers and industrial production can be improved, minimising cases and deaths due to malnutrition and food insecurity issues.

Prior to democratic freedom, South African water distribution and access were limited towards commercial farming, resulting into majority of small scale farmers being left out. During apartheid era, smallholder irrigation schemes were of secondary importance in SA in terms of land area and farmer participation (Van Averbeke, Denison, & Mnkeni, 2011). However, since 1994, the SA government has undertaken substantial reforms directed towards addressing rural poverty and inequities inherited from the historical apartheid regime. Amongst these programmes, water user's registration and licencing are top priorities that the government engage to improve equal water access for small-scale and commercial farmers (Perret, 2002). The outcomes from this registration still favours those already had access to water before, placing at vulnerable small scale farmers whom did not have an opportunity previously. Results from van Koppen and Schreiner (2014) study founded that only 35% of water licences issued between 1998 and 2012 were given to first time farmers who were historically disadvantaged before, while the other 75% were farmers who already had access before.

Water licences and registrations requires for users to pay subsidies in which affordability issues arise for smallholder farmers. Findings from the study by Njoko and Mudhara (2017), shows that subsidies paid to farmers will progressively decrease as they will increasingly have to pay for their water use. With these findings, smallholder farmers are more likely to quit farming as affording to pay for irrigation water might be challenging. On the other hand smallholder farmers in mitigating with water shortages and higher prices are likely participates in unlawfully and in appropriate actions towards accessing piped water for irrigation purposes to produce food and generate some income to meet household food security. van der Horst and Hebinck (2017) referred to this actions as irrigation by night, as small scale farmers will be irrigating unlawfully.

Climate Smart Agricultural Technologies (CSATs) are presumed to have massive impacts towards improving food production of rural subsistence farmers. Adoption of CSATs by rural farmers is expected to improve water use efficiency more importantly for agricultural purposes. CSATs is aimed at using as minimum as possible inputs to obtain as maximum as possible yields. This includes minimising water loss through runoff and evaporation, creating storages within the field and covering soil surfaces from direct sunlight.

2.4 Water use for Household Food and Nutrition Security

Water is the most significant element among the natural resources, and is essential for the survival of all living organisms including human, food production, and economic development (Halder & Islam, 2015). Water is the core requirements for food and nutrition security and a primary need for all living organisms. Due to threats posed by climate change, this precious resource has been noted to be a cause of multiple deaths globally, through famine and conflicts in many parts of the world. Climate change results in water related threats to food production including draught and floods in different parts of the world, affecting food and nutrition security.

These threats have prompted the need for ideas promoting food production through CSATs as one of the significant development that the whole globe has called for its implementation. Such ideas revolve around water and soil resources as they are the main inputs in food production for food and nutrition security globally. About seventy percent of global fresh water is used for irrigation purposes, while entire agricultural use represents about ninety two percent of total uses of stream water and rainwater (Appelgren, 2004). Given the large water input quantities by agriculture, the effect of draught imposed by climate change in agriculture is alarming. It is therefore essential that climate smart agriculture interventions adequate food production be urgently embarked on. Such interventions are critical for the quantity and quality of food to ensure availability, access, utilisation and stability of the food supply.

Sufficient water management inventions and innovations has been implemented with regards to commercial agriculture and its irrigation systems at a global level to minimize issues of global food and nutrition insecurities. However, smallholder agriculture lags behind, posing a great risk to food supply, particularly in Africa. According to o(Woyessa, Pretorius, Hensley, van Rensburg, & Van) “In South Africa, irrigated cultivation takes place on 1.3 million hectares of land (almost 10% of the total cultivated area) and uses an estimated 12.3 billion cubic meters of surface and groundwater per year, which is about 56%

of the country's total annual water use." Subsistence and small scale farmers are hardly irrigating their land, which makes their production vulnerable to climate change more especially in the western part of the country. However, implementation of massive irrigation systems for smallholder farmers is a near impossible task and therefore to improve their food production requires small scale CSATs.

Undisputedly, subsistence farmers manage to produce a little for household consumption. The issue of climate change causes massive challenges to subsistence farmers, disabling their optimal production ability. This is further explained by the findings from (Khapayi & Celliers, 2016) that there is no strong support system available to support previously disadvantaged farmers including subsistence farmers in South African context. Climate smart agricultural techniques has only been stressed for commercial farmers, leaving struggling subsistence farmers vulnerable to crop failure as result of draught. Efficient and smart water use for subsistence farmers may have an influence on achieving household food and nutrition security. Such technologies may enable farmers to grow crops where the climate is too dry and enables them to increase crop products where plant available soil water is a yield restraining factor, while also enabling farmers to grow plants annually (Van Averbeke *et al.*, 2011).

2.5 Available Water Sources Among Smallholder Farmers

Water access and harvesting practices are key elements towards achieving food and nutrition security globally. It is evidence that water is one of the essential resources in food production, making it a critical factor in food security (Wenhold *et al.*, 2007). In Sub-Saharan Africa, there is evidence that families with adequate access to water for small-scale irrigation are considerably less poor compared to households that do not have access to irrigation (Ducrot, 2016). It is however, unfortunate that majority of interventions and innovations are mainly considering commercial agriculture excluding struggling subsistence farmers. A study by (Bjornlund, Van Rooyen, & Stirzaker, 2017) advised that for new agricultural investment in irrigation to success without repeating past failures, it is critical to develop a business model for small-scale irrigation schemes. Such developments may significantly encourages production from smallholder farmers, while also equipping their water management skills and knowledge. High irrigation costs are increasingly discounting the poor, who are struggling to generate cash income from other sources to enable their ability to fund irrigation. This exacerbates food and nutrition challenges faced by the poor, increasing probability of death rates due to malnutrition and poverty.

Small scale farmers in the area engage different CSATs and indigenous knowledge towards collecting water for irrigation uses upon their household's garden plots. From observation and consultation made with farmers before implementation, different water sources were observed within the area. The list of accessible water sources by farmers included primarily rainfall, rivers/streams, communal taps and wells. Given the fact of different rainfall amounts, some water sources are seasonal making it challenging for rural farmers to produce annually. Although multiple water sources are available within the area, reliability is one of the most challenging issue faced by rural households towards accessing water. Table 1 below indicates the percentages of access and usage of different water sources mentioned by farmers. However limitations from affording adequate tools and resources were some of the top mentioned challenges that hinder some farmers from irrigating their gardens. This is also elaborated by Von Loeper *et al.* (2016) study outcomes which indicated that small scale farmers are vulnerable to poor infrastructure, inputs and markets which inhibits their potential to producing adequate food.

Table 1: Sources of water available in KwaSwayimane, usages and perception of quality by farmers

Water Source (%)	**Availability (%)**	**Usage (%)**	**Perceptions of quality (%)**
Tap inside house	95	84	84
Rainfall	79	79	16
River/stream	74	68	5
Communal tap	11	11	5
Water truck	53	53	26
Borehole	-	-	-
Well	5	5	-
Other	16	16	-

Source: WRC Project K5 NUMBER: K5/ 2555/4 (2016-2019).

2.6 Local Farming Methods Currently used by Smallholder Farmers

Access to water resources and arable soils for rural subsistence farmers plays crucial role in uplifting poverty challenges at household level. However unequitable distribution of land and access to adequate amounts of water for rural farmers inhibits their potential of participating profitable and sustainable in agriculture. (Muraoka, Jin, & Jayne, 2018) also elaborates from their study findings that land shortages is gradually becoming a problem inhibiting rural household prosperity in densely populated areas of Africa. They further emphasizes that commuters often end up renting land for cultivation to maximise food production for food security. Given such instances, proper decision making are required when it comes to water and soil resource planning and management in the 21st century as this has become increasingly challenging task due to conflicting burdens from various demand groups (Raneesh, 2014).

Combining different CSATs and local existing knowledge are some of the strategies that small scale farmers need to successfully address food insecurity and malnutrition challenges. Food insecurity is a serious threat accompanied by climate change worldwide. This is due to the fact that climate change will and has shown impact on crop production, livestock and fisheries production, and will change the occurrence of crop pests which many of these are experienced already (Campbell *et al.*, 2016). Soil arability and productivity are amongst challenges that are brought up by climate change including water scarcity and drought. Limited adaptive capacity results in farmers being vulnerable to climate-induced hazards which impacts food security at all levels (Lejju *et al.*, 2014). Through soil and water disturbances, meeting food and nutrition of the global population is threatened.

Dating centuries back, subsistence farmers using their climate smart local and indigenous knowledge systems managed to keep their production continuous and were food secured. Not only did they meet their food and nutrition security, but their production seemed to be of environmental sustainable and natural resources friendly. Indigenous knowledge is environmentally friendly and harmless both to man and his land. Estimates indicates that 60-70% of food grain grown in most countries is stored at household level under indigenous constructed structures ranging from bamboo baskets to mud structure, gunny bags and modern bins (Kumar, Patel, & Mishra). Results from a study by Ncube and Lagardien (2015) concluded that there is a gap in understanding and recognizing the significance of indigenous knowledge in decreasing susceptibility of rural societies to impacts of climate change. (Ncube & Lagardien, 2015) explain that the Khoisan have been living and coping with extreme environmental conditions such as drought for a long time. Such findings articulate clearly that indigenous knowledge may significantly improve food production more importantly when combined with modern CSATs.

Rural smallholder farmers have their traditional and indigenous smart techniques of producing food, storing and preserving for a longer period, but such knowledge is treated as inferior to modern food preservation and storage measures (Kamwendo & Kamwendo, 2014). Such coping methods includes recycling of greywater practice especially in low income settlements where water is difficult to obtain in South Africa (Rodda et al., 2010). The use of animal manure and mulching are amongst other practices that farmers use till nowadays to improve soil fertility and plant growth. (Rodda *et al.*, 2010) & (Mosebi, Truter, & Madakadze). Capturing and storage of rainwater practices continues to be rural farmer's methods of acquiring water. Such practices are done through the use of buckets and digging of small holes within croplands. These practices indicate positive influence that indigenous farming methods have on food security. For example, rural smallholder farmers have knowledge of seeds developed to resist climatic changing conditions of the region which improves crop survival and success for subsistence farmers. Through local seed storage and re-use by farmers, such farmers have the ability to plant continuously with seeds having better probability of succeeding within the area. Unlike genetically modified seeds, local seed varieties can be used for production for a quite number of years provided there is seed improvement thus maintaining household food and nutrition security.

In the African context, research has been done with findings indicating that the majority of rural women are major players in subsistence farming. The participation of women to work in African agriculture is regularly quoted in the range of 60 to 80 percent (Palacios-Lopez, Christiaensen, & Kilic, 2017). The majority of the African people, especially women subsistence farmers have low formal school education, but only depend on IKS for ensuring a sustainable household livelihood (Seleti & Tlhompho, 2014). Through this indigenous knowledge systems, rural farmers have been managing to alleviate poverty and meeting household food and nutrition security. It is however important to build on effective IKS and local knowledge CST's alongside the introduction of formal knowledge CTS's.

2.7 Climate Smart Agricultural Technologies (CSATs)

Food and nutrition security are major challenges faced by agriculturally dependent subsistence and smallholder farmers in African context. Resulting changes in regional water availability and soil moisture will distract the productivity of cropland, resulting into changes in food production (Calzadilla, Zhu, Rehdanz, Tol, & Ringler, 2014). As per different definition of climate smart agricultural technologies, the intended purpose is to integrate and improve agricultural production that is resistance to climate change effects. Lipper et al. (2014) clarify three objectives that CSAT anticipate to meet. These predicted objectives implies that CSAT has to increase productivity, enhances adaptation and minimises greenhouse gas emission. Although the mentioned three became the main objective of CSAT, the central core for development of CSATs was to enhance and improves achievement of food and nutrition security (Murray *et al.*, 2016).

Different CSAT systems suitability are chosen depending on a variety of factors. Before a system is chosen, a number of consideration and tests need to be made. These factors includes soil type, topographic location of the plot, crop type being grown and many others. Having this information at first may help in deciding the proper CSAT practice for a specific particular area, minimizing unnecessary costs and transfer of inadequate information to farmers. Considering a variety of properties before choosing a system is fundamental in ensuring natural resources like water and soil conservation as there is a growing demand for the resource (McCready, Dukes, & Miller, 2009). This may also serves as the guidance for the right amount of water requirement for crops, limiting water misuses and lost, soil erosion as well as drainage problems. Africa is faced with challenges with regards to water access due to physical scarcity of the resource and droughts in previous decades and current climatic changes (Muchara, Ortmann, Mudhara, & Wale, 2016). These challenges have brought about food insecurity at household level as a result of low food production, it is therefore crucial to consider conservation and efficient utilization of water to maximize production per unit volume of the limited available water (Daka, 2002).

Soil erosion and degradation are amongst the challenges that rural smallholder farmers face under floods from climate change. Although undisputedly, they put in place practices to minimise effects over soil resources, some still needs integration of CSATs with such local knowledge to improve their resilience. Adoption and implementation of technologies that enhances soil management, efficient water use may possible improve food production and rural household's food and nutrition security.

2.7.1 Anticipated Impact of Technologies on Soil Moisture

Different technologies are aimed at developing different soil characteristics with an overall aim of improving food production for household food and nutrition security. Soil moisture is an important element for plants from all growth stages. Even under humid and temperate climatic zones, massive damages can be experienced due to short spells of draught, unless moisture is conserved or supplementary irrigation is applied. Water is a fundamental determinant of plant growth from germination to maturity and any shortages in between may result in production losses and shortfalls. Soil moisture dictates all plant related growth and development processes ranging from plant canopy cover development, leaf area growth and transpiration particularly in arid and semi-arid regions. The water kept in diverse soil layers is recognized as a significant driver of productivity (Deng, Wang, Li, Zhao, & Shangguan, 2016). Smallholder farmers typically farm on depleted soils, however implementation of CSATs is likely to make significant difference in productivity.

Microorganisms are vital components of soils, playing an essential part in processes such as nutrient recycling, organic matter breakdown and many other soil processes. Microbial activities relies into conditions that are favourable for survival and conversion of organic humus into plant readily available nutrients. A study by Van Horn *et al.* (2014) supports the notion that although low temperature seems to be the main factor restricting soil microbial biomass and productivity, factors like moisture content and organic matter also poses extra stress on soil microbial function and diversity.

Infield Rainwater Harvesting (IRWH) is amongst the various technologies anticipated to potentially improve soil water content. Capturing water allows for maximum infiltration until saturation is reached. Through IRWH, water is captured in small reservoirs within the field. This prevents water from running off to nearby streams, allowing for maximum penetration towards deeper soil layers. Plants and microorganisms are able to access water and soil is kept moist for longer periods, a change rain fed dependent smallholder farmers would positively benefit from. Given the fact that smallholder farmers struggle to afford massive irrigation systems for implementation upon their fields, the use of CSATs may enable their ability to capture surface and rainwater to improve soil moisture and productivity.

2.7.2 Anticipated impact of Technologies on Nutrient Recycling

Nutrients recycling plays a crucial role in maintaining and improving soil productive potential. Minimum tillage and mulching are key technologies aiming to restore nutrients back into soil community. During plant growth, micro and macro nutrients are taken from soil systems into plants. Plant nutrient uptakes processes takes place through different mechanisms, be it diffusion from soil atmosphere to plant roots, be it through root growth accessing required nutrients and other forms (Barber, Walker, & Vasey, 1963).

Unless supplementary nutrients are added back to soil through fertilization, crop rotation, mulch and other technologies, agricultural soils are susceptible into experiencing nutrients deficiencies. Plants are similar to all living organisms and they require nutrients as their food for their growth and development (Uchida, 2000). Deficiency in essential nutrients may results into stunted growth, leaves changing colours, early maturity and many impacts towards plants. Production quality and quantity suffers significantly under soils with nutrient deficiencies giving rise to food and nutrition insecurity challenges.

Smallholder farmers in rural areas mainly remove plant residue from the fields before planting. Such practices only takes nutrients from the soil, resulting into nutrient depletion and deficiency for the following season. Minimum tillage technologies enhance nutrients recycling back to soil systems. Minimum tillage systems leave crop residue on the field, providing 15 to 30% surface coverage and causing minor soil disturbance. Furthermore, plant residue decay is a significant process for terrestrial ecosystem functioning, serving as a key source of nutrients and organic compounds sustaining plant productivity, contributing significantly to soil organic matter formation (Bonanomi *et al.*, 2017). Therefore by using minimum tillage technologies, depleted soil nutrients are recycled back into soil systems through break down and decomposition of plant and animal residues by microorganisms.

2.8 Challenges upon Adoption of New Farming Techniques by Smallholder Farmers.

Climate change places a large burden upon smallholder and subsistence farmers' production, creating a need for adaptation and mitigation strategies. Upon mitigating agriculture related challenges, different strategies and techniques have been developed world wide. Although such vast knowledge has been generated, decentralization and adoption of such developments is still a bigger challenge. Such challenges arise as a result of numerous factors such as demographic characteristics, farm plot features, access to market, socio-economics and access to extension services and training (Aryal et al., 2018). Not only are these factors affecting adoption of CSATs, a study by (Ntshangase, Muroyiwa, & Sibanda, 2018) further emphasized that age, level of education and farmers' positive perceptions are amongst key element towards adoption of technologies.

The majority of rural smallholder farmers are commonly elderly people dominated by women. Rural-urban migration is amongst major causes of these implication where man and youth tend to migrates to cities to hunt for better opportunities. Such instances however creates implications when it comes to adoption of CSATs. Some technologies requires a little man power, making it impossible for elderly people to adopt for the purpose of their production. Land access and ownership also exacerbates challenges towards adoption of CSATs. For farmers to adopt agriculture technologies, land availability and economic status of the farmer are crucial elements. This is because some CSATs may require a big portion of land to be effective, creating a bigger input budget which may limit farmers adopting that technology (Pola Kitsao, 2016).

Farmers' perceptions towards CSATs also plays a significant role towards adoption and success of technologies. A study conducted by (Pola Kitsao, 2016) found that farmers in the study area were prioritizing mulching as they perceived it saves a lot on labor for both land preparation, weeding and banding. They further found that it is preferred because the technology also offers multiple benefits ranging from enhancement of soil fertility to preventing soil erosion. Such perceptions may results into farmers disregarding adopting other CSATs regardless of the influence that might bring upon their production.

CHAPTER 3: RESEARCH METHODOLOGY AND STUDY AREA DESCRIPTION

3.1 Introduction

South Africa is a water scarce country and has unevenly distributed resources which is associated with multiple soil arability related challenges (Baleta & Pegram, 2014). Due to low and unreliable rainfall, smallholder farmers in many parts of the country are struggling to obtain maximum crop yields (Mpandeli, Nesamvuni, & Maponya, 2015). This results in the majority of householders abandoning their farming activities due to water shortages that disables them from irrigating, leaving them at risk of being food insecure. As a result, this affects food productivity for subsistence farmers and they become more vulnerable to food insecurity since the majority of rural farmers depends almost only on rain-fed agricultural practices.

Achieving food and nutrition security relies significantly on soil and water generosity. As such, coordination of different knowledge and ideas on CSATs from all perspectives is vital towards improving agricultural production more specifically for rural agricultural dependant households. It has been noted that the feasibility and need for interventions are stressed as resources available for food production to minimise food insecurity, including land or soil and water are becoming scarce and costly (Galhena *et al*., 2013). This study was a comparative study as it compared the impact of using different farming agricultural CSATs on plant growth and development versus non-use at a field trial. The methodology used when conducting this research was mixed method research approach. Both qualitative and quantitative methods were used. Qualitative research is concerned with developing explanations of social phenomena. The main purpose of this chapter is to present the methodology that was followed, data collection techniques that were used in finding the answers to the mentioned objectives. This chapter also looked at study area characteristics including location of the site as well as climatic conditions.

3.2 Description of the study area and field trials

This research was conducted in the area of KwaSwayimane, located under uMshwathi municipality, KwaZulu-Natal. The area is more of a rural area with majority of unemployed youth and adult people, giving rise to agriculture as the main source of income for food and nutrition security insurance. The area is characterized by cold winters and hot summers accompanied by rainfall. According to the information on Bio Resources Unit (BRUs) data of uMshwathi (Camp, 1999), most of the rainfall occurs in the form of high intensity thundershowers resulting in high water losses due to runoff. BRUs data categorizes environments of similar (rainfall, soil characteristics, temperatures, etc.) characteristics and group them into different categories. Regardless of little or no changes observed in terms of rainfall consistency over a long term patterns, villagers have observed that there is a shift in the rainfall pattern and intensity over the last few years. They have observed that it is starting to rain later in the season and the amount of rainfall received per rainfall event is more and with higher intensity. The occurrence of floods is now more frequent than in the past.

Swayimane is a village with majority of households farming to supplement their food and nutrition security needs. It is considered as one midlands area that favors agricultural production due to its climatic and weather conditions. The area has fertile soils and mean annual rainfall ranging from 694 -994mm in the five BRUs. Different parts of the area are exposed to different climatic conditions depending on the location within the BRUs. The data from BRU indicated that uMshawthi municipality is divided into five different climatic conditions. As farming seems to be the main practice used for uplifting poverty and livelihood, different technologies are better suitable for different parts of the municipality.

Due to hilly slopes and steeper gradients, the area requires a special intervention towards assessing environmental related challenges that farmers faces upon their agricultural production. Most farmers produce potatoes, sugar cane and green mealies in large fields, and these are sold to formal and informal traders. The production of vegetables and other crops for household consumption takes place in the homestead garden. Climatic changes are amongst challenges that farmers faces as their production is more reliant to rainfall (rain fed Agriculture). This climatic changes have increased water scarcity related issues, resulting into declined household production, possibly worsening food and nutrition insecurity in affected households.

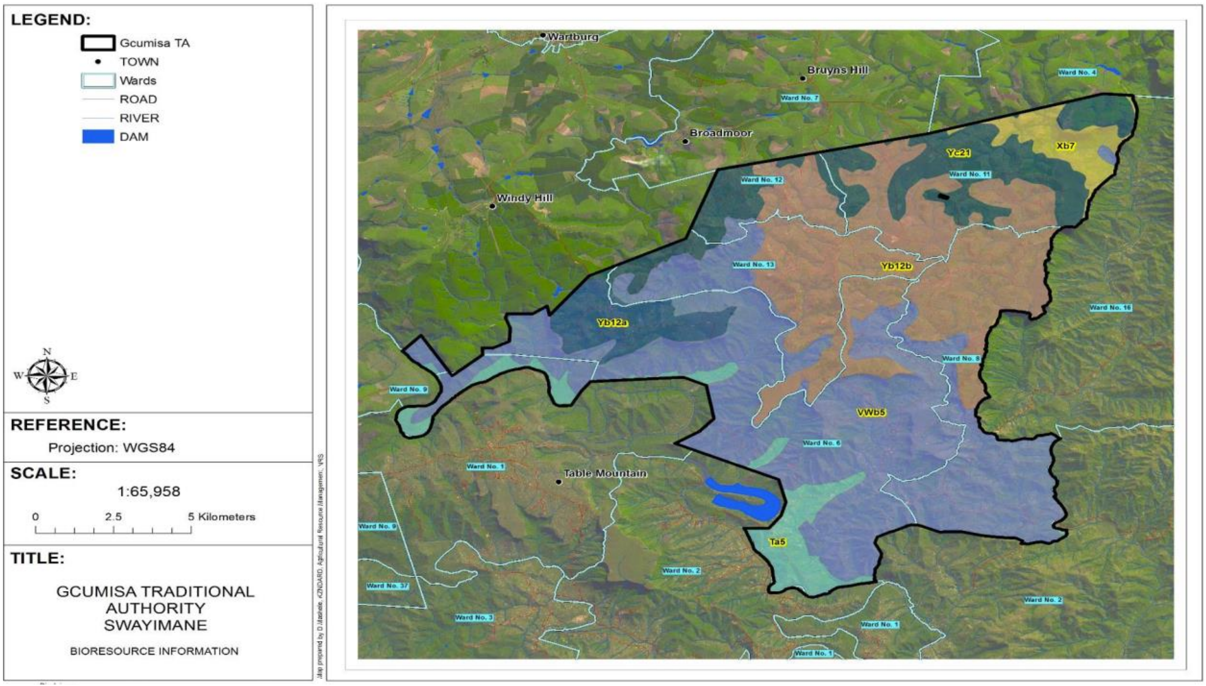

Figure 1: Different BRUs and their characteristics found in KwaSwayimane. Source: WRC Project K5 NUMBER: K5/ 2555/4 (2016-2019).

3.3 Selection of Climate Smart Agricultural Technologies

Swayimane is an area where agriculture is the main livelihood and seasonal employment for elderly people and some of the youth. The area receives adequate amounts of rainfall that favours sugarcane by commercial farmers, maize, amadumbe, beans and a variety of other vegetables by subsistence and small holder farmers. The variation of climate conditions within the same municipality were some of the findings shown by BRU data which raised necessarily analysis towards the considerations of the CSATs to be chosen and implemented for different parts. There was a number of factors that influenced the extent to which farmers in a particular location adopted CSATs. There are several potential adaptation options to reduce moderate to severe climatic risks in agriculture. Adaptation options that sustainably increase productivity, enhance resilience to climatic stresses, and reduce greenhouse gas emissions are known as climate-smart agricultural (CSA) technologies, practices and services (Khatri-Chhetri, Aggarwal, Joshi, & Vyas, 2017).

To give farmers fair options and looking at the environmental climate conditions given by a BRU data, a basket of soil and water adaptation technologies was developed. Figure 2 below shows a schematic diagram of basket of technologies that was developed. Soil and water management practices are implemented differently depending on the climatic conditions of an area. From the designed basket, some CSATs practices are suitable for dryland while some are suitable for irrigated lands. Soil CSATs can be applied in both dry land and irrigated farming practices. Since soils sustains most living organisms and act as an ultimate source of their mineral nutrients, it is of importance that technologies applied cause minimal or none soil disturbance to avoid microbial loss and vulnerability of soils to erosion. Good management of soils ensures that mineral elements do not become deficient or poisonous to plants, and that appropriate mineral elements enter the food chain, resulting into maximum plant uptake and food production for food security (White, Crawford, Díaz Álvarez, & García Moreno, 2012). CSATs were then selected with consideration of minimal soil disturbance to maximise microbial survival, soil water retention and holding capacity and also to minimise soil susceptibility to erosion and degradation.

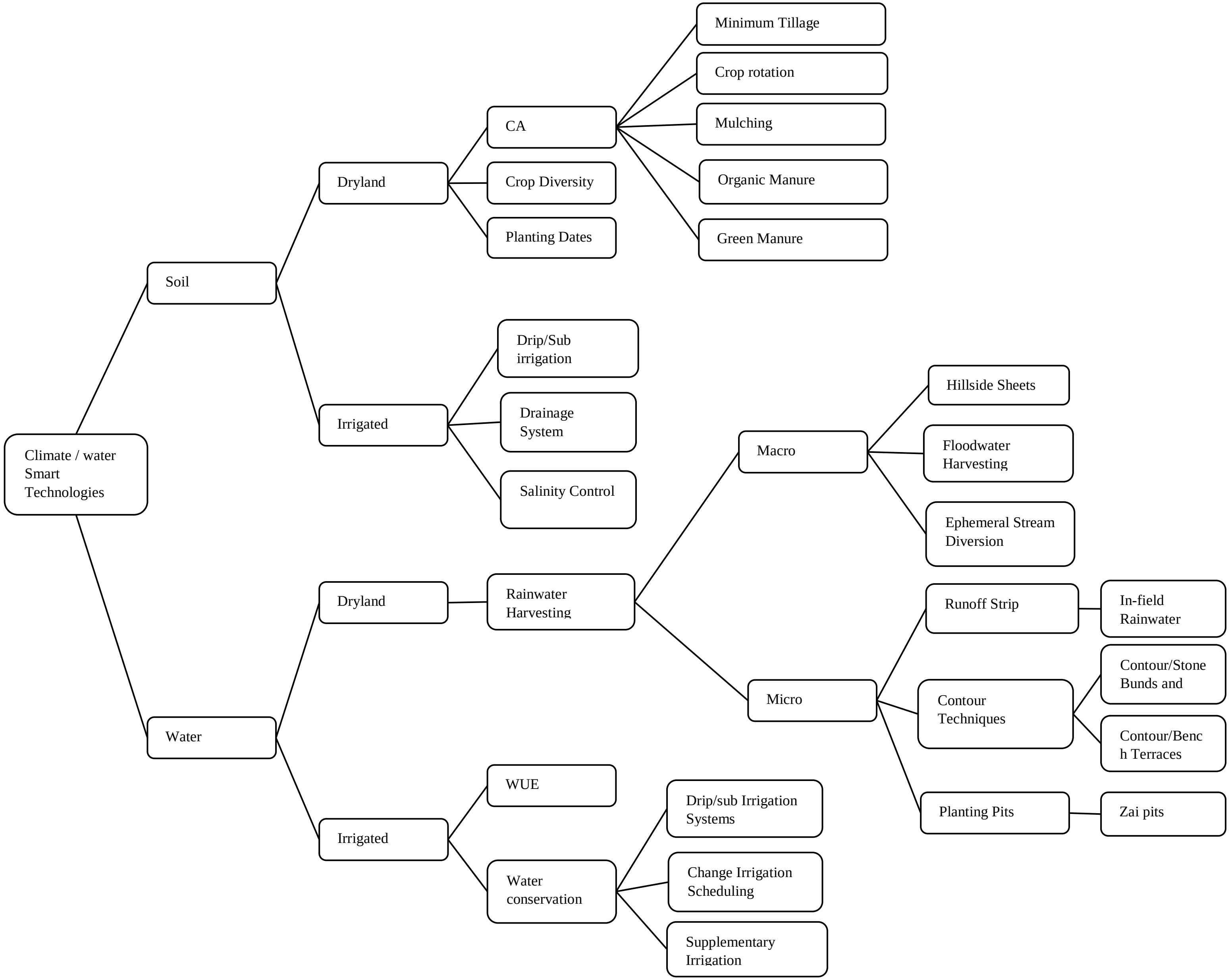

Figure 2: Depiction of different CSATs and their natural resources suitability. Source: WRC Project K5 NUMBER: K5/ 2555/4 (2016-2019).

3.4 Research Design and Data Collection Tools

The study allowed the participation of rural subsistence farmers who were willing to engage in finding answers and solution towards the issue and challenges of food insecurity faced by most South African rural households. A target sample of 60 smallholder subsistence farmers in area was aimed to be sampled for demographics and food security purposes and was successfully obtained. Amongst these 60 smallholder farmers, three farmers' fields were used for demonstration and testing of CSATs. A participatory approach was employed to engage farmers and stakeholders in selection of tools and support for the uptake of the tools. During the research, data was collected using the following tools: Focus Group Discussion, Research Questionnaires as well as Observation through Transact walks.

3.4.1.1 Field Trials

Since Swayimane has different BRUs, it was critical that CSATs are implemented in different BRUs to enable better comparisons and conclusions. Three different sites from ward 6, 8 and 13 were the wards at which the demonstration of CSATs were implemented. Figure 3 below indicates different sites at which field trials were done.

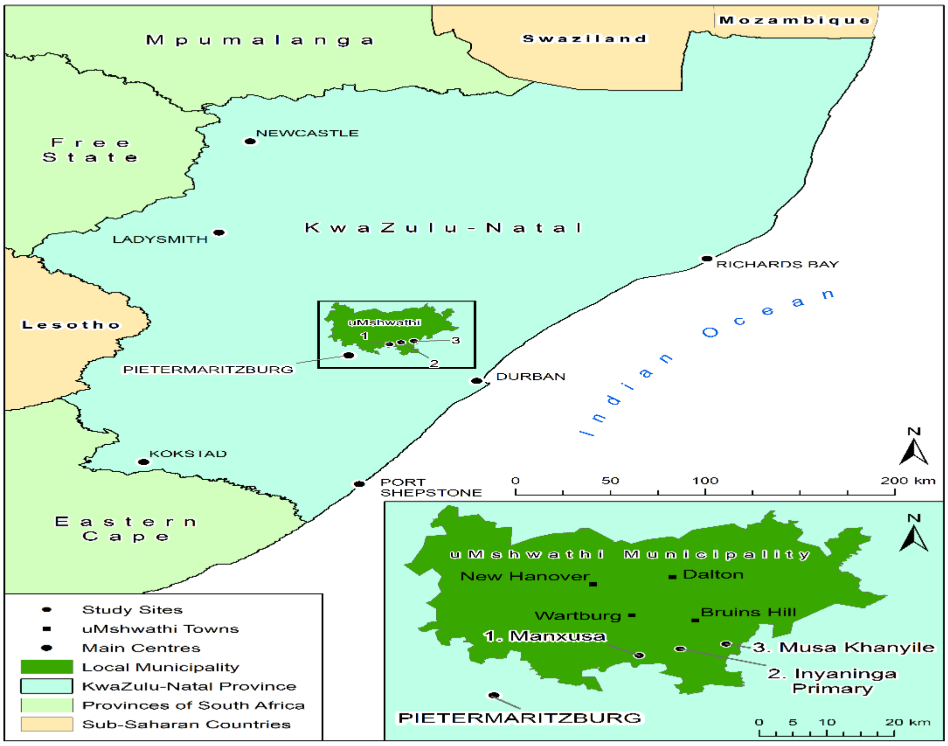

Figure 3: Location of sites used for demonstration.

3.4.2 Qualitative Data Collection Tools and Their Use

Different qualitative data collection tools were employed during this research. Such tools included Focus Group Discussion (FGDs), Stakeholder workshops as well as farmers' workshops. Arrangement and access to farmer's workshops for data collection were through extension officer of local municipality. FGD is a method where by people were gathered into groups, creating environmental conditions to be more conducive for more spontaneous expression of each one, and facilitating the interaction of everybody (Freitas, Oliveira, Jenkins, & Popjoy, 1998). FDGs research involves organised discussion with a selected group of individuals whom were farmres for the pupose of this research, to gain information about their views and experiences of a climate change and indigenous adaptation strategies. Such tool was critical during the study in generating understanding, application and knowledge sharing from farmers with regard to CSATs. This tool also allowed for farmers opinions with regards to the subject matter, encourageing the talking and sharing of different ideas amongst the participants. For this research, FDG method was encouraged as it is more of a natural environment than that of individual interview because during the process, participants get a chance to hear other helpul influence by others,which may be critical for their real life experiences (Dilshad & Latif, 2013). One of the main benefits of using FGDs is that the participants can become a forum of change (Gibbs, 1997). After the issue has been introduced to participants, they can be able to take action upon solving the issue. In addition, by getting the members to discuss among themselves, it makes data collection easier and faster in less time than it would be done for individual interview.

The main aim of this study was to introduce and implement different knowledge that rural farmers may intergrate into their farming skills to improve food production for food and nutrition security. The food security conditions of the households were measured before the intervention ussing Household Food Insecurity Access Scale (HFIAS). This is a tool that assesses through a set of questions, the access component of food security (Swindale & Bilinsky, 2006). However, the research did not provide tangible physical inputs to farmers rather than knowledge inputs, rather the physical input being purchased were seeds and fertilizer. The tractor was hired for field prepation on the demonstration fields. Therefore involvemnt of different agricultural and rural development stakeholder was a key inputs towards ensuring a continous support should such be required by farmers afterwards. Farmers and stakeholders (both internal and external) workshops were held to introduce the project, ideas and required inputs from all parties. Such actions were critical in ensuring successful achievement of desired ouctomes as emphisezed by Boon, Bawole, and Ahenkan (2013) that involvement of stakeholders in project design and implementation are keys to enhance project success. Farmers during these workshops were given opportunities to raise their concerns especially after demonstration and such data was collected as part of the ressearch.

3.4.3 Quantitative Tools

Prepared research questionnaires were used for collecting quantitative data for the research by face to face interviews. The local language was used employing code switching between English and IsiZulu by a trained and experienced research assistance alongside the researcher. This is a technique used for gathering information through asking respondents to answer specific structured questions. The instrument was critical in gathering information types including facts, activities, level of knowledge, opinions, expectations and aspirations within farmers of the study area population (Siniscalco & Auriat, 2005). Such techniques was also considered as it is particularly used for no experimental descriptive designs that seek to describe reality (Fox, Hunn, & Mathers, 2007). Demographic data for the purpose of the research was collected using the method.

3.5 Data analysis

Different models were used to find answers to research objectives. Data was captured and analyzed through IBM SPSS 25 Statistical Package for Social Sciences (SPSS). SPSS is a windows based program that plays a critical role in facilitating data entry and analysis, allowing also to create tables and graphs useful for analysis. This one model is capable of handling large quantities of data and can perform a variety of data analysis. Using descriptive statistics and chi-square analysis, data was analysed.

Further analysis were processed through descriptive statistics technique. This is a technique that includes numbers, tables, charts, and graphs to describe, organize, summarize, and present raw data and Microsoft excel was the tool used. For research data analysis that aims at describing and discussing, descriptive statistics are recommended (Loeb *et al.*, 2017). They are routinely used in reports which contain a significant amount of qualitative or quantitative data, as it is a critical technique that helps summarizes and supports assertions of fact.

The following chapter is written in a manuscript format and addresses the participatory process in engaging the farmers.

CHAPTER 4: DRAFT MANUSCRIPT 1: THE PARTICIPATORY PROCESS OF STAKEHOLDER AND SMALLHOLDER FARMER ENGAGEMENT IN SELECTION, IMPLEMENTATION AND ADOPTION OF CLIMATE SMART AGRICULTURAL TECHNOLOGIES (CSATS) IN KWAZULU-NATAL, SOUTH AFRICA

Abstract

Different ideas and inputs are key requirements for ensuring a prosperous accomplishment of anticipated goals and objectives within development projects. This study is part of an ongoing project that is assessing water use for participation in value chains and for the improvement of food and nutrition security. The main concept and objective of this study were to select and introduce CSATs, through a participatory process that smallholder farmers may adopt and use upon their individual fields to improve productivity and participate meaningfully in value chains while improving household food and nutrition security. From MDGs to SDGs, alleviation of poverty and hunger had been at the forefront of development globally. This indicates the need of implementing developmental programs and strategies to minimize environmental damages while improving food production. Research has shown that drastic impacts are being brought by climate change upon the environment. In trying to minimize some of the challenges brought by climate change on agricultural environments, adopting and implementing strategies that are climate smart is required to conquer food production challenges for smallholder farmers. Adoption of CSATs relies on a variety of factors such as external stakeholder, farmer incentives and farmer agency. The methodology used for this study was participatory mixed methods. This is a technique that involves incorporation of different parties with a similar mandate and visions. For the purpose of this study, the project incorporated different stakeholders where different commitments were made towards trying to improve the adoption of CSATs by smallholder farmers to improve adaptation over challenges brought by climate change. The main incentive towards their commitment was that the project aligned well with their developmental goals which was beneficial for all parties. Farmers vowed to participate knowing and with intentions of improving their adaptive farming knowledge. The results indicated that the presence of different stakeholders played an essential role towards the selection of appropriate CSATs which were then implemented into three plots within the

municipality. The input of different views and ideas with regards to suitability of technologies, knowledge development and food insecurity challenges were key drivers for stakeholder participation. Although commitments and decision were made with lead farmers upon using their plots for demonstration, results indicates that the fear of losing production resulted in some farmer taking an alternative decision for self-preservation without communicating their new decision with the project leaders despite intimate weekly contact. This clearly indicates that using larger portion of farmers' livelihood plots for demonstration purposes should be avoided. It can therefore be concluded that the quality of participation was found to be linked to relevance of stakeholders and their incentives to participate. Establishment of proper communication will play a greater role in the success of adoption of CSATs. This could enable farmers to report any challenges and seek for advices before greater damage is encountered. Therefore, it is recommended that initiation or strengthening of farmer development committees at village, municipality and provincial level in order to foster farmer agency and lessen the "search" and number of stakeholders that farmers need to engage with on development issues, especially formal stakeholders' farmers have to engage with in the adoption of CSAT's.

4.1 Introduction and Contextualization

Implementation of rural development projects is complex, yet a significant tool in achieving successful attainment of desired project goals. Such an approach requires taking into consideration in the diversity of knowledge and values of the rural residents. Given the idea that development goals aims to positively empower human lives, economy as well as the environment. Given the recent climate change impacts in the past decades, it is essential to ensure that there is involvement and participation of different stakeholders in decision-making processes to improve acceptance and adoption of such developments (Usadolo & Caldwel, 2016). Such collaboration has the potential to create ideas that may improve economic developmental processes and policies to better human lives more especially for rural areas in developing countries, where populations are at most vulnerable (Beg et al., 2002). Ideally, the involvement of different stakeholders should result in a process which acknowledges and integrates local knowledge, values and norms into the project (Talley, Schneider, & Lindquist, 2016). Engaging with different stakeholders is also critical in ensuring that correct developmental methodologies are implemented within the duration for the project to be completed on time and within all resources. Such engagements are also key to ensuring minimal environmental policy obstruction while achieving aimed developmental goals. Climate Smart Agricultural Technologies (CSATs) aims to improve food production while enhancing sustainable environmental development and collaboration with different environmental expect may hugely improves achievement of desired goals.

Overcoming food and nutrition insecurity has been one of the forefront challenges that the whole world has come together towards finding permanent and long-lasting solutions, from MDGs to SDGs established in 2015. Despite being amongst the mostly investigated challenges across the globe for nearly four decades, food security arguably remains a concept that is challenging and problematic to conclude to anything but the most general terms (Loring & Gerlach, 2015). Agricultural adaptation practices by farmers differ globally depending on local climatic conditions at which different regions and parts of the world experiences. As it has been proven from climate models that semi-arid and arid regions around the world are likely to experience increased rainfall variability and longer droughts, many parts of the world have reached and are experiencing those conditions. In regions dependent on agriculture as the main life-sustaining practices, such changes are exacerbating the existing food insecurity and economic underdevelopment challenges

(Burney *et al.*, 2014). Addressing the issue of food insecurity, malnutrition and poverty under current climatic conditions requires collaboration of different knowledge and techniques. The use of CSTAs and incorporation of different stakeholders and smallholder famers' knowledge aims at conquering the issue of food and nutrition insecurity. These aims links perfectly with the some of the goals and mandates of SDGs. Adaptation towards these exacerbated conditions has resulted in farmers enhancing their local knowledge while also some farmers still rely on their hierarchy of indigenous knowledge which they have piled from generations to generations. CSATs can play a massive role in empowering people with climate change adaptive knowledge and skills, which might improve food production for food and nutrition security at a household level. To ensure a successful selection and implementation of proper CSATs for this study, different stakeholders were brought on board and vowed to keep up with their assigned tasks and commitments.

4.2 Study Design and Methodology

The study adopted and used a participatory mixed research method. Such methodology can provide a concrete foundation for community based participatory action research (Ivankova, 2017). Participatory research methodology is a methodology designed to include all parties involved during the study, and this study involved community members, different stakeholders, and academic researchers in all phases of the research process, including knowledge generation and decision-making. To introduce the idea of CSATs to smallholder farmers, a mix of different tools and approaches were used. These tools were community and farmer's workshop presentations, focus group discussions and research questionnaires. Given the biophysical properties and different institutional arrangement within the community, a basket of multiple CSATs and management processes were designed. A selection of suitable CSATs was done upon a stakeholder meeting where different stakeholders were invited and showed interest to participate upon the project as it aligns perfectly with some of their mandates and visions. After the selection of suitable CSATs, field trials and setups were done on three sites from the community for demonstration purposes. The study further monitored maize growth after every two weeks. This was done based on the study by Du Plessis (2003), where he articulated different stages to monitor maize growth and development. The sites were used as field schools for all interested members within the community, assuming that the lead farmers will be fully responsible for management upon the sites.

4.3 Results

The following chapters present the processes and participation from selection to implementation of selected CSATs and further present farmers' choices of technologies and their perception after observing from demonstration sites.

4.3.1 Demographics of the Study Population

Smallholder farming in rural African countries is mostly dominated by elderly people and children. From this study, cooperative members that attended during the introduction implementation of CSATs upon demonstration site were elderly people. A total of 60 smallholder farmers showed an interest in participating upon the implementation and assessment of CSATs. Table 2 below shows the demographics of farmers.

Table 2: Demographics of farmers participated during implementation and assessment of technologies

Variable	Frequency	Percentage
Gender		
Male	19	31.7
Female	41	68.3
Total	60	100
Age		
0-30	11	18.3
31-40	2	3.3
41-50	12	20.0
51-60	15	25.0
+61	20	33.3
	60	100.0
Average Years in School	6.7 years	
Average farming experience	45 years	

From all members that attended the introductory meeting, 41 members were female while only 19 members were male. The majority of those smallholder farmers were aged above 61 years (20 members), followed by 51-60 with 15 members, 41-50 with 12 members, 31-40 with 2 members and 0-30 with 11 members, (refer to table 2). Due to personal commitment that individual farmers have, it was impossible for all smallholder farmers to be present during the implementation and assessment of CSATs upon all demonstration sites. The results also shows that farmers did not attend school for longer periods. The sampled farmers have attended schools for an average of 6.7 years and had no tertiary qualification in agricultural production and training. The majority of farmers indicated that they have been farming from the early ages and have up 45 years of farming experience in average. Such experience may results into adoption of CSATs being easy and productive towards improving food production for food and nutrition security.

Table 3: Employment status, household available land sizes and farming purposes

Type of Employment	Frequency	Percentage
Smallholder farmer	32	53.3
Government/Private Sector	6	10
Self employed	2	3.3
Smallholder and Self employed	7	11.7
Unemployed	13	21.7
Total	60	100

Smallholder farming is considered both as an employment and retirement activity for elderly people. This correspond with the majority of farmers being elderly people who are beyond 60 years from this study. Out of the 60 farmers that were present, 32 considered farming as their employment, 6 were government employees who considered farming as an extended food insecurity combat strategy to minimize spending their income upon things that they can produce for themselves (refer to table 3). 13 farmers considered themselves unemployed and they practice farming only to supplement household food and nutrition security (refer to table 3).

Prior to introducing the project, household food security conditions were assessed within the study area using Household Food Insecurity Access Scale (HFIAS). This is a tool that assess through a set of questions, the occurrence of food shortages within a household for a period of thirty previous days. Assessing food security conditions prior to intervention was essential to determine whether there has been improvement in household food security after the intervention.

Table 4: Households with HFIAS related conditions regardless of severity

HFIAS conditions	**Swayimane (%)**
Worried about enough food	21.1
Could not eat preferred food	31.6
Food had limited variety	21.1
Ate food they did not want	26.3
Had smaller meals	31.6
Had fewer meals	26.3
Had no food at all	21.1
Went to sleep hungry	21.1
Did not eat the whole day and night	10.5

The results from table 4 showed that the majority of household experience food insecurity. It showed that approximately three in every ten households had either consumed smaller meals or fewer meals at some point in the preceding month. These results presents the smaller portion of the community members, but it was assumed that since the community has similar production practices and livelihood strategies, such challenges are likely to be experienced by majority of households within the municipality. The main principle behind selection and implementation of CSATs is to improve agricultural production to enable smallholder and subsistence farmers to conquer challenges of food and nutrition insecurity at a household level. Through the proper use of these technologies, production may improve resulting into households accessing food for household food security. The age variety of smallholder farmers being dominated by elderly people appeared to be a challenging factor for the adoption of some CSATs. Since some technologies requires a bit of man power for implementation, having interested smallholder and subsistence farmers dominated by elderly could jeopardize acceptance and adoption of these CSATs. Proper external assistance from other stakeholders was a critical aspect towards ensuring adoption of technologies for individual households to improve food production under current climate to improve household food and nutrition security. Further demographic data from the households used for assessing insecurity challenges will be collected to assess if they is any positive changes after the adoption of CSATs.

4.3.2 The Processes of CSATs Selection and Implementation

The project aimed at uplifting rural smallholder farmer’s climate change adaptive capacity. Given such instances, community members were the most important stakeholders for the whole project. The research team selected community workshops as the tool for engaging with community members in Swayimane, KwaZulu-Natal under UMshwathi Municipality. The team selected workshops because they allow the facilitators, participants and different stakeholders to participate, collaborate with and empower one another. Since climate change impacts human livelihoods, economic development and the environments, incorporation of multiple stakeholders was assumed to possibly improve knowledge decentralization, sharing and adoption of these mitigation ideas. Workshops also allow interactive engagements and discussions between facilitators and stakeholders at which other solutions and feedback may be obtained (Durham, Baker, Smith, Moore, & Morgan, 2014). The research team firstly presented the aims and objectives of the overall project, and then spoke in detail with the community members about the proposed CSATs (based on literature, farmers’ knowledge and climatic conditions of the area) in the basket of technologies for Swayimane. Such discussions were significant in participant’s views and ideas of other technologies which they been using and showing positive impacts upon their production.

Achieving project desired goals required the involvement of other external stakeholders to facilitate and enhance its success. A meeting with different stakeholder representatives took place on 20 November 2017. The following stakeholders were present during the meeting and vowed to play parts towards ensuring the success of the project. These were Department of Rural Development and Land Reform, KwaZulu-Natal Cooperative Governance and Traditional Affairs (uMgungundlovu District), KwaZulu-Natal Department of Agriculture and Rural Development (Extension and FET), KwaZulu-Natal Department of Water and Sanitation and KwaZulu-Natal Department of Economic Development, Tourism and Environmental Affairs.

4.3.3 Roles and Tasks Assigned for Different Stakeholders

One major component of successful stakeholder management and implementation is co-ordination. However, the coordination needs to be strong in order for activities to yield results towards the desired outcome. All stakeholders were assigned and committed to keeping up with allocated tasks. The following table summarizes different tasks assigned to different stakeholders during the meeting.

Table 5: Different tasks assigned and committed to different stakeholders during the meeting.

Stakeholder	Proposed Roles and Responsibilities
Department of Rural Development and Land Reform (national)	Support and advice on work to be undertaken Advice on research reports on agriculture and water that the projects produces or vice versa Possible funding for 1 PhD depending on topic alignment
KwaZulu-Natal Cooperative Governance and Traditional Affairs (uMgungundlovu District)	Provide support in relation to access to traditional communication Assist in facilitating of involvement of other stakeholders
KwaZulu-Natal Department of Agriculture and Rural Development (Extension)	Support Advice, hands on involvement and local expertise
KwaZulu-Natal Department of Water and Sanitation	Provide capacity building and training Link with resource poor farmers and support the licencing process.

The following section presents the results, first the demographics of the farming group is presented followed by the performance results of each CSAT. The results are completed by an analysis of the perception and adoption incentives by the farmers.

4.3.4 Implementation of Climate Smart Agricultural Technologies on Demonstration Plots.

4.3.4.1 Introduction

Agriculture is the practice of cultivating plants and domesticating animals. Not only are these the attributes of agriculture, but it also incorporates the economic processing and managing of plants and animals reproduction, changing their characteristics through selective breeding, for favouring its survival under different climatic conditions. Agriculture signifies more of domestication of plants and animals valuable to human survival (Zvelebil & Pluciennik, 2011a). It is the main practice towards achieving food to conquer poverty and hunger while sustaining the lives of human and animals. It is that kind of activity that creates linkages between labours of different spheres ranging from soil, water and atmosphere (Yusuf, 2014). These are the main linkages that advocate for better living conditions for human around the world. It is considered amongst the sectors that have a significant potential for transforming the economy of many countries globally. The contribution of agriculture can directly or indirectly affect household food and nutrition security and the development of countries economy. The findings from the study conducted by Greyling (2012) indicated that the agricultural sector has the potential to generate employment through its requirement for relatively high labour intensity and the existence of some complementarities between capital and labour in the sector.

Due to the development and evolution of human lives, there have been a variety of changes which have diversified the farming methods from one place to another. These changes were driven and motivated by various issues ranging from an increase in population density, the greater survivorship of infants in the early stages of farming, but also greater spread of density-dependant disease, and of other pathological conditions related to poor diet (Zvelebil & Pluciennik, 2011a). These changes have called for modification and improvements of local knowledge and developments of Climate Smart Agricultural Technologies (CSATs) for farmers to adapt, with the main principles and the motives aiming at improving food production for food and nutrition security.

Food and nutrition security are major challenges faced by agricultural dependable subsistence and smallholder farmers in the African context. Resulting changes in regional water availability and soil moisture will distract the productivity of cropland, resulting into changes in food production (Calzadilla *et al.*, 2014). Some of the major challenges of climate change impacts on agriculture include crop cultivation suitability and associated agriculture biodiversity, decrease in input use efficiency, and prevalence of pests and diseases (Khatri-Chhetri *et al.*, 2017). As per different definition of climate smart agricultural technologies, the intended purpose is to integrate and improves agricultural production that is resistance to climate change effects. Kaczan, Arslan, and Lipper (2013) clarify three objectives that CSATs anticipate to meets. These predicted objectives imply that CSATs has to potentially increase productivity, enhances adaptation and minimises greenhouse gas emission. Although the mentioned three became the main objective of CSATs, the central core for development of CSAT was to enhance and improves the achievement of food and nutrition security (Murray et al., 2016).

Different CSAT systems are chosen depending on a variety of factors. Before a system is chosen, a number of consideration and tests need to be made. These factors include soil type, the topographic location of the plot, crop type being grown and many others. Having this information at first became a significant factor in deciding the proper CSAT for a specific particular area, minimizing unnecessary costs and transfer of inadequate information to farmers. Considering a variety of properties before choosing a system was vital in ensuring natural resources like water and soil conservation as there is a growing demand for the resource (McCready *et al.*, 2009). This may also advice the right amount of water requirement for crops, limiting water misuses and lost, soil erosion as well as drainage problems. Africa is faced with challenges with regards to water access due to the physical scarcity of the resource and droughts in previous decades and current climatic changes (Muchara *et al.*, 2016). These challenges brought about food insecurity at household level as a result of low food production, it is therefore crucial to consider conservation and efficient utilization of water to maximize production per unit volume of the limited available water (Daka, 2002).

During the week of the 5th -9th February 2018, demonstration of implementation for chosen CSATs commenced in the area of KwaSwayimane under three different wards (i.e ward 6, 8 and 13). A number of CSATs were selected with an aim of being implemented for the purpose of assessing their success and impacts in improving farm food productivity for food security, soil and water sustainability. Swayimane is an area with different climate variations within the same district. Due to its variation in local climate conditions, different crops are suitable and favorable in different parts of the districts. CSATs were grouped into four and implemented in each site. These four technologies were Infield Rain Water Harvesting (IRWH), Minimum Tillage (MT), Conventional Tillage (CT) and Mechanized Basins (MB). Due to different plots ownerships and the distance separating fields, the design and alignment of technologies settings were different from one another.

4.3.4.2 Infield Rainwater Harvesting

Rainfall is arguably the climatological phenomenon that has the strongest influence on human activity, including entirely living organisms. Through rainfall, rivers, dams, aquifers and water tables are filled. Decades and centuries people have relied on rainwater for their daily activities including farming and domestic activities. Due to the rate of development, millions of people throughout the world lack proper access to clean water for domestic purposes. Roughly 780 million people lack access to clean drinking water and some 2.5 billion people are without adequate sanitation facilities (Salaam-Blyther, 2012). In many parts of the world, conventional piped water is either absent, unreliable or too expensive. One of the biggest challenges of the 21st century is to overcome the growing water shortage. In addition, the continuous global population growth rate points out the predictable growth of food demand in the future, with an immediate influence on farming water use and human need (Mancosu, Snyder, Kyriakakis, & Spano, 2015). Given these challenges, it is clear evidence that new and efficient technologies to sustain and preserve water resources are needed.

Rainfall in the drier environments is normally deficient to meet basic necessities for crop production as it is poorly and unevenly distributed over the planting season. Even the least drop usually comes in intense surges, which becomes hardly used by farmers to supplement their economically sustainable farming. Topsoil is the measure significant agricultural playground at which farmer’s value for maximum and quality crop productions. Due to storm surges leading to catastrophic flooding (Kaniewski *et al.*, 2016), the topsoil that sustains most living organisms which break down nutrients for plant uptakes get eroded (White et al., 2012). To meet up with daily water requirement for livelihoods daily activities, rainwater harvesting has been amongst the practices used by human to supplement water for future uses. Rainwater harvesting is the process collecting, storing and use of surface runoff for different purposes which includes domestic and farming practices in the times of water shortages (Welderufael, Woyessa, & Edossa, 2013). There are many rainwater harvesting technologies used worldwide, ranging from tanks, buckets, furrows and infield rainwater harvest.

Infield Rainwater Harvesting (IRWH) refers to the capturing and storage of rainwater within agricultural farmlands to minimise water losses through runoff, while also enhancing soil water storage. It is an important technique in minimising topsoil erosion used as climate smart agricultural technology (CSATs). The findings from a study conducted by Van Heerden, Woyessa, and Pretorius (2005) indicated that IRWH technology increased crop yield significantly compared to other practices and small holderfarmers adoption of the technology grew from six to more than 950 households. The technique comprises runoff strips along the slope of the field and basin area across the slope of the field and at the end of the runoff strip. In this way, runoff is directed and stored into the basin area. The two metre runoff strip serves as a catchment area, where runoff is concentrated and directed into the storage area, the basins (Baiphethi, Viljoen, Kundhlande, & Ralehlolo, 2010).

During the implementation of IRWH, a tractor was used to build basins of approximately 30 cm deep and 1 m long. As indicated in figure 4 (a) and (b) the basin acted as water tanks or containers that hold water from running off across the field. Maize was planted on top of the basin ridges. This was significant in allowing the roots to easily access water from the basins. The basins were separated by a space of 2 m which was then cleared to allow water to runoff into basins.

Figure 4(a)

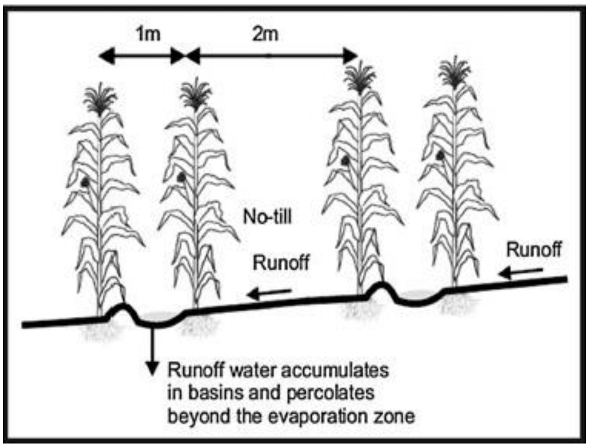

Figure 4(b)

Figure 4: (a) An image taken from Rensburg, Bothma et al. (2012) showing IRWH designs looks like and (b) shows the practical design in done in the field.

4.3.4.3 Minimum tillage

Tillage is the mechanical manipulation of the soil for any purpose (Blanco & Lal, 2010). This purposes may include agricultural production intentions, developmental intentions and any other purposes. Several soil problems and environmental impacts have been experienced over the use of tillage practices, affecting food production for food and nutrition security worldwide. Experienced impacts include significant damages of soil properties such as soil water conservation, soil temperature, infiltration and evapotranspiration processes (Busari, Kukal, Kaur, Bhatt, & Dulazi, 2015). Therefore this supports the idea by M. K. Alam, M. M. Islam, N. Salahin, and M. Hasanuzzaman (2014) that reducing the disruption of soil by reducing tillage influences numerous physically, chemically, and biologically interconnected attributes of the soil natural systems. However, also conservation measures have been reported to increase soil resistance and decrease erosion which backs up the idea that tillage exerts an impact on the soil purposely to produce crops and consequently affects the environment.

Minimum tillage is a CSAT targeting to conserve soil through minimum soil disturbances while improving food production. Although there is an urgent need to match food production with increasing world population, until recent decades sustainable land management strategies were neglected. However, the struggle to achieve food security had recently been an eye opener in sustainable management carried out to keeping soil where the crops more sustainable and managed (Busari *et al.*, 2015). Soil disturbance has been amongst soil challenges leading to maximum top soils lost through erosion. The findings from a study conducted by Y. Wang *et al.* (2018) where a comparison between different tillage practices was used indicated that disturbed soil detachment rates are substantially greater than those for comparable undisturbed soil experiments. Therefore, the susceptibility of loose soil towards erosion is much greater when compared to undisturbed soil particles. Soil erosion is directly related to reduced agricultural productivity and to water pollution, which clarifies that food and nutrition security are at vulnerable where least majors of soil and water management are neglected (Sun, Shao, Liu, & Zhai, 2014).

Suitability of CSATs differs with environmental conditions of the region. Minimum tillage indicates greater success in areas experiencing severe drought coupled with severe soil erosion. Areas with infertile soils that results in poor yields. Slope or area gradient does have massive impact towards the success of the techniques. Soil textural make up affect almost all agricultural practices ranging from soil management to harvest. Different soil textures are characterised by different clay content, which in turn determines nutrient and water flow within the soil systems. Sun *et al.* (2014) summarised soil loss due to water erosion as a function of climate which is determined by the quantity and intensity of precipitation, slope, soil erodibility, and flora cover. Minimum tillage minimises soil susceptibility to erosion as it minimises soil erodibility through minimal disturbances and vegetative cover removal.

Since the study site was a hilly and mountainous area, application of this technology was critical in avoiding soil loses through erosion. Minimum Tillage (MT) practices were done manually by farmers during implementation. Using a hand hoe, farmers dug shallow holes to put fertilizer and maize seeds. To avoid the effect of fertilizer burning the seeds, fertilizer was added first and manually mixed with soil. Direct application of seeds over fertilizer may results into seeds burn, affecting germination and production. Figure 5 (a) shows the images of how MT holes at which seeds were planted were constructed. In some instances, a shallow lines were dug in which the maize seeds were planted as indicated in figure 5 (b). Unlike from the IRWH, MT had 1 m distance that separated the lines of maize from one another.

Figure 5(a) Figure 5(b)

Figure 5: Field preparation for minimum tillage practices

4.3.4.4 Conventional Tillage

Soil management practices are significant towards fluctuating soil physical and chemical properties, resulting in massive impacts in soil productivity. Conventional Tillage (CT) refers to agricultural practices where soils are overturned through ploughing and up to ninety percent plant residues being removed for a purpose of planting seeds. It is characterized by rough surfaces covered by soil clods of different shapes and sizes. Random roughness and arrangements of soil aggregates are significant properties of tilled soils with regards to soil water storage, infiltration, evaporation and runoff retardation. (Guzha, 2004).

Different agricultural management aimed at improving food production for food security may result in positive and sometimes negative impacts towards agricultural soils. M. Alam, M. Islam, N. Salahin, and M. Hasanuzzaman (2014) also validate that any management practice implemented on soil for modifying the heterogeneous body may result in generous or harmful outcomes. Tillage practices loosen soil aggregates, creating more pores and spaces in between the aggregates. A healthy soil structure is one that shows a well-developed soil aggregates and porosity systems, increasing the exchange of gases between soil and atmosphere (Amoakwah, Frimpong, Okae-Anti, & Arthur, 2017). Tillage practices improve soil porosity and aggregates structures, it can therefore be assumed as a stimulant towards achieving healthy soils. On the other hand, disintegration of soil aggregates may also results in negative outcomes towards soil structure and stability. Lose soil clods are more susceptible to soil erosion as compared to clustered soil particles. Severe tillage practices at a larger scale can cause a decline of soil organic matter (SOM), resulting in low soil fertility and quality in arid and semi-arid ecosystems (Kabiri, Raiesi, & Ghazavi, 2016)

During the implementation of this technology, a tractor was used to plough the field. Similar to IRWH, the space between two maize lines was equated to one meter. To avoid congestion and allow the flow of air in between, a two meter ploughed bare surface was left between each two lines of maize. Al Mamun, Al-Mahmud, Zakaria, Hossain, and Hossain (2016) advocates the need to improve crop density as it negatively impacts greatly on plant development, yield and quality of the crop. Similarly, findings from a study by Jia *et al.* (2017) indicated that an increase in maize crop density results into a decrease in crop yield due to shortages of radiant energy penetration to lower canopy.

Figure 6(a) Figure 6(b)

Figure 6: Photographs of how conventional tillage soils appeared in the field.

4.3.4.5 Mechanised Basin

Capturing of rainwater for different purposes can be attained through different methods and technologies. This includes technologies that can be purchased like tanks or be constructed like dams. Mechanized Basin (MB) is agricultural technique of capturing rainwater within agricultural fields for farming purposes. Similar to IRWH technology, basin are constructed within the fields with crops planted on the ridges of those basin. The depth and the length of each basin was 50 cm and 1 m respectively. MB technology captures only rainfall water falling into the basins. This means that this technology has no runoff spaces to allow surface runoff to basins. The amount of plant available water only depends on the amount of rainfall obtained and captured within the basins. Soil characteristics also plays a vital role towards determining plant available water. Infiltration rates differs from one soil type to another. Sandy soils have higher infiltration rate, but lower infiltration time as compared to clay soils. This simply means that water can spend more time within basins of clay soils than it will on sandy soils.

Figure 7(a)   Figure 7(b)

Figure 7: Diagrammatic alignment of basins in figure 7(a) and a farmers instructing tractor driver on construction of the basins figure 7(b).

Immobile water has higher infiltration possibilities as compared to motion waters. Water through the basin is captured and stored minimising losses through runoff towards near by streams. Rises of infiltration rate is direclty propotion to soil moisture content, resulting in adequate plant water availability. Therefore, planting crops along ridges of basins is expecetd to improve plant water uptakes. Dependig on crop water requirements water use, some crops can be plated within the basins to enable maximum water uptakes.

4.3.5 Alignment and diagrammatic design of fields where CSATs were used

Plot 1 (MaNxusa)

Climate Smart Agricultural Technologies implementation commenced from the 5th February at the area of KwaSwayimane, Estezi location. An area of 100x50 m was marked and divided as the site for demonstration of different technologies as shown in the following diagram. The first subplot of the area was used for infield rainwater harvesting technology, second subplot used for mechanized basin, third subplot used for conventional tillage and the fourth subplot was used for minimum tillage practice. The whole plot was used for maize plantation Maize SC 701 (PAN 701) and MAP fertilizer was added to supplement the nutrients for crop uptake.

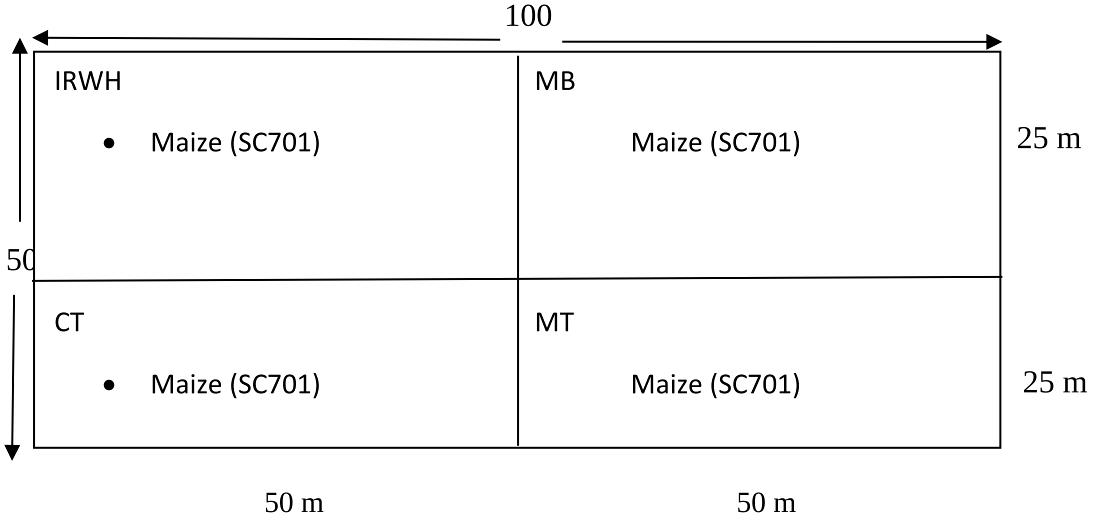

Figure 8: Field layout and division for different technologies at plot 1.

Plot 2 Inyaninga Primary School

Ward 13 farmers had no prepared area for demonstration of technologies as a co-operative which led into Inyaninga Primary School being used as a demonstration site.

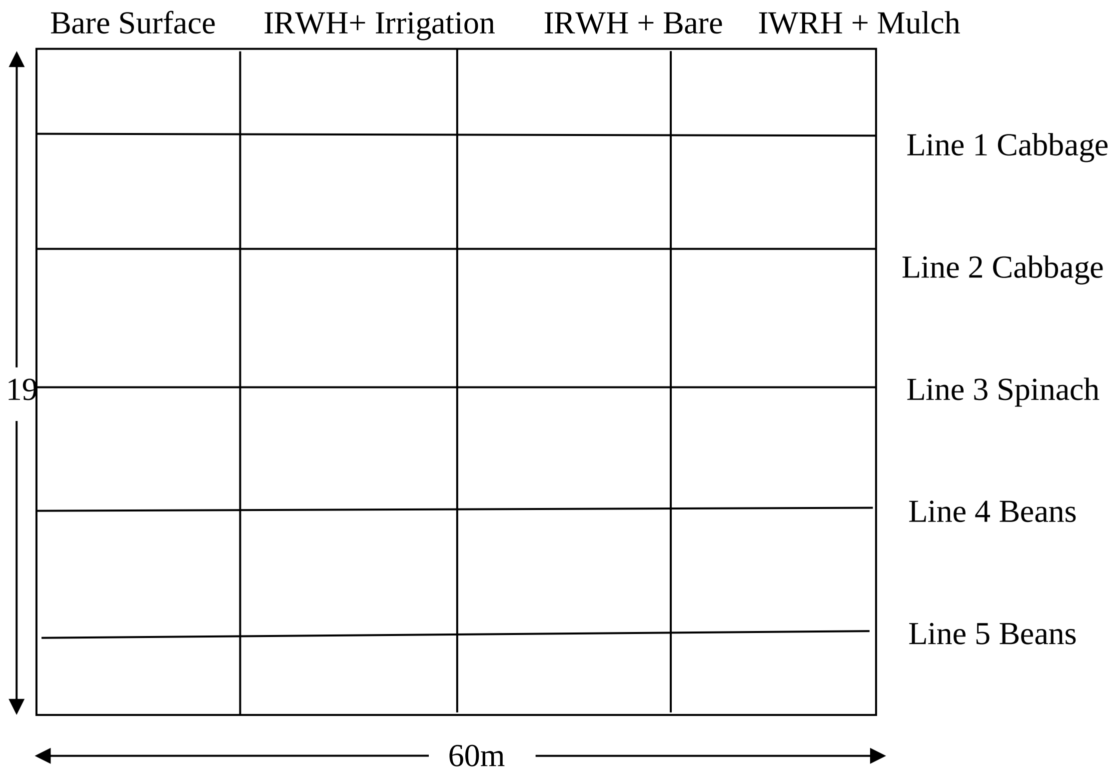

Figure 9: Field layout and plot division for different technologies at Inyaninga Primary School.

The above diagram in figure 9 is a schematic indication showing how the field was divided for different technologies and vegetables. The school plot was smaller in (19x60m) size which resulted into a minimum number of technologies being implemented. IRWH became the main technology that was implemented, incorporated with different treatments. Each column consist a variety of all the plots planted in the field. This was done to assess the effects of combining different treatments towards improving food production. The first column of the plot had no treatments or technology applied. The second column of the plot was under IRWH treated with supplementary irrigation. The third column of the plot was still under IRWH without mulch and irrigation while the last column of the plot had mulch but not irrigated.

Plot 3 (Mr Khanyile)

A plot of 90x52 m was used and divided for demonstration of different CSATs. Following is an outline of how the field was segmented.

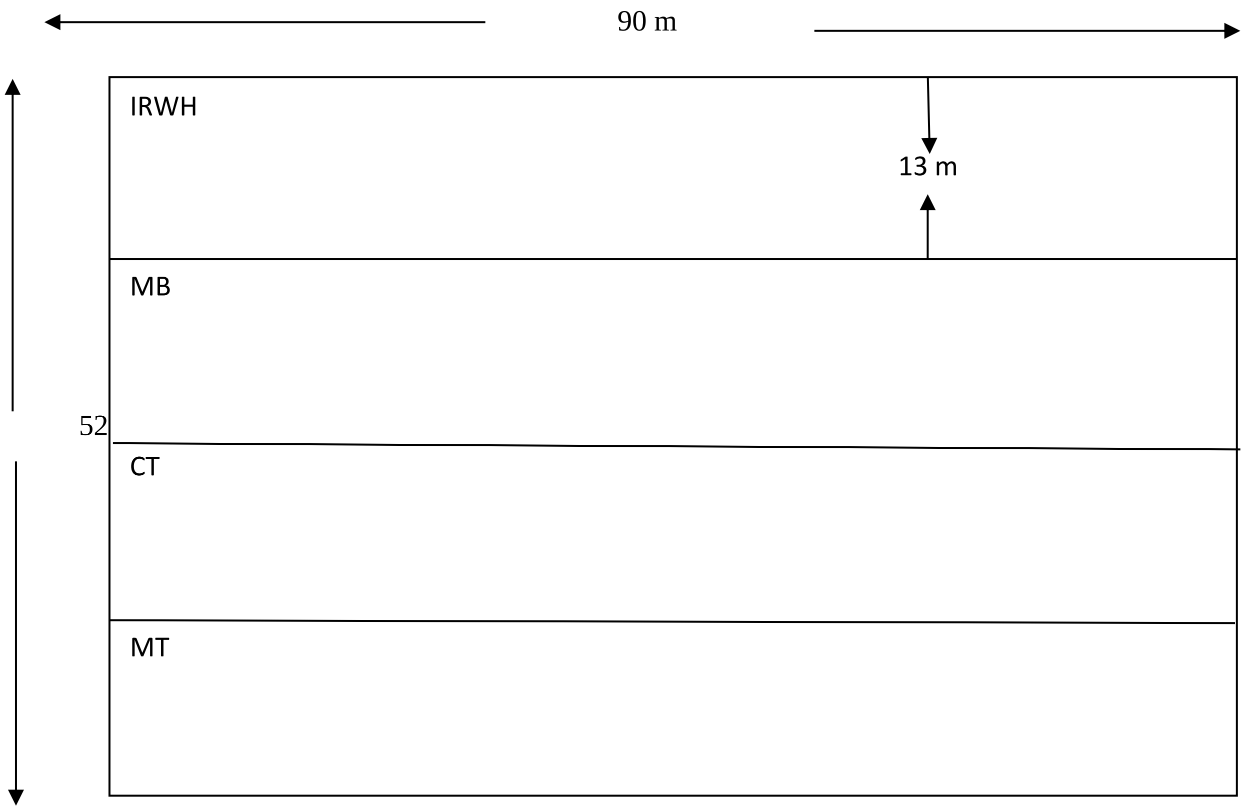

Figure 10: Division and layout of CSATs in plot 2.

The main crop planted was maize SC 701 for all the technologies. The plot was divided into four subplots for implementation of different CSATs. The first portion of the field was used for IRWH, second portion for MB, third portion for CT and last portion used for MT.

4.4 Participation and Farmers' Incentives for Adopting CSATs

The main objective of this research was to select and implement Climate Smart Agricultural Technologies (CSATs) on demonstration sites where farmers can be able to see and learn with an assumption that it will help and prepare farmers to adopt and use technologies upon their own individual fields. Invited stakeholders committed to participate on this research due to that it aligns greatly with their development goals and missions. Demonstration plots were used as schools at which farmers were exposed and taught about technologies. The incentive of smallholder farmers participating upon this study was to receive climate change adapting knowledge to adopt and implement upon their individual farmlands. The lead farmers' plots which were used as demonstration sites, the inputs were provided, but the final produce was theirs. After such demonstration and learning, research aimed at assessing farmer's view on technologies, their choice after observation and understanding as well as assess if farmers are ready to adopt the technologies. Assessment of farmer's willingness and readiness was done through seminars where clarification and explanation of technologies were further done.

Table 6: Farmers present during implementation of selected technologies and first time attendees.

Variable	**Frequency**	**Percentage**
Present during implementation	22	56.4
First time attendee	17	43.6
Total	39	100

From the initial sample of 60 farmers, only a total of 39 farmers attended seminars at which results from different sites of implemented CSATs were presented. Personal commitments and the loss of interest were amongst the reasons for the 21 farmers that did not attend the results presentations. Out the total number of attendees, 56.4% were farmers whom were present during implementation of selected technologies. 43.6% were farmers whom did not attend implementation but interested after observing and learning from presentations.

Implemented technologies were chosen from a basket developed based on climatic and slope information of KwaSwayimane area, under uMshwathi municipality. From the basket (figure 2), four main technologies were chosen and implemented under three different sites within the municipality. Selected technologies were Infield Rainwater Harvesting (IRWH), Mechanized Basin (MB), Minimum Tillage (MT) as well as Conventional Tillage (CT). During implementation of these technologies, it was a busy season for farmers which resulted into some being not present during implementation. To cater for those who were not present during implementation, multiple presentation of results showing critical stages of each technology were presented to farmers. This was critical towards equipping farmers' knowledge regarding technologies while also trying to help with their choices of technology. Based on this implementation results and presentation made during seminars, farmers were allowed to choose technologies of their choice which they would like advisory and help to implement during the following winter season.

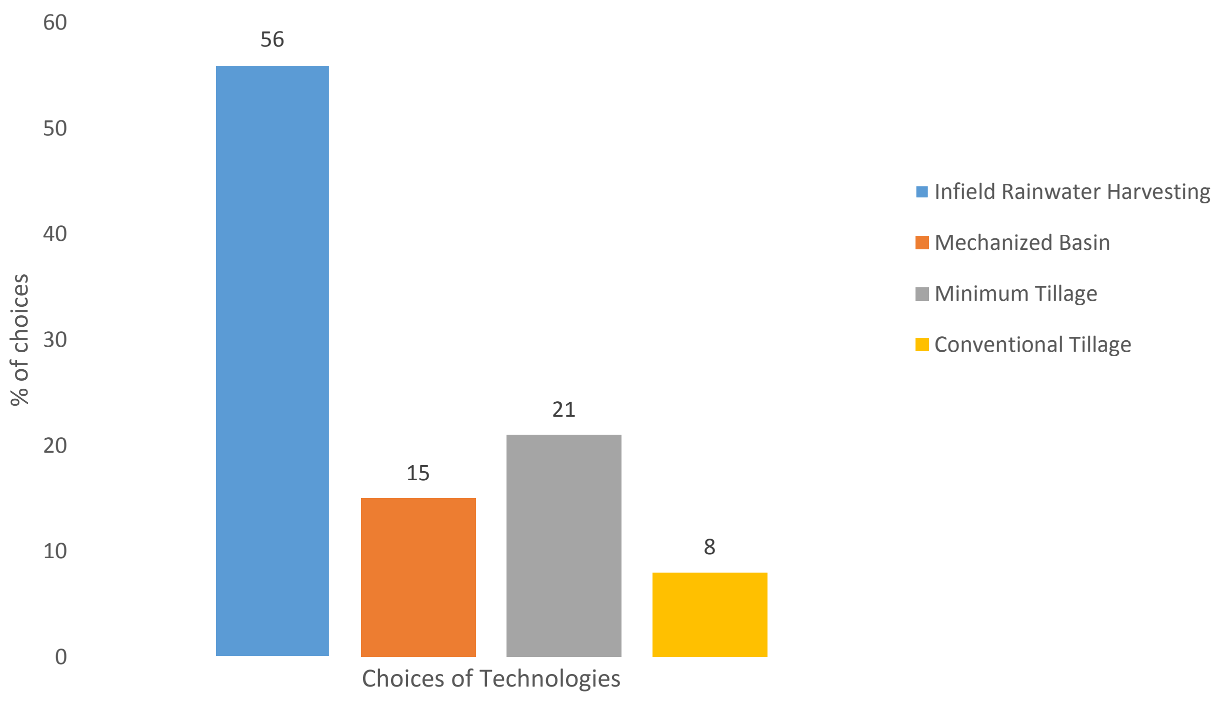

Figure 11: Farmer's choices of technology for individual field implementation.

After presentation of results from implementation and clarification of technologies to farmers, they made their choices. From observation and Bio resource Unit data (BRUs), it was apparent that Swayimane is mostly a hilly and mountainous steep area. This can also be confirmed by farmer's choice of technologies from above figure. Fifty six percent of farmers opted that IRWH can be an option for their choice of planting for the following season. Smallholder farmers within the area relies on rain fed agriculture as their source of irrigation upon their agricultural fields. This entails the significance of capturing rainwater for their production. Results from studies by (Welderufael, Le Roux, & Hensley, 2012) and (Rensburg, Bothma, Fraenkel, Le Roux, & Hensley, 2012) also proved that IRWH can increase crop yield (maize yields specifically) significantly and subsistence farmers can also improves productions which can satisfies and improves their household food and nutrition security status. It therefore can be concluded that farmers that chose IRWH as their choice for next agricultural season are in better chances of improving their food productions.

Soil and water resources are primary inputs for human survival. Towards achieving food and nutrition globally, conservation agriculture has been amongst most preferable methods of farming. This technological method has been identified as a production system that enhances resource management for greater and long term consistency while also ensuring maximum productions. Amongst other CA practices falls minimum tillage (MT). 21% of farmers from the study preferred minimum tillage as a technology of their choice. If the technology is well implemented and practiced, massive increase in crop production can be obtained. Countless studies that have been applied with the technology has shown quiet improvement towards crop production and food security in different parts of the world. A study by Dhar, Islam, Jannat, and Ahmed (2018) Also emphasizes that proper application of conservational agriculture can lead to descending spiral of soil and water degradation, minimise cultivation costs for subsistence farmers and making agriculture more resource-use-efficient. The key attributes of obtaining such magnificent outcomes from this technology is to equip farmers with as much help and knowledge as possible.

Mechanized basin and conventional tillage practices were least chosen by farmers as their choices for the next coming season with 15 and 8 percent respectively. Choices of technologies by farmers were motivated by different reasons that each individual farmers saw as guidelines within their agricultural plots. The following table quotes some of the responses that farmers gave as their drivers for choosing technologies.

Table 7: Focus Group Discussion on farmers' incentives for different choices of technologies

Technology of choice	Motive behind the choice
Infield Rainwater Harvesting	• "My plot is steep and whenever it rains, water floods all my crops get washed into a stream " • "Shorter rainfall, so I want to capture and store it upon my field soils."
Mechanized Basin	• "I would have preferred IRWH but due to that my field is smaller and runoff space can take most of my field, MB seemed to be suitable for my field."
Minimum Tillage	• "Unlike other technologies, this one does not require more time to use." • "This technology is also financial affordable for my farming as compared to other techniques."
Conventional Tillage	• "I have been using this method and obtaining maximum yields. It's like a natural method to my farming."

Farmer's choices of CSATs and the reasoning are key components that determines their understanding and willingness to adopt technologies. With right help and information, farmers may achieve maximum production at which household food and nutrition security can be met. Maximum production can also ensures surplus for markets purposes. Majority of farmers were elderly people dominated by woman. Such findings correspond with the study by Akter *et al* (2017) that women plays a significant role towards ensuring household food and nutrition security. Their participation may be jeopardized by other commitments since women have more household roles and limited time. The level of farming experience that they have is crucial and may facilitate acceptance and adoption of CSATs, but the age variation on the other end may limit acceptance of CSATs that requires a bit of energy to be implemented. A study by Subakanya (2015) emphasizes that an old aged and female dominated rural agricultural area may have serious challenges for sustainability of prevailing national agricultural strategies. Extensive work during the implementation from demonstration sites resulted into some farmers opting to go with minimum tillage method as it seemed to require less energy. Those are some of the reasoning for farmers to continue using their current farming methods regardless of the effect that CSATs may bring upon their production.

4.5 Conclusion and Recommendations

Fighting the challenges brought by climate change on human and environment are amongst key process to improve human livelihood. Food and nutrition insecurity is exacerbated by climate change and requires collaboration from different experts to conquer it. The main objective of this chapter was to bring on board different stakeholders to fight climate change challenges faced by rural smallholder farmers, through selection and implementation of CSATs. Collaboration and participation of different stakeholders from rural farmers to external sectors played a crucial role in the processes of selection and implementation of CSATs. The incentives of all stakeholders were the key drivers of participation to achieve a similar goal of livelihood empowerment and environmental management. Through the use of different methodological tools, the objectives set for this chapter were achieved, although there were minor challenges. Firstly, the lead farmers allowed the use of their plots as demonstration sites. Those were the plots at which they produce for marketing to generate income for household livelihood and food security. Given such instances, farmers felt the need to intervene without proper communication with the project leaders. Such actions interfered with the results since comparison of different technologies can no longer matter as different actions have been applied to one plot. To minimize and limit farmes' self-preservation and fears of production losses, it is recommended that on initial introduction of CSATs, a smaller portion of the land be used. A proper communication between farmers and project leaders must be emphasized to ensure a proper beforehand sharing of information and actions being applied within the fields. The aims and objectives of projects are to empower people. It is therefore important that developmental meetings be held within the communities at which the projects will run. Farmers have indicated technologies of their choice and the willingness to participate, it is recommended that all the interested farmers are attended on the following season of planting. Given the fact that majority of rural dwellers are children and elderly people, setting and implementation of some CSATs nay be labor intensive, it is recommended that external stakeholders help by the provision of implements.

CHAPTER 5: DRAFT MANUSCRIPT 2: PERFORMANCE OF MAIZE CROP UNDER DIFFERENT CLIMATE SMART AGRICULTURAL TECHNOLOGIES (CSATs)

Abstract

Plant growth and development are affected by different soil and water management practices implemented by farmers. Different implemented CSATs were associated with different soil and water management practices that resulted in different maize height and development. The results in plot one displayed that IRWH and MB outperformed MT and CT. These results revealed that IRWH and MB collected and stored more water in the soil to support plant growth and production since it captures water from runoff area and stores it in the basins, which was not the case for CT and MT. Similar trends were observed in plot 2 site except that CT also performed better which can be associated with farmer's management practice. Biases in the application of management treatment by a farmer resulted in excessive maize growth under CT practice when compared to other technologies. Lack of responsible individual and animals resulted in a complete vegetable failure in the school plot. The crops were crowded by weeds and did not grow to maturity. Rabbits also grazed upon the crops, resulting in failure and there were no results to present.

5.1 Back-ground of the Study

Smallholder agriculture and subsistence farming in South Africa has been recognized as the plan of action through which poverty reduction and rural development can be accomplished. Majority of rural dwellers shows an incredible passion for farming, especially elderly and retired people where a larger proportion being women. This is seen through a number of co-operatives established in rural areas which include farming and stokvels organisations, and small plots of gardens that the majority of rural dwellers have within their households yards. With this recognition of subsistence farmers passion and love, South Africa's National Development Plan (NDP) has recognised smallholder agriculture as a driver towards development in rural areas, improving up to at least 370 000 people's livelihoods (Pienaar & Traub, 2015).

The influence of subsistence agriculture on people's livelihoods in the majority of rural African places is directly related to food security. Besides the mere fact that subsistence farming provides food at a household level, it also acts as an income generating strategy enabling dwellers to exchange products at cheaper prices from one another. In some instances, subsistence farmers sell their productions onto commercial markets, creating jobs for their fellow community members. However, their vulnerability to climate related issues places a massive burden upon their production, creating food shortfalls and insecurity at household. Several studies have found that subsistence and smallholder farmers suffer massively from the results of climate change more specifically in the Southern African region (Thorlakson & Neufeldt, 2012), (Habtemariam, Kassa, & Gandorfer, 2017), and (Abdul-Razak & Kruse, 2017).

Climate Smart Agricultural Technologies (CSATs) has found its way to be amongst practices and innovations aimed towards equipping subsistence farmers with knowledge and skills suitable for adapting under this conditions. This is in proportion with findings from the study by Habtemariam *et al.* (2017), which indicated that proper agricultural interventions are necessary to minimize climate change impact over struggling subsistence farmers. CSATs have a massive potential for improving food production to meet hiking population growth. Not only does CSATs aims at maximising produce, but Kaczan et al. (2013) emphasize that integrated management of soil, water and biological resources are amongst significant outcomes aimed by farmers using these technologies. Although CSATs aim to attain all possible good for agriculture and conservation, it does not suggest that every practice applied in every location should produce the desired outcomes (Lipper *et al.*, 2014). Given such instances, selection and implementation of CSATs require adequate local and regional climate conditions to minimise chances of failure. Consideration of soil depths and crops types are amongst crucial characteristics need to be considered before implementation at any place.

The key significant attribute towards achieving food and nutrition security in rural African household is the ability of farmers to be willing and be ready to accept change. This is critical in assessing farmer's readiness and willingness of adopting new technologies and innovations aimed at improving food production. Smallholder farmers tend to stick with their knowledge regardless of changing times and climates. In many cases, subsistence farmers tend not to accept change as they believe in what they doing and myths regardless of production shortfalls. Given the fact that the resilience of different crops to climate related issues are different from what they used to be and continues to change, it is crucial that smallholder farmers are well equipped with such knowledge to enable their continuous food production for food and nutrition security at household levels.

Maize plants grow to maturity after a period ranging from 4-6 months depending on the variety. Local weather conditions determine the frequency and the rate at which the plant grows passes from one stage to another. The period at which a particular plant takes to complete a particular growth stage is directly related daily temperatures of the location, and cooler temperatures tend slow down and delay the growth while warm temperatures accelerate maturity rates (Moeletsi, 2017). The study was conducted under two different sites within the same municipality. Varying weather conditions within the wards resulted into different growth rates and maturity being reached differently. Climate Smart Agricultural Technologies have also resulted in maize heights and development stages being reached during different times, regardless of the fact that they were all planted during the same week.

5.2 Study Methodology

The study was conducted in the area of KwaSwayimane under uMshwathi municipality. Given the variety of climate attribute by Bio Resource Unit data, three sites from different wards were used as the demonstration of CSATs for farmers with an impression that a better suitable technology will be identified after several tests have been done.

Different research methodologies were incorporated to gather enough data and evidence for creating answers to research question and objectives. Data was collected using a mixed method approach technique. This is a technique that combines the qualitative and quantitative approaches within different phases of the research process (Terrell, 2012). It involves scientific assumptions that guide the direction of the collection and analysis of data and the mixture of qualitative and quantitative data in a single study or series of studies (Cameron, 2011). During this study, subsistence farmers were sampled purposively with the main priorities being those engaged in farming and whom also are willing to be included in the study.

Data concerning household demographics were collected using a research questionnaire. Further data were collected during and after the implementation of selected technologies. This data was critical towards getting feedback from farmers after observing technologies and further explanation being made. Through this technique, household who still participates in agricultural production were determined. Focus Group Discussions (FDGs) is another data collection technique that was also employed during the research in gathering information regarding farmer's local knowledge, and also at explanation and clarification of selected climate smart agricultural technologies. Under this technique, people are gathered into groups, creating environmental conditions to be more conducive for more spontaneous expression of each one, and facilitating the interaction of everybody (Freitas et al, 1998). This method is significant in the manner that participants can become a forum of change through sharing of information and knowledge regarding soil and water management ideas from farmers which can be integrated with CSATs for the purpose of the project (Gibbs, 1997). To measure maize performances under different technologies, the study used maize growth and development stages by du Plessis (2003). The study grouped maize growth and development into 10 stages, emphasizing that the height is closely affected by plant water availability. For the purpose of this study, a random sample maize height was measured from each technology at every growth and development stages.

5.3 Results and Discussion

This chapter presents findings from the study where a comparison of maize growth under different CSATs is monitored for the first production. One of the research aims is to decentralize CSATs to other members of cooperatives and therefore the study also presents farmer's choices of technologies and willingness to adopt for their own agricultural fields.

5.3.1 Demographics

A large proportion of farmer's cooperative members attended demonstration sites where CSATs were done were elderly people with the majority being women. Of these, 68.3% were female subsistence and smallholder farmers while 31.7 % were male farmers. These findings further correspond with the majority of studies emphasizing that the majority of subsistence and smallholder farmers in African rural communities are women. This also complies with findings that women are important for household food security as their contribution is over fifty percent of the world's food (Akter *et al.*, 2017).

Table 8: Basic demographics of farmers participated during implementation and assessment of technologies.

Variable	Frequency	Percentage
Gender		
Male	19	31.7
Female	41	68.3
Total	60	100
Age		
0-30	11	18.3
31-40	2	3.3
41-50	12	20.0
51-60	15	25.0
+61	20	33.3
	60	100.0

Above that admirable contribution, women are core players towards household's income generation as they contribute 10 times more compared to men. Women are also key players towards ensuring that household members are taken care of in all aspects of life ranging from household food and nutrition security, child health as well as their educational requirements (Akter *et al.*, 2017) and (Sharaunga, Mudhara, & Bogale, 2016). The data findings also indicated that the majority of farmers were over 61 years (33.3 %), followed by 51-60 years with 25%, and followed by 41-50 years with 20%. The majority of this elderly farmers were pensioners who have retired from their jobs, and considered farming as their passion keeping them busy within their houses. The study also found that 21.6% of farmers partaking part in agricultural functions within the cooperatives were youth (20-40 years of age). The majority of youth in South African context after completing their matric move to urban cities try and secure job opportunities. Not only this is a South African issues, studies by (Naamwintome & Bagson, 2013) and (Brooks, Zorya, Gautam, & Goyal, 2013) over different parts of the globe also confirms findings that youth participation in agriculture is missing. Bednaříková, Bavorová, and Ponkina (2016) emphasizes that from 2005 to 2014 the proportion of youth farmers working from agriculture related sectors has decreased from 20.7% to 19.2%. Consequently, agricultural production is bound to suffer dramatically given the lack of youth participation in the next coming decades.

5.3.2 Farmer's livelihood strategies

Farmers participated during the study defined employment differently. To some farmers, spending days within their field planting and caring for crops is not seen as an employment, but seen as leisure time while some farmers consider that as employment. Famers also participate in different jobs other than farming to meet household food and nutrition security. The following table (table 3) shows different characteristics of farmers and households and also the extent at which they participate in agriculture.

Table 9: Employment status, Household available land sizes and farming purposes.

Type of Employment	**Frequency**	**Percentage**
Smallholder farmer	32	53.3
Government/Private Sector	6	10
Self employed	2	3.3
Smallholder and Self employed	7	11.7
Unemployed	13	21.7
Total	60	100
Household Available Land Size		
-0.5 Ha	8.3	8.3
0.5-0.9 Ha	5.0	5.0
1 Ha	23.3	23.3
2-4 Ha	63.3	63.3
Total	100	100
Farming Purpose		
Household Consumption	24	40
Consumption and Selling	19	31.7
Selling	16	26.7
Not Farming	1	1.7
Total	60	100

A larger proportion of rural dwellers in African developing countries are not formally employed where they spend their daily hours working for formal salaries. This favours the results from the study by Nagler and Naudé (2014) conducted in many African developing countries that rural commuters where lack of sufficient formal employment is prevalent, people participate into low-risk activities for survival. The contribution of such activities towards household income in Africa is significant and improves household food security. Meeting household food and nutrition security require farmers to participate in different income generating streams to support household livelihoods.

From farmer's responses and perceptions, the study indicates that 53% consider farming as valid employment at which they use to sustain household livelihood and achieve food and nutrition security. Although a larger percentage considers farming as permanent employment, a majority (21.7%) also considers themselves unemployed regardless of the fact that they participate on farming daily. Results further shows that 40% of participants farm to supplement and improves food security, they only plant for household consumption only. Similar findings from the study by Sibhatu and Qaim (2017) indicates that much of the food in Asia and Africa is produced by smallholder farmers, making this practice crucial in ensuring household food and nutrition security.

Land accessibility for farming purposes seemed not to be an issue for farmers that participated during the study. Although not everyone has an equal portion of land, everyone does have a smaller portion where vegetables can be produced to supplement household food and nutrition security. 13.3 percent of farmers had less than a hectare of plot used for farming while 23.3 percent had a hectare field. 63.3 percent of farmers had more than a hectare of farming field owed or borrowed. Given that each farmer has a piece of land at which they produce something shows how dedicated and passionate are smallholder farmers towards achieving food and nutrition security at a household level. A study conducted by Van Averbeke and Khosa (2007) in Limpopo indicated that food obtained from household agricultural lands contributed significantly to household nutrition and without farming, households food security would be reduced massively. From the table above, this can be further approved by the findings that 40% of farmers are only farming for household food. To further enable their access to other household necessities, farmers sell their surplus food mostly to informal markets. 31.7 farmers from the study population indicated that they farm for household consumption but when there is surplus and markets avail their willingness to buy, they sell. Through such actions, income is generated enabling farmers to access other inputs for household livelihood needs.

Farming is the major livelihood strategy to creates and build societies in African rural household dwellers. Co-operatives are formed at which mostly farmers shares adapting strategies towards new farming techniques to improve food production and other life necessities. Income generating and employment are created through agriculture. Recently, smallholder farmers have realised the possibilities and opportunities that agriculture can bring towards their living conditions. Through the study, it was found that 26.7% of the farmers in the study population farms only to sell all their produce.

5.3.3 Local Adaptation and Indigenous Knowledge Practices

Adapting to climate change challenges has called for smallholder farmers in KwaSwayimane to innovate their adapting knowledge and skills to ensure a continuous food production for household food and nutrition security. Adapting technologies by farmers differs from one region to another. As discussed by Zilberman, Lipper, McCarthy, and Gordon (2018) on the study conducted, climate change impacts on agriculture are diverse over space and time and the impacts vary from one region to another. Therefore, innovation in agriculture is a significant response towards achieving effective and equitable adaptation and mitigation technologies for improved production and food security. Table 4 below shows adapting technologies that farmers who participated in the study use to improve their food production for food and nutrition security and manage water and soil natural resources.

Table 10: Farmers current adapting technologies

Technology Applied	Frequency	Percent
Animal Manure	11	18.3
Two Different Practices	19	31.7
More than 3	22	36.7
None	8	13.3
Total	60	100.0

Results from the study indicated that the majority of farmers participated during the study apply more than three indigenous based farming technologies towards improving soil productive capacity and conserving water resources. From farmer's responses, animal manure seemed to be the main application used. The reasoning behind this was that majority of farmers own livestock and even those who do not own one, the atmosphere within the community is conducive enough to allow farmers to share farming implements and practices from tools to inputs.

During Focus Group Discussions (FGD) sessions, farmers gave explanations towards soil and water management technologies which they apply upon their fields. FDGs are commonly used as a qualitative approach to get a deeper understanding of social concepts (O Nyumba *et al.*, 2018). This was critical in enabling farmers to further explain and give technologies that are valid in their region and also share amongst themselves to help one another improves their household food productions. The technique intends to acquire data from a purposely chosen group of individuals rather than from a statistically representative sample of a broader population which happened to be subsistence farmers for this research. The following table (table 5) quotes some of the responses that were given by farmers as their techniques of ensuring successful adaptation under current climatic conditions.

Table 11: FGDs responses of local adaptation strategies by farmers

Management/Adaptation Strategy	Responses from farmers
Soil Related Practices	• "I spread animal manure immediately after harvesting. By doing so, it will decompose and spread all over the field and when next season come, the soils will be ready and have nutrients required by plants." • "I plant my plots twice a year using different crops. For instance, if I planted maize during summer, later winter I put beans so that the soils does not get tired and loosen up." • "A mixture of sugar cane leaves, cabbage leaves, potatoes leaves and many other trash is also what I use. This mixture is commonly known as Ivundela locally. This is buried under shallow holes within the field before planting." • "The soils in my field are a bit loose (sandy). So to prevent erosion I do furrows at the edge of the field to prevent water from running into my field and erode my crops."
Water Related Practices	• "Within my garden, I dig small holes so that when it rains water fills up and get stored within those holes." • "I use grey water to irrigate my garden. Soap causes damages on plants sometimes. In order to eliminate such damages, I mix grey water with ashes and leave it for a day before applying to crops. This method also helps towards killing insects that attacks my crops." • "I do not irrigates frequently, only irrigates when I notice some plants wilting or when it has been sunny for more than few days."

Different farmers from the same region also use different technologies depending on challenges at which they individually faced upon their plots. Out of all the technologies, farmers had a common interest in managing both soil and water resources for better production towards food and nutrition security. Animal manure seemed to be a more incorporated method of adapting by farmers as both for soil and water management activities. Different studies also indicate that animal manure and plant residues play a crucial role in subsistence farming. Such practices improve soils humus, indirectly binding soil particles (Zemánek, 2014). Decomposition of such organic matters releases soil nutrients taken up by plants. Animal Manure treatments addition also minimise soil water evaporation in sowing, resulting in an increase soil-water contact and plant water uptakes being increased (X. Wang *et al.*, 2016).

5.3.4 Maize growth performances under different technologies.

Maize plant performed differently from one Climate Smart Agricultural Technology to another. Different technologies affected soil water and nutrients differently, resulting in plant growth differences. CSATs comparison is done to assess which one can be suitable for an area, given that it results in a better plant performance when compared to other technologies. Climate variations and soil characteristics are key inputs that need to be assessed and addressed before the selection of technologies. Given such instances, failure and success of technologies may be determined not only by its potential, but also different circumstances faced upon the growing season may result in unforeseen failures.

Plot 1

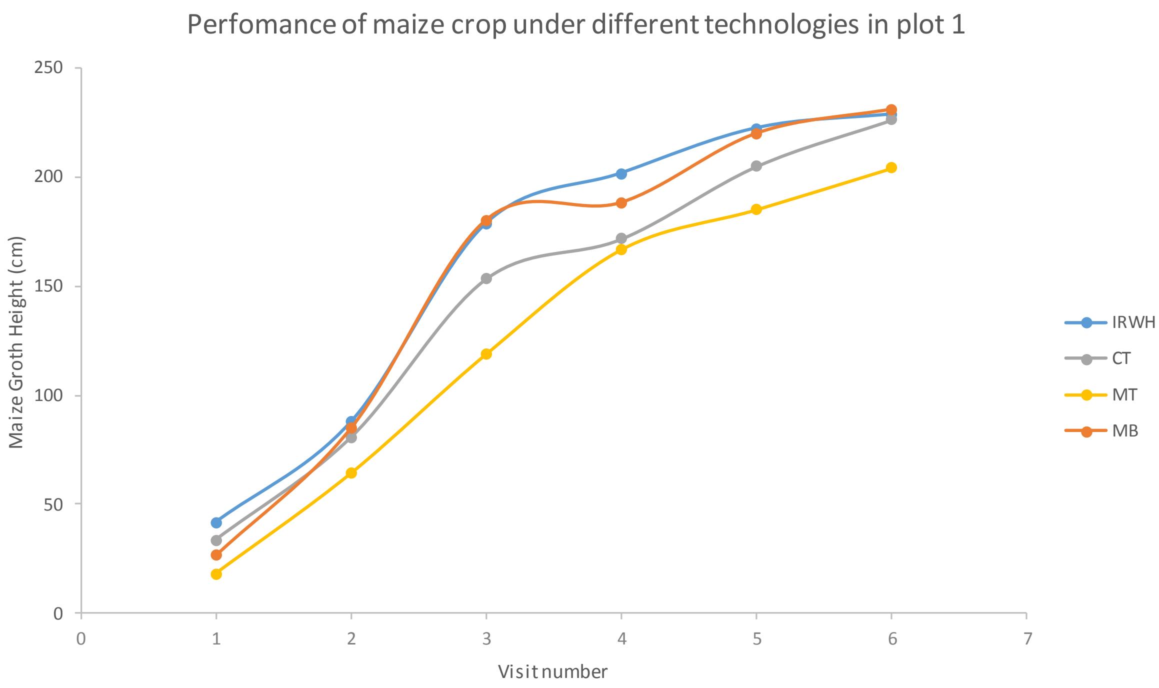

Figure 12: Comparison of maize height under different technologies in plot 1

From figure 12 above, it can be seen that maize height measured under different technologies was significantly different from one another. During the first visit, maize from Infield Rainwater Harvesting (IRWH) appeared to be growing faster than any other technology. Conventional Tillage (CT), Mechanized Basin (MB) as well as Minimum Tillage (MT) technologies followed respectively. This may have been caused by a number of reasons. Firstly, the plot was as big as one hectare. Planting the whole hectare within the same day using hand pulled hoes could have been impossible given the state and age of subsistence farmers. The separation between planting days could be amongst reasons as the later germination of maize from other technologies. Overall, all maize heights under different technologies were below fifty centimeters.

Capturing and storing rainfall water within agricultural fields is an essential element towards improving crop growth and development. Water is a necessity for all living organisms, plants also being included. Up to 90% of all growing plant constituents are water contained. Water plays a crucial role towards transportation of nutrients within different plant part from roots to leaves, therefore measuring plant height indirectly indicates water effects and availability for plant uptakes (Limjuco). Observation from the above figure indicates an observable maize growth from all technologies during the second visit. IRWH and MB technologies are useful towards capturing and storing rainfall and runoff water within soil film for plant uptakes and development. The study also found that during the second visit which was the next stage of maize development, plant heights of and MB IRWH were much taller compared to MT and CT respectively. MB sprung out and grew past CT whom was initially taller. From such observation, concept of rainwater storage is clearly practically articulated. CT have soft and porous soil films, giving a higher infiltration rate as compared to other technologies. This could potentially result into large water quantity infiltrating towards water table, reducing plant available water for growth and development. IRWH and MB have a slower infiltration rates resulting into enough time for plant water uptakes. Given enough plant water contact and uptakes, development and growth can be expected to be higher and faster for these technologies. Yield and products can also be expected to be much higher where efficient plant water is available since it solubilize nutrients to be available for plant uptakes. This findings can also be in consistency with the study by (Lebel, Fleskens, Forster, Jackson, & Lorenz, 2015), (Botha, Anderson, & Van Staden, 2015) which concluded that conservation agriculture more especially application of technologies that captures and stores rainfall increases food production for smallholder farmers.

Minimum tillage and conventional tillage technologies on plot one appeared to have slowest maize growing rate throughout when compared to MB and IRWH. One key component towards achieving maximum production under MT or no-till practice is to minimise weeds within farmlands. Similar conclusion from different studies has emphasized that weeds are leading restriction to crop production and are responsible for considerable crop losses in maize production systems throughout the world (Mhlanga, Chauhan, & Thierfelder, 2016), (Jha, Kumar, Godara, & Chauhan, 2017) and (Sardana, Mahajan, Jabran, & Chauhan, 2017). Management practices under MT in plot one were delayed unintentionally and weed outgrown and outcompeted maize growth. Observing from results above, maize growth under MT technology was struggling due to a competition of available nutrients and water sources between maize plants and weeds.

Towards the maturity stages, maize under all technologies reached similar heights except for that on MT. CT maize also sprung to similar heights as those from IRWH and MB towards final growing stages. Maturity and maximum heights for maize are not reached at once regardless of same planting dates. Similar to seed germination, it takes five to fourteen days for maize seeds to germinate from soil depending on weather conditions and they do not germinate all at once (Dlamini, 2015). Results from the above figure show little difference in maize heights between fifth and sixth visits of IRWH and MB. This indicates that maturity stage was reached earlier under this technologies as compared to MT as and CT.

Given such outcomes from all technologies implemented in plot one, it can be concluded that IRWH and MB technologies outshined CT and MT respectively. Faster growing rate and maturity were reached earlier under this technologies. Such results can be essential benefits of using these technologies as adapting strategies under the influence of climate change. Early maturity can also enable farmers to plant under one field for multiple times within the same season. By so doing, food production for household food and nutrition security can be improved, giving farmers an opportunity also to rotate crops. Marketing opportunity can also arise by application of this CSATs. Increased production can enable farmers to sell surplus products whether on commercial or informal markets. Cash generated from such practices is crucial for small-scale farmers to supplement household nutrition security aspects as they can buy products that are not produced within their fields.

Plot 2

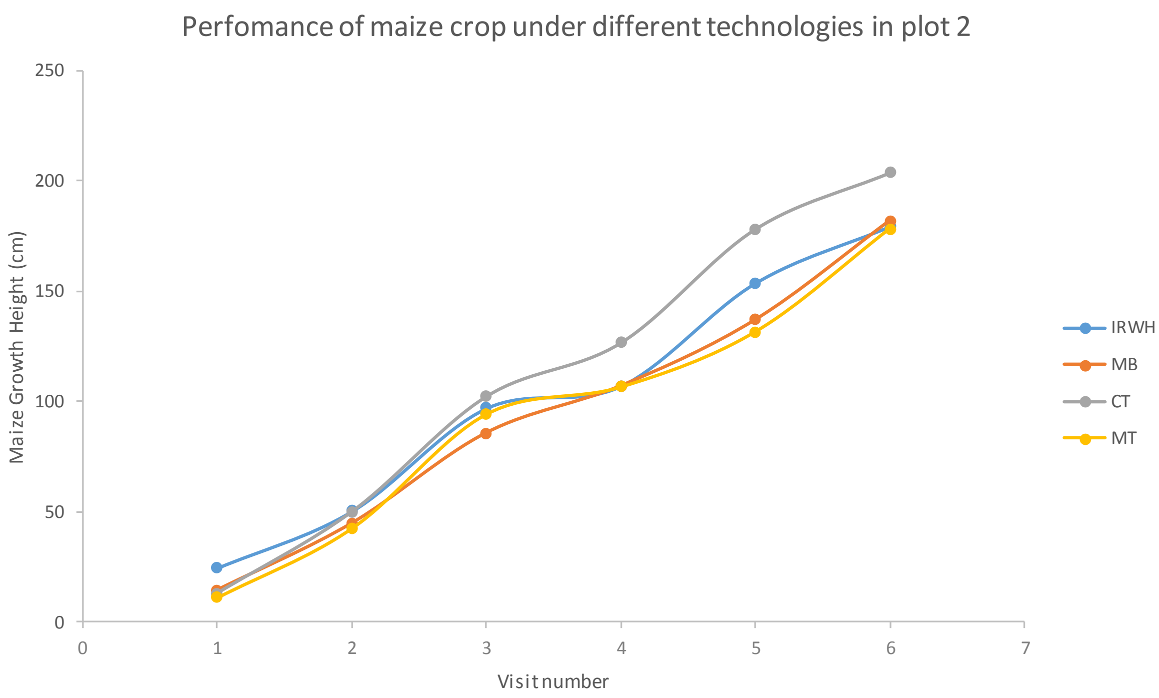

Figure 13: Comparison of maize height under different technologies in plot 2

Study area plots were distant from one another, resulting in different weather variations upon crops and technologies. As attributed by bio resource unit data, Swayimane is classified as an area with different climatic variations within the same municipality. Maize growth from different technologies in plot two differed from one technology to another as depicted from the above diagram. From measurements taken during first growth stages or the first visit after germination, IRWH appeared to have emerged faster than other technologies. MB, CT and MT were of the similar height during the first visit. Two weeks after germination, CT technology picked up and reached a similar height with IRWH. There was a slight height difference between MT and MB, where MB has grown taller.

Competition between crops and weed critically endangers maximum development and crop growth. Such competition results into plant available resources and nutrients being up taken by weeds instead of plants, resulting into crop wilting and dying (Gallandt & Weiner, 2007) and (Swanton, Nkoa, & Blackshaw, 2015). Outcomes from such competition result into production shortfalls and crop quality suffers tremendously. During the implementation of all technologies in plot two, the field was not well sprayed of weed. Observing from the fourth visit, MT technology outshined all technologies with a massive difference. Implementation of this technology was done by overturning the soils through tractor pulled plough. Such practices resulted into weed being overturned underneath surfaces and literally dying off. Although it grew back during seed germination, its competitiveness with the crops was not of greater effect towards crop growth.

The transition of growth rate from stage three to stage four was severely lagging under IRWH, MB, and MT. Observing from the graph above, the height measured from visit three does not differ significantly from the height measured in visit four. Such observations clearly articulate the effects of crop and weed competition for resources. Improper attention of weed upon croplands for small scale farmers may possibly decrease their productions. Food and nutrition insecurity challenges can subsequently increase. Overall, CT technology outshined all others in under plot two. Although towards the maturity stages all four technologies were reaching for similar heights. The sprung of maize growth within IRWH technology from visit three to visit four after weeding shows that if weeding was applied properly in the beginning, the results would have been different as what they are after the first season of growing.

Plot 3

Cooperation and coordination between parties involved in any partnership play a significant role in achieving desired goals and outcomes. Unless clear tasks are assigned to each individual and they become committed to their assigned tasks, achieving intended objectives has a higher probability of failure. To ensure successful accomplishment of anticipated objectives and goals, Mensah, Karantininis, Adégbidi, and Okello (2012) proposed from their findings that there should be consideration and setting formal contracts between involved members to ensure their cooperation. By so doing, each member’s commitment and participation upon obtaining cooperative’s vision can be improved.

Spinach, cabbage and beans were vegetables planted in plot three using the IRWH technology. IRWH was integrated with sub-technologies since the plot was smaller in size compared to the other two plots. Crop growth to maximum maturity failed over multiple reasons. Firstly, animals grazed and fed out of the crops in the field. Preventing such challenge was impossible due to the fact that the school is properly fenced. Lack of commitment and passion from assigned cooperative members also played a bigger role towards the failure of technologies and production. Vegetables were crowded by weed and could not grow and develop properly. Contrary to findings by (Kolade & Harpham, 2014) which found that Cooperative membership has a high impact compared to other socioeconomic factors, lack of cooperation and coordination of members resulted in a failure of technologies and production losses for this study. Despite such contrary and failures obtain throughout this study, another key component to achieve success through cooperatives is ensuring a lower number of members. (Cazzuffi & Moradi, 2010) emphasizes from their study that a larger number of members can create group confliction and problems.

Lack of cooperation and commitment could have contributed mostly to technology failure, but also natural characteristics of the field contributed. Textural characteristics of soils in plot three were too sandy, resulting in higher susceptibility to erosion. Unlike clay soils, sandy soils contain more loose particles which can be easily eroded. To aggravate such failures, the slope from plot three was steeper. Implementation of IRWH requires the creation of ridges to stop from running down the slope. Due to soil textural characteristics, ridges were eroded whenever rainfall came.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusion

Climate Smart Agricultural Technologies (CSATs) are an alternative exploration of farming techniques other than normally used conventional farming. Majority of such technologies are agriculturally sustainable, promoting management and conservation of natural resources for future uses. However, CSATs also aimed at ensuring and improving food production for communities that undergoes greater crop production failures under climate change. The objective of this study was to evaluate various CSATs for increased crop production and to identify those that are applicable to the current conditions of selected study sites for implementation purposes. After selection and implementation, the study aimed at assessing and comparing the growth rate under different implemented technologies with an assumption that suitable technology will show a faster growth rate and taller maize plants, while also vegetables mature faster. Successfully, selection and implementation of various CSATs were done into three different plots in the area of KwaSwayimane, with assessment and comparison of growth done at every growth stage. Due to climatic variations and the commitment of responsible partners, different results and observation between implemented CSATs were obtained.

Final conclusions cannot be drawn from this results as farmers were exposed to these CSATs for the first time. Nonetheless, different technologies resulted into different growth rate when compared to one another. In plot one, Infield Rainwater Harvesting (IRWH) and Mechanized Basins (MB) appeared to have a faster growing rate than Conventional Tillage (CT) and Minimum Tillage (MT). It can be concluded that the creation of water storage basins improved soil water content for these two technologies hence they showed a faster growing rate. Soil water content may not have been a cause of slow growth measured under MT. Crops under this technology struggled to compete for both water and nutrients since the plot was highly populated with weed.

However, climatic variations and farmer’s activity resulted in different outcomes for plot two. Unlike in plot one where significant growth differences were clear from the second stage, in plot two clear differences were observed from stage three upwards. Unequal application of similar treatments within technologies resulted in significant growth differences. CT technology showed a significant growth compared to other technologies in plot two. Since CT overturns and destroys much of weeds during its implementation, such practices yielded to less weeds. Late spraying of weeding chemicals resulted in severe competition between maize and weeds for water and nutrients. After weeding which happened from stage three, IRWH grew abruptly followed by MB and MT respectively. Such findings signify the impacts of unequal applications of treatments within technologies. Such actions need to be avoided as they could lead to wrong conclusions and suggestions, misleading farmers to use improper technologies for adapting to climate change and creating production shortfalls.

Proper assignation of tasks and responsibilities to each individual is critical towards ensuring the achievement of desired outcomes under communities and school plots. Although some failures in school were caused by natural characteristics of the plot, significant failures were mainly from anthropogenic and need to be carefully prevented on the next season.

6.2 Recommendations

Success of decentralizing CSATs to other farmers requires commitment and responsibilities from farmer's themselves and a virtue and determination towards achieving maximum food production for food security. The following recommendations can be critical towards achieving such outcomes:

- Clear clarification and assignment of tasks and responsibilities to all involved parties.
- Formal or informal contracts binding each party or stakeholders to their responsibilities.
- Early commencement of implementation of activities and co-ordination of activities to ensure implementation and planting within the season.
- Advice towards the significance of recording all farm related activities including required inputs, yields, planting dates etc.
- Ensuring effective communication with involved stakeholders to ensuring the provision of implements to farmers in time.
- Clarification of incentives and creation of learning and empowerment culture.

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APPENDICES

Questionnaire 1: Demographic Data

Section a: general information

Questionnaire #:	
Enumerator:	
Respondent name and surname	
Mobile No	
Province	
Municipality	
Ward	
Community/Co-op Name	
Date	

A1. HOUSEHOLD DEMOGRAPHIC: Please list the names of everyone considered to be a member of the household, starting with the respondent.

ID CODE	**Name of household member**	**Gender** **Code** 1 = M 2 = F	**Relationship to the household head?** **Code** 1 = head 2= spouse 3= child 4= brother/sister 5=parent 6=in-law 7=grandchild 8= other (specify)	**Age**	**Marital status?** **Code** 1 = single 2= married 3= divorced 4= separated 5=widow 6=in-law 7= cohabiting 8= other (specify)	**Number of years at school?**
1						
2						
3						

A2. How many people in the household are:

I. Younger than 15 years old ___________
II. Between 15 -64 ___________
III. Over 65 ___________

A3. How many people in the household:

I. Work ____________
II. Work in agriculture __________
III. Are at school _____________

A4. What grants do people in the household receive?

I. Child ______________________; how many people receive this grant ______
II. Old Age pension ______________________; how many people receive this grant ______
III. Disability ______________________; how many people receive this grant ______
IV. Chronic illness ______________________; how many people receive this grant ______
V. Other grant ______________________; how many people receive this grant ______

A5. EMPLOYMENT STATUS

ID CODE	Name	**Primary Occupation** **Code** 1 Smallholder farmer 2 = Government or private company 3= Self-employed 4= unemployed	**How much money did the household member earn from this job**? **Code** 1. <R 1000 2. R 1 001 – R5000 3. R5 001 – R10 000 4.R10 001 – R15 000 5.R15 001 – R20 000 6. >R20 000 7. None	**How often is the member paid for the primary occupation?** **Code** 1=Daily 2=Weekly 3=Forth night 4=Monthly 5=Seasonal	**Other Source** **Code** 1 = remittances 2= government grant 3=business/petty trade/self-employed 4=other	**How much money did the household member earn from this job**? **Code** 1. <R 1000 2. R 1 001 – R5000 3. R5 001 – R10 000 4.R10 001 – R15 000 5.R15 001 – R20 000 6. >R20 000 7. None	**How often in the member paid for the secondary occupation?** **Code** 1=Daily 2=Weekly 3=Forth night 4=Monthly 5=Seasonal
1							
2							
3							

A6. HEALTH STATUS

Is there anyone who is disabled in your household?.... ....

A Yes	**B** No

Is there anyone who is on chronic medicine?....... ...

A Yes	**B** No

Has anyone in your household been to the clinic or hospital due to illness in the last month?....... .

A Yes	**B** No

A7. HOUSEHOLD LAND

Land No.	What is the land type? 1=Home garden 2= mixed cropping field 3= community garden Dry-land fields Irrigation plots inside a scheme Irrigation plots outside a scheme	What is the size of [LAND]?		Tenure status of the [LAND] 1= rights given by the chief 2=inherited rights 3=purchased rights 4=free borrowing/leasing 5=rented *** If purchased: explain the amount and the process of the purchase ***How long is the term for free leasing (a year, a season?) ***How secure is this? (Can the owner demand it back any time?)	Whose name is on the "title "or other document of [LAND]? What type of document is it? **Is it a PTO**	What was the main use of [LAND] during the last growing season? 1=Planted Vegetables 2= Planted Field crops 3= Fallow (probe if this was by choice)
		a. Area (Number)	**b. Unit**			
1						
2						
3						
4						
5						
6						
7						
8						

A8. Do women own land in your community? 1=Yes 2=NO

A9.If **Yes**, How do women get land ownership rights in your community?

1. Marriage	2. Given by Chief	3. Given by Father	4. Buy	5. Other

A10. What do you use the land for? (Please tick √ all relevant answers)

1. Farming	2. Livestock Keeping	3. Residence	4. Others (Specify)

SECTION B CROPPING SYSTEMS AND WATER USE

B1. Which crops are you growing now (indicate whether season) and how do you irrigate them?

Key: watering methods

Current Crops grown	1.Wet season Yes 2. Dry season	**Field planted in?** 1=Home garden 2=Community garden 3=Mixed cropping field	**Do you irrigate?** **1=Yes** **2=No**	**Watering method**	**Farming Purpose(s)** 1=Household consumption only 2=Household consumption & surplus 3=Selling	**Which crops do you buy for household consumption?** **1=Yes** **2=No**
1.						
2.						
3.						
4.						
5.						
6.						
7.						
8.						
9.						
10.						

1. Watering can
2.Treadle pump
3.Motorized pump
4. Sprinkler
5.Bucket drip
6.river/spring diversion
7. Family drip irrigation
8. Rain
9. Not watered
10.Other (specify)

From the above mentioned systems, which Five are more suitable for your land (Please rank them according to suitability/ preferences)

………
………

B2. What water sources do you have access to and which is the main one that you use? *(Please tick√)*

Sources	**Access** ***1=Yes*** ***2=No***	Do you use this water source for all water demanding activities in the house ***1=Yes*** ***2=No***	Do you feed your animals with the same water? ***1=Yes*** ***2=No***	Do you water your vegetable garden with this water? ***1=Yes*** ***2=No***	Do you have the legal right to? ***1=Yes*** ***2=No***	Do you drink this water?) ***1=Yes*** ***2=No***	Water bill (if you pay) in Rands **(R)**	Distance between the garden and the water source? **Measurements**: Time travelled (in seconds/minutes/hours); steps/metres/kilometres)
1. Tap water in house								
2. Communal tap outside house								
3. River/stream								
4. Borehole								
5.Well								
6.Spring								
7.Rainfall								
8.Water truck								
9. Other: Please specify								

B3.Do you usually have enough water to water your garden?

1.Yes	2.No	3.Sometimes

B4.How often do you not have enough water?

1. Between 1 week		2. between 2 weeks		3. between 3 weeks		4. between 4 weeks	

B5.What is usually the cause of having no water to water your homestead garden?
……………………………………………………………………………………………….......................................
....

B6. What do you do when you do not have enough water?

1. stop cultivation	2. Change of crops	3. Buying water	4. use polluted sources	5. Other (specify)

B7. In a week, how often do you water your homestead garden and what quantity of water do you use?

1. Once a day quantity	2. Twice a day quantity	3. Once every two days quantity	4. Once every three days quantity	5. Other (Specify) quantity

B10. Are any of the following farming decisions affected when there is no water and How?

SECTION C FARMING SYSTEMS &WATER MANAGEMENT (WATER HARVESTING & CONSERVATION

Decisions	**Effect on farming 1=Yes 2=No**	**How? (Please explain whether Yes or No)**
1. The planting time/season		
2. The types of crops planted		
3. The use of fertilizer		
4. The planting area (size) which you usually plant		
5. Your planting purpose		
6. Other (specify)		

C1. Do you know the term "Indigenous Knowledge" (IK) 1=Yes 2=No

What does it mean to you?
………
………
………

C2. Do you use any indigenous knowledge water management practices in your farm?

1.Yes	2.No

If yes, please name then
………
………
……......

C1. Do you as an individual capture rain water?

1.Yes	2. No	3. Sometimes

C3. Please indicate which method you use and whether it is owned by you as an individual or as collective community members?

1. Ponds 1= Individual 2= Community 3. Government	2. Tank 1= Individual 2= Community 3. Government	3. Reservoir 1= Individual 2= Community 3. Government	4. Other (Specify) 1= Individual 2= Community 3. Government

C4. How would you describe your vegetable garden soil?	Yes or No
1.**Clay** (smallest particles sticky to the touch when wet)	
2.Sandy (It's dry and gritty)	
3. Silty (Smooth to the touch. When moistened, it's soapy slick)	
4.Peaty (dark brown or black in color, soft)	
5.Chalky (soft rock which breaks down easily)	
6.Loamy (soil feels soft and crumbly)	
7.Other (Specify)	

C5. Which cropping patterns do you practice? *Indicate with a tick below.*

Intercropping	Mono cropping	Crop rotation	Agro forestry

C6. Have you seen any signs of climate change? 1=Yes 2=No

C7.What do you think are the main causes of climate change?

……
……
…….

C8. Do you think the following is as a result of climate change? What do you do to your homestead garden soil to cope with the condition?

Climate change condition	**1=Yes 2=No**	**Coping/ adaptation strategy**
1.Low rainfall		
2. Mid-season dry spells		
3.Late rains		
4.High rainfall (higher than normal)		
5.High temperatures		
7.Hail/Frost		

C9. Is the amount of water you have right now less, more or the same as the previous year 2016? (Please tick √)

1. Less	2. More	3. Same

If so, what is it that you suggest to be the cause of those water shortages?

____

____

C10. How has the water change (if any) affected your agricultural activities? Indicate yield increased/decreased

…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………

C11. What have you done for the following in order to protect your vegetables? Did it work?

Activity	**Strategy/technique**	**Did it work?** **1=Yes 2=No**
Retaining moisture in the soil		
Soil protection		
Soil quality		
Water run off		
Other (specify)		

Key:

1. Stone bunds	2. Ridges broad beds	3. Furrows
4. Trench beds	5. No tillage	6. Infiltration pits
7. Contour bunds	8. Vegetative bunds	9. Mulching
10. Cover cropping	11.Covering with plastic	12. Other

C13. Which factor(s) influence the farmer's choice of soil management activities?

…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………

C14. Using Indigenous Knowledge (IK) acquired from generation to generation, how do you deal with soil problems? What are activities that you as farmers implement to conserve your soil which are traditionally/ indigenous system so the production is maintained for food security?

…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………

C15. Do these activities show any success in improving food production?

1.Yes	2.No

C16. Do you practice the following to improve your soil fertility?

Kraal Manure ***1=Yes 2=No***	Fallow ***1=Yes 2=No***	Chemical Fertiliser ***1=Yes 2=No***	Compost ***1=Yes 2=No***	Other (specify) ***1=Yes 2=No***

C17. What is the main constraint preventing you from implementing other strategies you wish to use?

……

C18. Overall, how do you perceive your vegetable farming practices?

Efficient ***1=Yes 2=No***	Expensive ***1=Yes 2=No***	Time consuming ***1=Yes 2=No***	Labor intensive ***1=Yes 2=No***	Other (specify) ***1=Yes 2=No***

C19. Does using indigenous soil and water management knowledge affect household food and nutrition? Please indicate in the table below.

Impact	1= Yes = No
Improves Food Availability	

Decreases Food Availability	
No Changes observed	

SECTION F: AGENCY AND ENTREPRENEURIAL CHARACTERISTICS

F1. What is your main reason for farming?
1=Income 2=Extra food 3= Leisure time 4=Employment 5=Other________________

F2. You consider farming as a business and can be managed as such?
1= Strongly agree 2= Agree 3= Neutral 4=Disagree 5= Strongly disagree

F3. Do you distinguish (separate) your farming operations from family operations?
1. Always 2. Often 3. Sometimes 4. Rarely 5. Not at all

F4a.You are interested in expanding your farming operations (including increasing plots)
1= Strongly agree 2= Agree 3= Neutral 4=Disagree 5 = Strongly disagree

F4b. If disagree or strongly disagree, what are the factors holding you up?
………
……….

F5. Do you see yourself as a potential commercial farmer one day? 1=Yes 2=No

F6. How high is your confidence in farming as a means to a sustainable livelihood?
1 =Very high 2= High 3= Neutral 4= Low 5= Very low

F7. How high is your confidence in yourself as a farmer?
1 =Very high 2= High 3= Neutral 4= Low 5= Very low

F8. **Response**
Please rate the extent to which you agree with the following statements
Strongly disagree=1 Disagree=2 Neutral=3 Agree=4 Strongly agree=5

a. The government is responsible for the wellbeing of rural households	
b. The government must create more job opportunities	
c. I do not blame anyone for the poverty of my family	
d. I have power to affect the outcome of my farming	
f. I trust other farmers	
g. I have interest in running a farm as a business	
h. I have sufficient capital to farm	
i. I often fail to sell farm produce due to lack of market access and poor market prices	
j. Input costs of farming are far too high	
k. Labour costs are too high	
l. My right or claim to water is secure	
m. In general, availability and security of water constrains my performance	
n. In general, the water distribution network is not in a good condition	
o. I have the ability to pay for water and water-related services **Yes=1 No=2**	

SECTION G AGRICUTURAL SUPPORT &INSTITUTIONAL ARRANGEMENTS

G1. Is the food garden of benefit to you?

1.Yes	2.No

G3. What happens to the produce when there is a surplus?

G4. Are potential buyers available after vegetables have been produced? 1=Yes 2=No

1. Local (neighbours, community, schools etc.)	2. Formal market (Shops, fresh produce market)	3. Hawkers	4. Others (Specify)
Reason:			

G5. If you sell, who do you sell your produce to, and what's the reason for this choice?

G6. Do you face these challenges in your homestead garden? **1= Yes 2=No**

1. Lack/shortage of water	
2. Lack of money to buy seeds	
3. Animals eating the crops	
4. No fencing	
5. Cost of fencing	
6. Pests such as insects and diseases	
7. Lack of skill and knowledge on gardening practices	
8. Hard soil	
9. Infertile soil	
10. Lack of gardening implements	

G7. Do you have the following farming implements?

Type of asset (Farm implements)	**1= Yes 2=No**
Plough	
Tractor	
Planting machine	
Irrigation pipes	
Water pump	
Watering can	
Wheelbarrow	
Spade/hoes	
Others	

G8. Have you had any training that equipped you in running and managing water for the following?

	1.Yes 2.No
Homestead gardens	
Community garden	
Dry-land field	
Plot inside scheme	
Plot outside scheme	

G9. Do you think social connections/networks are important to the success of your homestead gardens? Please explain.

....

....

G10. Have you received any assistance from any organisation to cope with the following? If so, explain how/what.

Activity/resources	**1.Yes 2.No**	**Assistance received**
Agricultural education Training/ skills		
Seeds		
Water equipment's i.e. tanks, irrigation pipes		
Soil management training (retaining moisture, increasing fertility)		
Business management and Marketing		

G11. Are there any organisations helping you with agricultural extension services?

1.Yes	2.No

If yes, name them and the type of assistance.
……….
……………………..……………………………………………………………………………………………….

G12. Do you know of any water committee that represents you in your area?

1.Yes	2.No

If yes, please specify
………………………………………………………………………………………………………

G13. Are you in a water committee?

1.Yes	2.No

G14. Would you like to be part of a committee?

1.Yes	2.No

G15. How long have you been in the committee?

1.0-5	2.6=10	3.11-20	4.More than 20yrs

G16. What are the rules for using water to irrigate for the following sources and the penalty for breaking them? (Eg. supply Cut off, fines etc.)

Spring	Tap	River	Other (Specify
Penalty:			

G17. Do you have these rights over water in your area for watering?

Water rights	1.Yes 2.No	Explain
1.Use		
2.Access		
3.Control		

G19. Who enforces water use & access rules?

1.Chief	2.Community members	3. Co-operative	3.Community Water Use Committee	4. Government association	5.Other (Specify)

G20. According to the rules in the area, which water need is given first priority or addressed first, by the person/organization in charge of water in the area? (Rank: 1= Top priority 2= Second priority 3= least priority)

1. Domestic water use.	2. Livestock water use	3.Irrigation water use

G21.Were you involved in the decision when water restriction rules were made?

1.Yes	2. No

G22. Have you ever broken any water restriction rules? Why?
………
G22. Who is intervenes in resolving water related problems in the community? Is it useful?
………
………
……………………………………………………………………
G23. How does this committee interact with the broader water policy and institutional environment?
………
………
……………………………………………………………………
G24.When you have a water shortage issue, who do you approach?
………
………………………………………………………………………………………

G25. Is this person or organization useful?

1.Yes	2.No

G26. Do you normally share water for watering with neighbours if they do not have?

1.Yes	2.No

G27. Are you forced to?

1.Yes	2.No

G28. What are the rules on sharing water for watering (Name source/resource & explain)
………
………
……………………………………………………………………
G29. Do you have any problems sharing water with neighbours? (Eg. Spring, river, tap, borehole etc.)

1.Yes	2.No

G30. How do you handle dispute within your neighbours /community about what the water available should be used for? ....
……………………………………………………………………………………………………

G31. In terms of the maintenance of water sources, who bears the burden of maintaining them (either by cleaning, digging or fixing when broken)?

1.Chief	2. The individual	3. Co-operative	3.Community Water Use Committee	4. Municipality	5.Other (Specify)

G32. Is there involvement of any of the following authorities in water management? Does it improve water access? (**0.** never been involved; **1.** No improvement **2.** Don't know; **3.** Good improvement **4.** Very good)

Government management	**Rank (0-4)**
1. Involvement of local Department of Agriculture officials in water management (local managers and extension officers.)	
2. Involvement of Department of Water Affairs personnel Local/Community management	
3. Involvement of block committees	
4. Involvement of ordinary non-committee members	
5. Involvement of traditional authorities (headmen/Izindunas)	
6. Involvement of the Water Users Association (WUAs)	

G33. Is there any water provided, available to you purely for watering your gardens?

1. Yes Who provides? How? (Explain)	2. No

G34. Do you think enough has been done to help rural farmers to cope with water constraints?

1.Yes	2.No

Explain

………

……………………..……………………………………………………………………………………………………….

Food security section

Question		Code	Response
Q1	In the past 4 weeks was there ever no food to eat of any kind in your house because of lack of resources to get food?	1 = Yes 2 = No (if No>>Q3)	
Q2	How often did this happen in the past 4 weeks?	1= Rarely (1 – 2 times) 2 = Sometimes (3 -10 times) 3 = Often (> 10 times)	
Q3	In the past 4 weeks did you or any household member go to sleep at night hungry because there was not enough food?	1 = Yes 2 = No (if No>>Q5)	
Q4	How often did this happen in the past 4 weeks?	1= Rarely (1 – 2 times) 2 = Sometimes (3 -10 times) 3 = Often (> 10 times)	
Q5	In the past 4 weeks did you or any household member go a whole day and night without eating anything at all because there was not enough food?	1 = Yes 2 = No (if No>>Q7)	
Q6	How often did this happen in the past 4 weeks?	1= Rarely (1 – 2 times) 2 = Sometimes (3 -10 times) 3 = Often (> 10 times)	

Q7 – HKI Food Frequency Questionnaire (ask with reference to food consumed in the last seven days)

Name of food item	Number of days eaten per week
Main staple foods (maize, rice, cassava)	
Spicy, hot peppers	
Milk	
Carrots	
Ripe Mango	
Dark yellow or orange squash e.g. butternut and pumpkin	
Spinach or other dark green vegetables	
Ripe pawpaw	
Wheat products (bread, noodles)	
Eggs with yolk	
Small fish (liver intact) e.g tinned fish	
Peanuts (or other legumes)	
Yellow or orange sweet potato	
Chicken or other poultry	
Imifino e.g imbuya etc.	
Any kind of liver	
Sweet potato leaves	
Beef or pork etc	
Butter	
Lentils	
White fleshed sweet potatoes	
Cod liver oil	
Foods cooked in oil	
Peaches and other fruits rich in vitamin A	
Coconut or other oils and fats	
Food fortified with vitamin A	
Margarine fortified with vitamin A	
Multivitamin supplements	

Q7 – 24 hr Dietary recall

Date ____________________________________ (consider a 24hr period that started from midnight and ended at midnight on the previous day e.g. Saturday midnight to Sunday midnight)

Was it a typical day (e.g. no party of feast) ___________

Time	Quantity	Food Consumed
e.g. 7am/ breakfast	1 cup 2 slices	Tea with 2 teaspoons sugar and full cream milk Brown bread with margarine and peanut butter

Questionnaire 2: Farmer's View and Choices of Technologies

Respondent Name:

1. Were you here during demonstration of these technologies?

   a) Yes ☐ b) ☐

2. From the technologies demonstrated last time, which one(s) do you prefer for your plots?

Infield Rainwater Harvesting	
Mechanized Basin	
Minimum Tillage	
Conventional Tillage	

3. What challenges do you think will limit you from adopting other technologies?

____

____

4. As a farmer, will you advise other farmers whom are not part of your co-operative to adopt and use this technologies on their own plots?

   a) Yes ☐ b) No ☐

5. Do you apply weed control upon your fields? Which chemical do you use? What is your purpose of applying weed control?

   a) Yes ☐ b) No ☐

____

____

6. Which maize cultivar do you use and why do you specifically use that one?

____

____

7. Are you willing to use mulch upon your farmlands?

   a) Yes ☐ b) No ☐

8. Can you apply cover crops as agricultural treatments?

   a) Yes ☐ b) No ☐

9. If yes, what type of cover crops will you prefer and explain why.

____

____

ETHICAL CLEARANCE

UNIVERSITY OF KWAZULU-NATAL™

INYUVESI YAKWAZULU-NATALI

06 July 2018

Mr Ntokozo Mazibuko (212533571)
School of Agricultural, Earth & Environmental Sciences
Pietermaritzburg Campus

Dear Mr Mazibuko,

Protocol reference number: HSS/0849/017M
Project title: IKS driven-based Climate Smart Soil and Water Management practices to improve water use for improved crop production at household garden to meet houshold food and nutrition security: Identification, selection and testing of an Irrigation System

Approval Notification – Expedited Approval

In response to your application received on 21 June 2017, the Humanities & Social Sciences Research Ethics Committee has considered the abovementioned application and the protocol has been granted **FULL APPROVAL.**

Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through the amendment/modification prior to its implementation. In case you have further queries, please quote the above reference number.

PLEASE NOTE: Research data should be securely stored in the discipline/department for a period of 5 years.

The ethical clearance certificate is only valid for a period of 3 years from the date of issue. Thereafter Recertification must be applied for on an annual basis.

I take this opportunity of wishing you everything of the best with your study.

Yours faithfully

....

Professor Shenuka Singh (Chair)

/ms

Cc Supervisor: Dr Joyce Chitja
Cc Academic Leader Research: Professor Hussein Shimelis
Cc School Administrator: Ms Marsha Manjoo

Humanities & Social Sciences Research Ethics Committee
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