Water use for Food and Nutrition Security at the Start-up Stage of Food Value Chains

Report to the
WATER RESEARCH COMMISSION

by

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with

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EXECUTIVE SUMMARY

The project (K5/2555/4) was awarded to focus on water use for food and nutrition security status at the start-up stage of food production. It was a four-year project, based in KwaZulu-Natal and the Free State. The rationale for the project was the food and nutrition deficit of the very poor, where poverty and food insecurity are expressed by an endless cycle of malnutrition and poor societal and economic development.

The high rates of malnutrition in rural communities are a stark reminder that the link between agriculture and nutrition is broken. There is no value chain system between seed and plate and where farmers and poor households purchase most of their fresh produce. Given the high unemployment rate in rural communities in KwaZulu-Natal and the Free State, many families suffer from hunger and poverty on a daily basis and this impacts on the early development of the children. Although some of these families receive some form of government grant and help from a school feeding scheme, they are not food secure and do not have sustainable livelihoods.

Malnutrition negatively affects all aspects of an individual's life and households suffer long-term effects and irreversible changes as a result of poor nutrition in early life. Globally, there is a growing interest in strengthening and intensifying local food production initiatives to mitigate the effects of food price shocks.

Home gardens and homestead smallholder production are viewed as household food security status and nutrition-enhancing strategies that are important in the local food system. Homestead gardening plays an important role in contributing to the food security status of poor households in developing countries, including South Africa (SA). Effective water use at the household level would mean increased production of food, which may guarantee an adequate supply and open up selling opportunities of any surplus, thus allowing the poor to enter the agricultural value chain and earn an income.

Agricultural value chains in SA are driven by agri-business with negligible contribution from smallholder farmers, yet most vulnerable households (rural and peri-urban) depend on produce of smallholder farmers for access to extra food albeit it not adequate, nutritious and not always safe food. It is thus important that the contribution of food production in homesteads is explored. Water is very important for value chain development in agriculture, but it is scare. Therefore, water use productivity must be enhanced using climate-smart technologies (CST) so that yield and nutrition outcomes can be improved. The rationale is further premised on the fact that findings from this research will contribute to which technologies are available to improve productivity and to be scaled up by the end-users. The rationale of the study included eight key rationales as follows:

1. Conduct a detailed literature review of techniques and practices (homestead-, community- and school gardens) to improve water use for food and nutrition security at the start-up stage of food value chains for household food security and livelihoods enhancement in peri-urban and rural environments.
2. Describe and analyse the current natural resources (water, soils, climate), human resources

(demographics, gender, age, vulnerability, agency, current social reality, state of health, nutrient status and needs, etc.), institutional arrangements, farming systems and water use in homestead-, community- and school gardens and food value chain at start-up level.

3. Identify and select CSTs and practices to improve water use for improved crop production to match dietary and nutrient needs for early childhood development and for improved households and livelihoods enhancement.
4. Demonstrate and implement selected technologies for improved production at homestead-, community- and school gardens in the selected areas for improved households and livelihoods enhancement.
5. Evaluate, monitor and analyse water use for food and nutrition security at the start-up stage of food value chains at homestead-, community- and school gardens improved households and livelihoods enhancement.
6. Explore the role of homesteads, community- and school gardens in producing sufficient food and in entering the food value chain for producers in the selected areas for improved households and livelihoods enhancement.
7. Monitor and evaluate the influence of workable institutional arrangements (water, land use security and market players) and organisational structures on incentives and/or disincentives for homestead-, community- and school gardens with the intention of improved households and livelihoods enhancement.
8. Develop guidelines on best management practices to improve water use; develop guidelines for security at the start-up stage of food value chains for improved households and livelihoods enhancement.

A mixed-methods research approach was used for this project to attain a comprehensive understanding and observation of performance of the technologies. Monitoring of field trials and the learning of the farmers and extension officers was done. The impact of agronomy treatments on nutrient content was analysed by planting vegetables rich in Provitamin-A and the concentration of the nutrient along each CST treatment was assessed during planting.

Descriptive analysis was utilised to analyse quantitative data using the Statistical Package for Social Sciences (SPSS). Thematic analysis was employed to analyse qualitative data and field trial analytical methods included soil analysis and biomass analysis. Nutrient data was analysed to determine concentrations of minerals and Provitamin-A in planted vegetables. Overall, this multi-pronged approach to data collection and analysis helped illuminate the processes that might enhance the agency and empowerment of farmers, households and communities in their journey towards attaining improved water and land-use security. The major findings of the study can be organized into three main groups:

- ❖ **Climate smart technologies (CSTs):**

Results from on-farm demonstration plots showed a considerable increase in yields from homestead garden production and smallholder farming plots through the use of appropriate CSTs. In Swayimane, yields increased by 45% and 55% on the respective two demonstration sites compared to their normal farming practices. Similar improvements were also observed in the homestead gardens, where a variety of vegetable crops were produced through the use of in-field rainwater harvesting (IRWH) alongside recommended crop and soil management practices.

In Gladstone (Site 3 & 4) homestead gardens were utilised as demonstration plots for vegetable production. No field crops were planted due to restricted land. The yield increases for spinach at the same sites were 60% and 96% respectively, indicating the beneficial effect of IRWH, which further stopped ex-field runoff completely. This helped to increase the water available for plant growth and increased yields. The results further showed benefits of combining IRWH with sound management practices, including mulching and fertilizer application, as shown by the beetroot yields increase of 236% compared to the control at 68%. The research demonstrated that resource-poor farmers can improve yields, and thus incomes, through the use of IRWH and sound management practices. It is thus recommended that the technologies be promoted particularly in low-rainfall areas. Insufficient rainfall is the most limiting factor for crop production to improve food production and household food security status.

- **Institutional arrangements**

Different methods of data were used with the aim of understanding both villages in detail. Both primary and secondary data were used. The data collected played a critical role in the study since it indicated the natural resources base is somewhat capable of production in various capabilities. With regard to natural resources, detailed soil tests were conducted to ascertain the current conditions of the plots in order to recommend a specific soil management plan for both areas. In KwaZulu-Natal, the Bio-Resource Unit (BRU) information shows what crops are possible for production and also provide yield potential. The rainfall data is encouraging with BRUs that receive up to 900 mm in mean annual rainfall. The Free State sites, although drier, has similar potential. The South African Soil Classification System (SASCS) played a vital role in understating the situation in this area. Although encouraging, the data is predictable as a 10-year average for commercial production and that resource-limited farmers will have to be engaged differently to bring about such yield potentials.

Institutional arrangements were studied and analysed for natural resource management, human resources and markets for this study. For natural resources, the Bio-resource Data (Swayimane) and the SASCS (Gladstone) were used to distil the natural potential of each area in order to assess the human- and market-related resources for ensuring food and nutrition security.

In human resources, various demographics were analysed. In both areas of study, older people (older than 40) dominated the groups. Frequency of ill-heath was expressed by participants. In both areas of study, the household food insecurity access scale (HHFIAS) indicated that households experience food insecurity, but that in Gladstone the households were more food insecure.

There were differences in the farming systems in the two sites to water availability, but largely due to land usage. In KwaZulu-Natal there were smallholdings for farming and food gardens, while in the Free State only food gardens were applicable to the study since croplands were not used for more than thirty years. In Swayimane, all community members have very big gardens that can be classified as croplands, based on their size (1-8 ha and more). The large sized lands were being used effectively in Swayimane. In Gladstone, only 0.5-1 ha land was utilized.

Both study sites are still governed by traditional leadership. The traditional authority (TA) in Swayimane facilitates and manages access to, and the use of communal land, which is ultimately held in trust on behalf of the community. Similarly, in Gladstone the land was in trust by

Barolong-Boo-Seleka Traditional Council. In both areas the TAs are consulted on access and use of land. Therefore, implications on interventions in the food gardens and field must be considered.

Loose and non-identifiable arrangements were found for water use in both study areas, indicating a need for intervention. The institutional arrangements were also weak for enterprise development and great intervention will have to be embarked on, based on the findings.

With regards to institutional arrangements for marketing, they were poor to non-existent. Although farmers in Swayimane were part of co-operatives, these were for primary production. No secondary co-operatives existed as there were no marketing committees and crop scheduling was not a concept that was understood. Marketing of crops was uncoordinated and largely at farm gate, through external merchants and traders known as "bakkie/van" traders due to them arriving in loading vans.

- **Nutrition and food security**

CSTs implemented in the study included combining IRWH technology with sound management practices. These included mulching and fertilizer application, vegetables were harvested and analysed to asses if the treatments, agronomic treatments and water use have had any effect on nutrient profiles of the various vegetables.

The results indicate that there were significant difference in the nutrient composition of vegetables cultivated in two seasons (season 1: February to May and season 2: September to December). Overall, vegetables produced in the first season showed higher nutrient content.

In general, the treatment combination IRWH and mulching resulted in the highest ash, fibre and iron content, compared to the other treatments ($p<0.05$).

Beetroot: The beetroot produced by the treatment that combined IRWH, mulching and inorganic fertiliser had the second-highest fibre content. Beetroot produced under the CON with the combination of organic and inorganic fertiliser showed significantly low protein content as compared to the other treatments ($p<0.05$). There was a similar fat composition for the beetroot produced under CON with the combination of organic and inorganic fertiliser, and mulching with the combination of IRWH. The calcium, phosphorus and zinc content of the beetroot were not significantly affected by the treatment.

Cabbage: Significantly, high composition of ash and calcium content was registered when cabbage was cultivated under IRWH with the combination of mulching. Cabbage grown under IRWH with the combination of mulching and CON showed a significantly higher content of fat and phosphorus content as compared to the other treatments. Cabbage produced by the CON method had significantly high protein, iron and zinc content.

Spinach: Similar to the beetroot, the ash and fibre composition of the spinach produced under IRWH with the combination of mulching was significantly higher than the other treatments. All the treatments had no effect on the fat and iron content of the spinach. There was significantly low protein, phosphorus and zinc content for the spinach produced under the treatment that combined IRWH, mulching, organic and inorganic fertilisers.

Sweet potato: The treatment that combined IRWH and fertiliser had a significantly higher proximate composition for fat and fibre, as well as a higher content of zinc and iron. The total mineral content was not significantly affected by the treatment. However, the individual mineral content for calcium, phosphorus and zinc was significantly enhanced by the treatment that combined IRWH, mulching and organic and inorganic fertiliser.

Generally, the results imply that the nutrient content of vegetables can be enhanced using different agronomic treatments. The overall nutrient content of different vegetable types was better when planted under the IRWH technique during the summer time. In winter, due to less rain, this was not the case. However, since the first trial was performed during the March/April 2017/18 period of the year, it might not be ideal to practice the IRWH technique due to rain and water shortage.

For Provitamin-A, it was found that the level of Provitamin-A varied among the vegetables assessed. In the first season, the Provitamin-A level for both cabbage and beetroot did not significantly change as a result of agronomic treatment and water use.

However, in the second season, a significant variation in the levels of Provitamin-A was observed among the treatments for all tested vegetables. In the second season, when spinach and beetroot were cultivated under CON with the combination of organic and inorganic fertilisers, there was a significant improvement on the level of Provitamin-A content. This implies that the Provitamin-A content of spinach and beetroot increases as vegetables are cultivated under drought stress conditions. The opposite was true for sweet potato, as the Provitamin-A content was highest when the vegetable was produced under the IRWH technique with the combination of inorganic fertiliser.

The season of planting had significantly affected the Provitamin-A content of beetroot. Overall, higher levels of lutein, zeaxanthin and Provitamin-A content were recorded from the beetroot cultivated in the second season. While lutein and zeaxanthin are types of carotenoid pigments, they do not possess Provitamin-A activity.

Marketing of crops was uncoordinated, was largely at farm gate, through external merchants and traders known as “bakkie/van” traders due to them arriving in loading vans. Unsurprisingly, both areas studied find it difficult to access these lucrative markets, despite being close to urban areas that have large retailers and wholesalers for fresh produce. This is the outcome of smallholder farming and not occupying a niche market. The crops planted by farmers in both study areas are common therefore; they struggle to attract demand from larger markets. However, there were a few successes where farmers knew an external merchant that buys directly from them. A limited few supplied to formal supermarket retailers and wholesalers such as Spar. In Swayimane, there are weak market networks and links, which result in a high proportion of co-operatives not selling their vegetable produce to large formal markets. In Gladstone, there are no existing markets apart from informal markets where prices are sometimes set by the buyer instead the seller. Many Swayimane smallholder farmers sell their produce informally to middlemen, neighbours, pension markets, and street vendors on the roadside in Pietermaritzburg, Dalton and Wartburg. Other available markets for smallholder vegetable farmers in and around the area are government schools through their feeding schemes. Potential exists in producing niche crops such as Madumbe. An application-based platform has already started buying niche crops from Swayimane. Facilitating market access and improving value chains can be improved. A process called Smallholder Horticulture Empowerment Promotion (SHEP) adopted from Japan was revitalised by this project. Extension officers have been trained and refreshed on the process and getting farmers ready.

Farmers have been engaged and training has been scheduled in the participating farmer groups. Farmers already benefiting from the SHEP model are being identified for farmer-farmer learning in Swayimane. In the Free State, a SHEP co-ordinator has been identified but difficult to locate and engage.

In the section Conclusions and Recommendations, the study shows that IRWH combined with agronomic management practices, including mulching increased yields, improved mineral and Provitamin-A in various vegetables. Planting vegetables with the use of IRWH in the first season improves Provitamin-A in sweet potato and various minerals in the other vegetables. It is recommended that water harvest technologies, particularly the IRWH be up-scaled and supported by extension services and other lead farmers. Increased water availed by the IRWH technology availed more nutrients, hence the improved nutrient profile in the vegetable. Upscaling the use of IRWH is encouraged to be implemented by farmers with the support of extension officers. Increased yields mean farmers can sell more produce for improved income and improve food security and livelihoods. However, institutional arrangements related to water, and water should be strengthened to improve access to these resources in order to afford farmers an opportunity to improve their opportunities for income. Market access needs to be improved through improving current value chains and accessing establishing others. The SHEP process is one model that should be strengthened for farmers and extension officers to co-identify opportunities and niche markets for farmers.

Future research should focus on technology adoption processes for communities to explore human capacity and capabilities of both farmers and extension staff that supports them. Appropriate policies for the implementation of CSTs with special focus on the involvement of youth and market access should be further studied. Further, the best models for appropriate commercialisation for homestead farmers should be explored where niche markets can be occupied sustainably by the farmers. Further research should also include more physiological studies related to nutrient improvement of crops and specific wellbeing outcomes and attempt to attain direct cause and effect of agricultural interventions, crop interventions, etc.

This report consists of eight chapters addressing the terms of reference. They include the Introduction, Review of Literature, Baseline Information on the study areas, Approaches and CST, Evaluation and Monitoring of CSTs in water use, Institutional Arrangements and Markets, Food and Nutrition Security and finally Recommendations and Conclusions.

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LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
AOAC	Association of Analytical Chemists
ARC-ISCW&AE	Agricultural Research Council-Institute of Soil, Climate and Water & Agricultural Engineering
AU	African Union
BRU	Bio-Resource Unit
CAADP	Comprehensive Africa Agriculture Development Programme
CON	Conventional tillage
CSA	Climate Smart Agriculture
CSATs	Climate Smart Agricultural Technologies
CST	Climate Smart Technology
CWP	Community Work Programme
DARD	Department of Agriculture and Rural Development
DWA	Department of Water Affairs
DWS	Department of Water and Sanitation
Es	Evaporation from the soil surface
FAO	Food and Agriculture Organization
FS-DARD	Free State Department of Agriculture and Rural Development
GDP	Gross Domestic Product
HDDS	Household Dietary Diversity Score
HH	Household
HHFIAS	Household Food Insecurity Access Scale
HPLC	High-Performance Liquid Chromatography
ICP	Inductively Coupled Plasma
IRWH	In-field Rainwater Harvesting
IWMI	International Water Management Institute
KZN	KwaZulu-Natal
LGBER	Local Government Budgets and Expenditure Review
MB	Mechanized Basins
MIN	Minimum Tillage
MMM	Mangaung Metro Municipality
MoU	Memorandum of Understanding
NDF	Neutral Detergent Fibre
NDP	National Development Plan
NFNSP	National Food and Nutrition Security Policy
NGO	Non-Governmental Organization
NT	No-till
PDA	Provincial Department of Agriculture

PTO	Permission to Occupy
PTS	Permission to Stay
RAIN	Realigning Agriculture to Improve Nutrition
RSA	Republic of South Africa
RWH&C	Rainwater Harvesting and Conservation
RWP	Rainwater productivity
SA	South Africa
SADC	Southern African Development Community
SANDP	South African National Development Plan
SANFNS	South African National Food and Nutrition Security
SASCS	South African Soil Classification System
SDG	Sustainable Development Goals
SHEP	Smallholder Horticulture Empowerment and Promotion
SLF	Sustainable Livelihoods Framework
SPSS	Statistical Package for Social Science
SSA	Sub-Saharan Africa
SWOT	Strengths-Weakness-Opportunities-and-Threats
TA	Tribal Authority
UKZN-ACFS	University of KwaZulu-Natal-African Centre for Food Security
UN	United Nations
WRC	Water Research Commission

1 INTRODUCTION

Globally, food and nutrition security is now a central theme in policy and programmes (Giampietro, 2020). This is due to the recognition that much of the food security effort and focus in the past has been on improving food availability, especially in the Southern African context. On the African continent, the Comprehensive Africa Agriculture Development Programme (CAADP) policy makers, researchers and practitioners recently met in SA to review the CAADP and its role on food and nutrition security in development over the past decade (CAADP, 2008).

One key outcome of this meeting was to refocus on improving nutrition security due to the underlying irreversible under-development evident in poor communities that in turn has serious and irreversible effects on human development (CAADP Meeting, 2014). In SA, the strategic goal of the National Food and Nutrition Security Policy (NFNS) is to ensure the availability, accessibility and affordability of safe and nutritious food at national and household levels (DAAF, 2013).

There is evidence to show that food insecurity is experienced differently in urban and rural areas. Food poverty and food insecurity are largely associated with rural areas (Drysdale *et al*., 2019). However, food security is a growing challenge for South African cities in particular, while many African cities are urbanizing at an alarming rate of twice the global average (SA Cities Network, 2009). Urban households are increasingly becoming food insecure due to myriad reasons. These include rising food prices, urbanization, concentrated urban poverty, economic instability and rising inequality, suggesting that urban households are at risk of food insecurity. On the other hand, rural households tend to largely experience general food poverty as a result of lack of availability (Shackleton *et al.*, 2019).

Food and nutrition insecurity were for a while associated only with rural areas (Crush *et al*., 2011; Hunter-Adams *et al.*, 2019). Indeed, food access is difficult for rural poor largely because of the higher cost of food in rural areas, in addition to other challenges including few off-farm employment opportunities, poverty, limited access to water, etc. Many rural households have neglected agriculture and rely on cash purchases for food.

However, urban food insecurity is a growing challenge not only in SA but also in the SADC region (Crush *et al.*, 2019) where rapid urbanization is fast placing cities, their infrastructure and social and economic capacity under immense pressure. Cheap and highly processed foods are easily accessible to the urban poor, thus contributing to the undernourishment and malnutrition already experienced in developing countries.

The lack of urban agriculture policies by most municipalities in SA is an indication of cities not poised for the food and nutrition challenge that is upon them. Access to production resources in urban areas is of critical importance, due to the cost of land and water in urban areas. A study by Crush *et al*. (2011) investigated the role of urban agriculture in food security, finding that household food production in poor urban communities in eleven different Southern African Development Community (SADC) was negligible, and that there was a heavy reliance on purchasing food from supermarkets and the informal sector. Given the low incomes and lack of jobs in SA, the question of who will feed the masses who migrated to urban areas and remain jobless beckons.

Exploring food production in urban areas as the beginning of a value chain or several thereafter is therefore critical for providing food and nutrition access, alleviating poverty and creating much-needed jobs within cities (Donn-Arnold, 2019). The ability to produce food primarily depends on access to land and inputs such as water. How available are these to households located in urban, peri-urban and rural areas?

Observations suggest that land is highly limiting in urban areas when compared to peri-urban and rural areas (Nyembo and Lees, 2020). Are producers in urban areas hindered from entering the value chain, due to the dominance of supermarkets? Is market integration possible using current policy instruments or is there a void? Does peri-urban farming have the advantage of being near the big urban markets compared to rural-areas-based smallholder agriculture, due to numerous challenges including poor infrastructure and high transaction costs? Contributions to knowledge in this area and evidence on these questions could be generated by this study.

Food security is defined in several ways, however this study adopts the South African NFNS (2013) that defines it as "*Access to and control over the physical, social and economic means to ensure sufficient, safe and nutritious food at all times, for all South Africans, in order to meet the dietary requirements for a healthy life*". This definition implies four dimensions, namely that for food security to be realized food must be available and accessible, there must be safety of supply and it must be utilized adequately for a healthy life. It is an established fact that food availability depends primarily on the overall performance of the agricultural sector, while also being dependent on a country's competence and ability in processing, importing, storing and distributing this food.

Unlike most of the southern African countries, SA is largely food secure at a national level (Stats SA, 2019). However, access to this food by poor household is a serious issue where more than 14 million people struggle daily to access food (Stats SA, 2019).

Domestic food production continues to be affected by factors such as land availability and access to irrigation water, while non-agricultural activities such as mining continue to take over more agricultural land and water, thus decreasing arable land availability and irrigation capacity. Furthermore, other factors that may affect stability of supply are related to crop storage and limited road and market infrastructure, especially in far flung places where government intervention may be required (NFNS, 2013).

One major challenge to consider when engaging with food production is climate change. The impact of climate change affects food availability, water availability and diversity of grown crops, especially for the poor. The link between water and food security is increasingly being recognized globally. The South African National Food and Nutrition Security (SANFNS, 2013) is silent on water use security, yet the role of water in food production is unquestionable. The HLPE Report 9 (2015), states that water for food security should be thought of as similar to other Food and Nutrition Security dimensions, namely; availability, accessibility, stability and utilization. The report notes there are four pathways in which water contributes to food security, these being:

- Utilization of nutrients and foods: safe drinking water and food preparation (including urban, issues of quality, etc.), key to food absorption, etc.;
- Determining availability of food: water for food production and transformation (considering the impacts of climate change, from global to local, the role of markets, etc.);

- Access to food: as a key factor for livelihood, especially smallholder farmers, for the poor, vulnerable, hungry; and
- Stability: contributing to stability of food security, including issues of stability of water supply, access, rights, etc. conditioning the three roles above.

There are several correlations between water quality and food security. Below are the three most common linkages that have been noted for the purpose of the study. Firstly, there is a strong link between water quality and food safety in terms of production. Hence, the processing of food with wastewater or with water that is contaminated with pollutants poses many health threats to those who will consume the produced food. Secondly, there are also links between water quality and inputs in the food production process, such as chemicals (fertilizers and pesticides) and livelihood assets such as soil quality. Thirdly, there are links between water consumed with health and nutrition outcomes.

Water safety is thus one of the most pressing development challenges of the early 21st Century. Over 1.8 million people die every year from diarrheal diseases (including cholera); about 90% are children under five, mostly in developing countries (McCarty *et al.*, 2020). In SA, the highest killer of children under 12 has been linked to water diseases mostly in vulnerable households (Stats SA, 2014).

Water use-security is an important emerging concept and is currently defined by the United Nations Water Agency as the capacity of a population to safeguard sustainable access to adequate quantities of and acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, so as to ensure protection against waterborne pollution and water-related disasters, and to preserve ecosystems in a climate of peace and political stability (UN-Water, 2013).

Several studies, including ones in SA, have shown a link between agricultural water, agricultural practices (husbandry) and food safety, with implications for nutrition outcomes (Mdluli *et al.*, 2013; Beharielal *et al.*, 2018). Access to safe water for agricultural use, sanitation facilities and good hygiene have the potential to positively impact nutrient outcomes by addressing both the direct and underlying causes of malnutrition.

Furthermore, poor sanitation has been strongly linked to food insecurity negative outcomes (Dangour *et al.*, 2013). Therefore, enhancing agency and empowerment through knowledge and skills improvement of households, especially women, is a critical element in developing skills to improve nutrient outcomes. Food production activities at school, homestead and community level are important for introducing and developing food production, particularly for young people, and thus inculcating a passion for agriculture (Woo *et al*., 2020).

This passion is an important building block for entrepreneurial activities linked to agriculture with a better possibility of igniting ownership, management and capacity for accessing land and water. The youth may become involved in the value chain when they see evidence that an income is possible, provided markets are available. Given the overwhelming evidence that more women than men are involved in production, especially at the beginning of the value chain (Greenberg, 2017), the following section focuses on women farmers and barriers to entering the value chain.

It is noted that although the study has a mixed methods approach involving qualitative and quantitative aspects of data collection and analysis. The methods include surveys, focus group discussions, field-based experiments and laboratory analysis for nutrient content of the crops. Due to the multidisciplinary nature of the study, each chapter has its stand-alone methodology specific to the objective being addressed in it. The report begins with a detailed literature review, baseline information covering various livelihood and contextual aspect of the study areas, institutional arrangement, water use and CSTs, markets and value chains and food and nutrient analysis. The study concludes with conclusions and recommendations.

2 LITERATURE REVIEW

2.1 INTRODUCTION

Food insecurity has emerged as a global crisis following the global economic meltdown (GFIPI, 2009). According to a report by the Food and Agriculture Organization (FAO) (2004) on the state of food insecurity in the world, more than 814 million people in developing countries are undernourished. Of these people, 204 million live in countries in sub-Saharan Africa, including SA. Despite the political and economic advances seen in SA since 1994, the country is plagued by poverty and unemployment, and following the 2009 global economic crisis, by steep food and fuel prices, high-energy tariffs and increasing interest rates (Economic and Social Council, 2009). The continued decline of the South African economy of 2018 and 2019 (Stats SA, 2017) has only made poverty of the most vulnerable in society. These adverse conditions have placed severe pressure on ordinary South Africans already struggling to meet their basic household needs. Thus, a proper definition of the term "food insecurity" and measures that are suitable for the South African context must be urgently developed.

According to the FAO (2014) the development of sustainable food value chains can offer important pathways out of poverty for the millions of poor households in developing countries. Food value chains are complex systems. The real causes for their observed underperformance may not always be obvious. Typically, multiple challenges have to be tackled simultaneously in order to truly break poverty cycles. This in turn implies the need for collaboration among the various stakeholders in a value chain, including farmers, agribusinesses, governments and civil society. Further compounding the challenge, improvements to the value chain must be economically, socially and environmentally sustainable: the so-called triple bottom line of profit, people and planet.

The other issue discussed is food security. In short, food security means access by all people at all times to enough food for an active, healthy life. Food security ensures the availability, accessibility and proper utilization of food. The critical importance of food security in the SADC region was emphasized in the 2004 Dar-es-Salaam Declaration on Agriculture and Food Security setting goals that are in-line with the sustainable development goals. This is still relevant with the Sustainable Development Goals (SDGs) since they were set in 2015 (UNDP, 2020). Some of these SDGs were set with direct aim of making sure that no one goes to bed hungry (SGD 1&2). Therefore, what needs to be understood is that food itself is a basic human need. Without food nothing can be alive. More information is discussed in this chapter, further covering gender-related issues, specifically looking at the contribution made by women even though they are side-lined when it comes to land ownership.

This study aimed to explore the water use for food and nutrition security in homestead gardens and preparedness to enter available food chains through the use of agency. This chapter reviews literature on homestead gardening strategies employed in rural areas in SA and narrows down the discussion, looking at water and gender relations in the rural areas. In addition, the chapter discusses the link between the value chain, gender relations and agency, finally discussing food and nutrition security and policy responsiveness. The specific focus of the study is on crop farming and the literature review examines the key issues in production that can contribute to the available food value chains in the garden farming system.

2.2 PREPAREDNESS OF HOMESTEAD, COMMUNITY AND SCHOOL GARDENS IN ENTERING THE VALUE CHAIN

2.2.1 Overview and definition of terms

The alleviation of poverty is the most profound challenge facing SA today. High levels of poverty are compounded by high levels of inequality and lack of access to natural, political and financial resources (Schreiner and Naidoo, 2002). According to Shackleton *et al*. (2008) those facing the highest risk of poverty and marginalization are women, women-headed households, the young, the elderly, African and rural people. Finding appropriate and effective ways to reduce the prevalence of malnutrition in Africa, including SA, remains a problem for agriculturalists and nutritionists. The growing populations and dwindling resources exacerbate the challenge (Wenhold *et al*., 2007).

Water is one of the essential resources in food production, making it a critical factor in food security. Achieving food security for growing numbers of people with the same amount of water is thus an important societal concern. This report aims to connect the dots and review the literature available on the linkages between water use, food and nutrition security, homestead gardens, and the value chain. Shisana *et al*. (2014) points out that the potential to improve household, community and national food and nutrition security through gardening activities is high if issues of water availability, cost and availability of inputs, the value chain, and farmer empowerment can be addressed. Baiphethi and Jacobs (2009) and Shisana *et al*. (2014) stress that most institutions have been supporting software (training) and recurrent (inputs and equipment) aspects of garden production, with limited support for hardware (physical assets, i.e. land, water, etc.).

The following are key concepts of the study that defines and draws boundaries on relevant literature reviews:

- **Food and Nutrition Security:** It exists when all people at all times have physical, social and economic access to food; which is consumed in sufficient quantity and quality to meet their dietary needs and food preferences, and is supported by the environment providing adequate sanitation, health services and care, allowing for a healthy and active life (Committee on World Food Security, 2012). It is also defining as an "*access to and control over the physical, social and economic means to ensure sufficient, safe and nutritious food at all times, for all South Africans, in order to meet the dietary requirements for a healthy life*" (Mugabe, 2014 and Muzigaba *et al*., 2016).
- **Water use:** According to Dam *et al*. (2003), there are several definitions of the water use concept, as it is not uniform and it changes with the background of the researcher and stakeholder involved. The basic definition of water use can mean the amount of water used by a household or a country, or the amount used for a given task or for the production of a given quantity of some product or crop, or the amount allocated for a particular purpose (FAO, 2012). A definition based on economic value and nutrient value is, therefore, more appropriate for this study, since the aim is to explore food and nutrition security based on water use in home gardens.
- **Food gardens:** Are agro-ecosystems located close to the area that serves as a permanent or temporary residence. The typical food garden is a traditional land use system around a homestead where many types of crops and vegetables are cultivated and maintained by the household, with the primary objective of fulfilling the family's consumption needs

(Abdoellah *et al*., 2002; Eyzaguirre and Linares, 2004; Gautam *et al*., 2004). The term homestead gardens will be used as denoted by (Musotsi *et al*., 2008).

- **Agency:** Is an actor's ability to make meaningful choices and purposefully choose among options (Alsop *et al*., 2006). Alkire *et al*. (2013) also defines agency as the ability to act on behalf of what one values.
- **Food Security:** Exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (FAO, 1996)
- **Nutrition Security:** Is a multi-dimensional phenomenon, requiring secure physical, economic, social, and physiological access to adequate food, a sanitary environment, adequate health services, and knowledgeable care (Andersen *et al*., 2013).
- **A Food Value Chain:** Is the series of processes and actors that take a food from its production to consumption and disposal as waste (Hawkes and Ruel, 2011). In a value chain, the emphasis is on the value (usually economic) gained (and lost) for chain actors at different stages in the chain, and the value produced through the functioning of the whole chain as an interactive unit.
- **Entrepreneurial:** Activity is the enterprising human action in pursuit of the generation of value, through the creation or expansion of economic activity, by identifying and exploiting new products, processes or markets.

2.2.2 Conceptual framework

Real life issues are often complicated and the use of frameworks simplifies a cluttered reality (Patton, 2011). The present study adopted and adapted the Realigning Agriculture to Improve Nutrition framework (RAIN), due to its advantages (Molden *et al*., 2010). The framework is developed from the notion that upgrading of home gardens is important for sustainability of household livelihoods. The conceptual framework helps to define the domain of "*research on home gardens for improved food and nutrition security*". The framework puts home gardens at the centre of the process, emphasizing food and nutrition security as an endpoint. It presents a hierarchy of nutrition-related outcomes and the economic status, the top being change in nutrient status, which provides the strongest evidence of impact on nutrient outcomes. The framework shows that (Gelli *et al*., 2015) increasing the demand for nutritious foods would also lead to expanding marketing opportunities for producers (homestead gardeners).

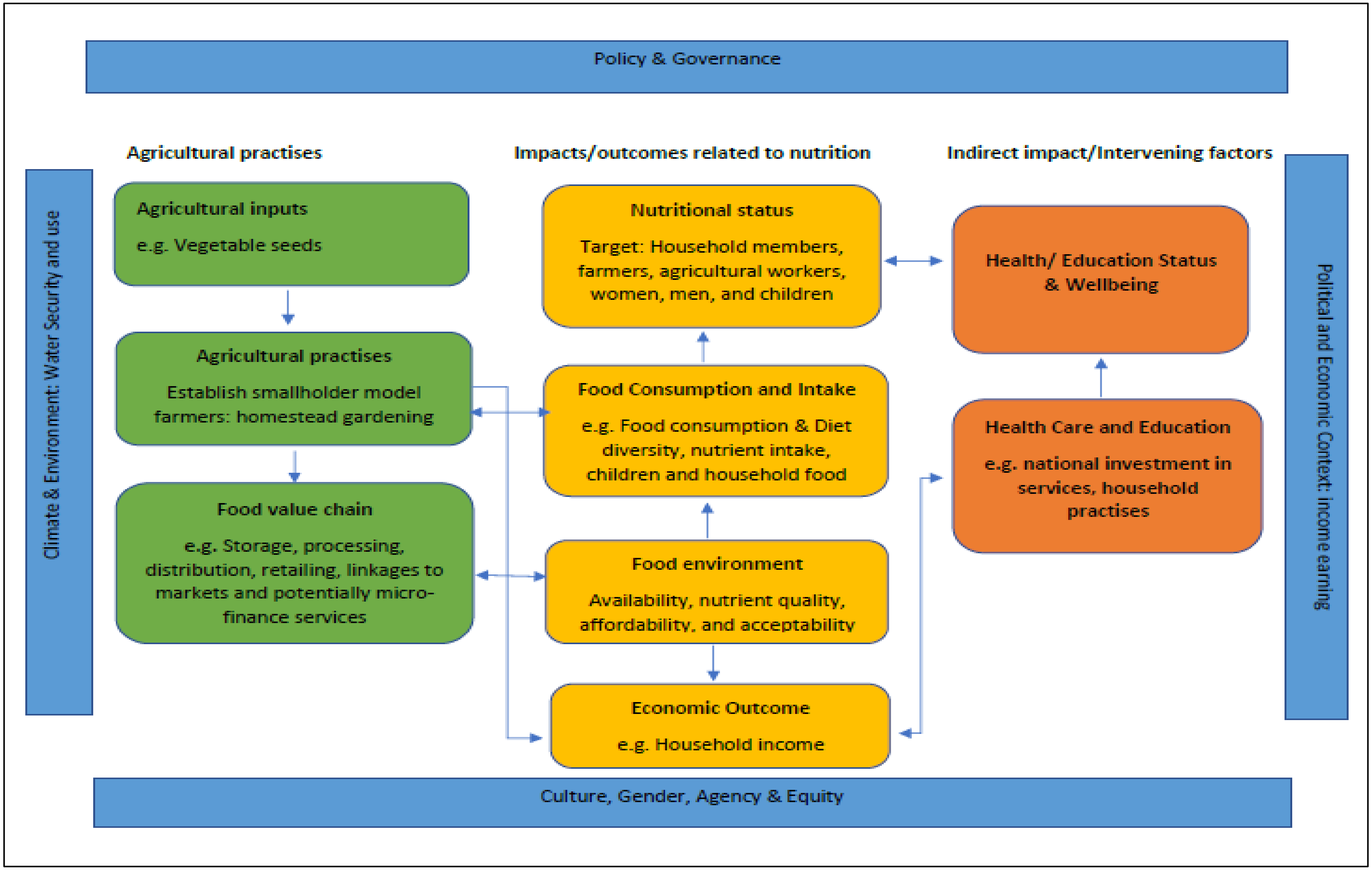


Figure 1 Realigning Agriculture for Improved Nutrition (Haseen *et al*., 2012).

In this framework, the production of food by farmers has the potential to influence the nutrition of members of their households, either through direct consumption or by generating income which allows them to buy food locally (Waage *et al*., 2013). The present study adopted and adapted the Realigning Agriculture to Improve Nutrition (RAIN) framework due to its advantages. The framework was run for different groups of people in different environment (i.e. poor, rural and urban householders, women farmers, etc.) (Waage *et al*., 2013). The framework has four factors and contexts which can influence agriculture and its nutrient outcomes and these are shown on the borders of the framework to indicate their cross-cutting nature. They comprise:

- **Policy and governance:** Policy is a critically important target of research because of the role of agricultural and related policies in influencing nutrient and health outcomes at the macro-level, and the potentially large (and cost-effective) impact this could have. Governance is also a significant macro-factor because of the known barriers to implementing cross-sectoral approaches to address nutrition through agriculture in institutions and policy processes – questions concerning why decision-makers make the decisions they do, what influences policy processes, and the ability of different sectors to work together (Haseen *et al*., 2012).
- **Culture, gender and equity:** Research demonstrates that gender is an important dimension to all nutrient issues and outcomes. Inequity and culture have usually been inadequately addressed in poverty-focused research (Handley *et al*., 2009; Haseen *et al*., 2012).
- **Climate and environment:** Food production and supply through value chains will be greatly influenced by environmental change, including that related with changing land use, water availability and climate change (World Bank, 2008; Haseen *et al*., 2012).
- **Political and Economic:** Context-fragile states or conflicts which create humanitarian situations will create particular contexts for the relationship between agriculture and nutrition, and challenges for research (Haseen *et al*., 2012).

2.2.3 Food gardening in South Africa

In the rural areas of SA, dietary diversity is typically moderate to low, which makes people vulnerable to ill health and food insecurity. The world currently faces an important task of ensuring that a large number of families living with insufficient food have access to enough food to uphold a healthy natural life. Home-based gardens are a community's most handy and adaptable land resource and are a vital element in reducing vulnerability and safeguarding food safety. Home gardens are vital to families since they deliver income, food and nutrition during the year from the mixture of crops produced at different times.

For poor rural families, unable to pay for luxury animal products, home gardens offer a cheap source of nutritive foods to fulfil their nutrient requirements. Through gardening, households can have improved access to a mixture of plant and animal food substances that lead to a general rise in dietary intake and increase the bio-availability and absorption of essential nutrients. Home gardens offer relaxed day-to-day admission to a variety of fresh and nutritious foods for the household and increase staple-based diets with a substantial portion of proteins, vitamins, and minerals, leading to a well-balanced diet mainly for growing children and mothers. The addition of livestock and poultry farming to home gardening strengthens food and nutrient security for families, with milk, eggs, and meat from home-raised animals providing key animal protein. In some residences, home gardeners are furthermore engaged in mushroom farming and beekeeping, and even fresh-water fish pools are integrated into the garden space, thereby adding to the portion of proteins and other nutrients obtainable for the family. Home garden production has improved in the country and has been active in alleviating "hidden hunger" and disease caused by micro-nutrient shortages. Home gardens can guarantee food to disadvantaged and resource-poor households because they can be established and cultivated inside a small patch of land using a few inputs.

Home gardens have been an integral part of local food systems in developing countries around the world. Many studies provide descriptive evidence and analysis of home gardens in developing countries in Asia, Africa, and Latin America and pinpoint their numerous benefits to communities and families (Galhena *et al*., 2013). Generally, home gardening refers to the cultivation of a small portion of land which may be around the household or within walking distance from the family home (Kortright and Wakefield, 2011). Home gardens are found in both rural and urban areas in predominantly small-scale subsistence agricultural systems (Baiphethi and Jacobs, 2009). Since the early studies of home gardens in the 1930s by the Dutch scholars, Osche and Terra, on mixed gardens in Java, Indonesia, there have been wide-ranging contributions to the subject, creating definitions, species inventories, functions, structural characteristics, composition and socio-economic and cultural relevance (Galhena *et al*., 2013). Home gardens are defined in multiple ways, drawing attention to different aspects based on the context or emphasis and objectives of the research (Galhena *et al*., 2013).

The majority of available literature on food gardens is based on experiences in developing countries in Africa, Asia and Latin America (Galhena *et al*., 2013). South African agriculture is made up of a subsistence agricultural sector (which includes homestead gardens) and a commercial sector (Chikazunga, 2013). The subsistence agricultural sector is made up of mostly black farmers, while the commercial sector is made up of mostly white farmers. Home gardening is a longstanding practice in SA, particularly in the rural households.

The literature shows that most of households produce for consumption although homestead gardens can be consumption or market-oriented (Marsh, 1998). The home garden frequently uses family labour and women, children, and elders are of particular importance in their management. The benefits of homestead gardens are broadly categorized into three components in many developing countries, including SA: (1) social; (2) economic; and (3) environmental (Galhena *et al*., 2013). However, even though homestead gardening plays an important role in improving the food security status of many households and offers different benefits, there are many obstacles associated with it. These include climate change, gender discrimination related to land and water ownership and many more (Chikazunga, 2013).

2.2.4 Access to land, water and gender relations

Very few small-scale farmers or rural households use land for a single purpose. Rather, a typical mix includes rearing of some poultry or livestock, growing of some vegetables and fruit trees in a homestead garden, small plots of maize for homestead or livestock consumption, collection of a range of non-food resources (such as firewood, medicinal plants, fencing materials, weaving fibres), burial sites, perhaps space for some small enterprise (such as brewing, welding or weaving) and affirmation of deep cultural and spiritual connections to the land. A minority also cultivate fields for subsistence use and the selling of any surplus.

One of the New National Water Acts of 1998 on entitlement to water use states that a person may use water in or from a water resource for purposes such as reasonable domestic use, domestic gardening, animal watering, firefighting and recreational use. According to Zwarteveen *et al*. (2013) water can be accessed by owning land; purchasing water; state provision and common property access (obtaining water from a river or public tank through some communal rights of access). Each of these types of access has specific characteristics, or social dimensions: cost, labour time, decision-making (agency), historical trajectory and response to external shocks (Zwarteveen *et al*., 2013).

Rural SA is largely male-controlled and governed by tribal councils; consequently, productive resources such as water and land are largely controlled by men (Cousins, 2007). Knight, (2010) pointed out that though specific customs differs among societies in SA, many broad generalities can be drawn. Typically, a family's land in SA is principally under the control of the man, who is responsible for social obligations and who bears overall responsibility for the family's land activities (Adams *et al*., 1999; Knight, 2010). Though gender equity is promoted in the South African constitution, together with the right to water this is not really the reality. The right to access water is specified in the Constitution of South Africa (RSA, 2013), but according to Department of Water Affairs [DWA] (2013) there is a lack of improved access to water and sanitation that impacts most heavily on women, who are responsible for collecting water, and children, who are victims of poor sanitation in rural and peri-urban areas.

Most women, as well as other historically disadvantaged individuals in SA such as the black community, have been systematically excluded from proper water access and its benefits. As a result, almost no black women have had land and/or water entitlement in their names (Van Koppen *et al*., 2011).

Households without land may have more limited access to water (Crow and Sultana, 2002). This situation affects food security, since it cannot be separated from the broader socio-political issues impacting on individuals and communities. For example, access to water, land and other natural resources, have a significant bearing on an individual's and a community's vulnerability to food insecurity. While agricultural water management and development play an important part in poverty reduction, they cannot eliminate poverty alone. Also needed are complementary investments in education, health, rural infrastructure, capacity building and supportive institutions, together with pro-poor, pro-gender research on low-cost and gender-suited technologies, crop research advances, and improved agronomic and water management practices and related dimensions of social exclusion, equity and empowerment.

2.2.5 Value chains, gender relations and agency

Value chain describes a '*full range of activities which are required to bring a product or service from conception through the different phases of production involving a combination of physical* *transformation and the input of various producer services, delivery to final customers, and final disposal after use*' (Kaplinsky and Morris, 2000). Value chains have become a key concept in international discussions on development, in particular in relation to the effects of globalization on employment and poverty reduction in the South (Riisgaard *et al*., 2010). An agricultural value chain is therefore defined as the people and activities that bring a basic agricultural product like maize or vegetables from production in the field to the consumer, through stages such as processing, packaging, and distribution. Value chains are all about human interactions, they are about linkages between people and businesses who transfer or exchange products, money, knowledge and information.

According to Adam *et al*. (2014) food value chains represent a business model in which producers and buyers of agricultural products form strategic alliances with other supply chain actors, such as aggregators, processors, distributors, retailers, and consumers, to enhance financial returns through product differentiation that advances social or environmental values. FAO (2014) defined food value chain as: "*the full range of farms and firms and their successive coordinated value-adding activities that produce particular raw agricultural materials and transform them into particular food products that are sold to final consumers and disposed of after use, in a manner that is profitable throughout, has broad-based benefits for society, and does not permanently deplete natural resources*". Those farms include both men and women who are working hard to achieve their objectives at the end of the day, which is to produce quality food to feed the nation at all times, despite challenges they face on a daily basis.

Who benefits from value chains? Everyone who participates in a value chain adds value as the product moves from the beginning of the chain towards the consumer. In exchange for adding this value, all participants receive an economic rent. That is the main benefit or incentive for participating in a value chain. Most of the small-scale farming in SA is carried out for household food supply, and only a small proportion of the product is sold (Van Averbeke and Khosa, 2011). Even subsistence farmers participate in value chains by growing some crops or raising some animals for sale. In the most remote areas, many subsistence farmers are connected to markets, and sell small amounts of their produce in local markets or to traders who visit the farm (Baiphethi and Jacobs, 2009).

Why value chains? According to scientists, by 2050 the world's population will reach 9.1 billion, 34% higher than today. Nearly all of this population increase will occur in developing countries. Urbanization will continue at an accelerated pace, and about 70% of the world's population will be urban (compared to 49% today). This will put pressure on the food value chains to double their efforts in making sure that no one goes to bed hungry. According to the FAO (2014) there is an urgent need for public and private sector cooperation in order to facilitate the investment in greater productivity and value chain efficiency required to deliver more local food of high nutrient value to domestic markets, including growing tourist markets.

At times many rural households generate a surplus production of a specific crop or cultural food from their homestead garden. Such surplus is donated to family or is left unused. Very few attempts to sell the surplus because they are not interested in doing so, the quantities are too small, or they do not know how or where to sell it. This surplus need not be wasted if the shelf-life is extended by drying, pickling or canning. Such processing then makes the food available during periods of scarcity, or it can be sold in the off season at prices 3-10 times higher than selling the fresh produce in season. However, in most areas, the knowledge and practice of such processing is relatively rare. Providing information and demonstrations at clinics and women's groups could increase the prevalence and benefits of such processes to increase the shelf-life of surplus produce, whilst contributing to women's empowerment. These can be promoted via shows or competitions, along with recipes and cultural foods.

2.2.5.1 Impact of gender relations and agency on food and nutrition security

It is noteworthy to mention (Crush *et al*., 2011) that although subsistence agriculture is dominated by women, their socio-economic disadvantage remains unabated. In agricultural settings, women are often not visible although they do a large part of the farm activities (Laven and Verhart, 2011). Moreover, it is well-documented that women-owned rural businesses tend to face many more constraints and receive far fewer services and support than those owned by men (Mayoux, 2010). Women often face disadvantages in terms of mobility, access to inputs, productive resources, and market information and are thus particularly challenged to access and maintain profitable market niches and economic gains in value chains (Laven and Verhart, 2011).

Women are not a homogeneous group, but they experience similar gender barriers in the household and in communities and these may negatively affect their agency (Mahmud *et al*., 2012, Malhotra and Schuler, 2005). Herr and Muzira (2009) pointed out that in order to integrate gender relations in value chain, a new dimension must be introduced – agency. Agency is the capacity of individual humans to act independently and to make their own free choices (Alsop *et al*., 2006; Alkire *et al*., 2013). The presence of agency helps to understand the positioning of a rural entrepreneur (rural farmer) in a value chain and the constraints to upgrading or changing that position. It can be stated that there are arrangements relating to land tenure, access to water, property rights and business that determine which member of the family has access to and ownership of economic resources. Moreover, in developing countries, women are often excluded from accessing and owning land – land which is a powerful tool not only for obtaining physical assets for participating in value chains but also gaining access to chain services.

It can be stated that at farm or start-up level, women are more active than men, especially in rural communities. Their efforts, hard work and hope for land ownership cannot be ignored forever, since they play a significant role when men are not around. Food security can only be achieved if everyone is involved in making sure that food demands are met. As pointed out by Baleta and Pegram (2014), the pivotal role played by women who strive to put food on the table for their families at all times cannot be over-emphasised.

2.2.5.2 Impact of transaction costs on access to food and nutrition security

Three quarters of the poor population in developing countries, including sub-Saharan Africa, live in rural areas and are highly dependent on agriculture for income and household food security. Amongst these are female farmers. Marketing is an important tool for income generation and access to information relating to prices, quality and quantity demands, including the costs involved, is essential (Urquieta, 2009). Transaction costs can be defined as the costs associated with trading, acquiring information and transporting goods (Urquieta, 2009). These costs are a major contribution to the hindering of rural farmers, especially women, from accessing or participating in the markets. In addition, the lack of adequate transportation and access to telecommunications can make transaction costs even more disadvantageous for farmers and can also lead to an increase in the cost of gathering information on potential trading systems and strategies (Urquieta, 2009).

A study conducted by Overa (2006) illustrated that transaction costs are the main determinants of the producers and traders capacity. They affect income as well as the availability of goods for consumers. Moreover, women are not only constrained by the lack of access to agricultural resources and other forms of support but also transaction costs including communication channels, transportation and pricing have implications for their participation in markets. Urquieta (2009) states that high transaction costs have major implications for rural female farmers and this is because they produce and sell low quantities, thus making it difficult to extend and maintain fixed costs of acquiring information (Urquieta, 2009). Urquieta (2009) also puts emphasis on the importance of proper communication and transportation systems, as well as access to market information, particularly for pricing purposes. This will enhance excessive participation in markets for women, thereby reducing the perishability of crops.

In terms of poverty reduction, it is not land efficiency that is the key performance measure here, but labour productivity in terms of the value of output per unit of labour. The value of output is not only determined by volume but also by the ability to sell at a good price; furthermore, for smallholder producers, this ability is undermined by high transaction costs, low market power and limited access to finance, services and infrastructure (FAO, 2014).

2.2.5.3 Value chains and female farmers

Women are the main drivers of crop production and household food security in most households, especially in rural areas. Given that up to a contested 60% of South African households are female headed, the situation should be similar for urban and semi-urban households. Thamaga-Chitja *et al.* (2012) notes that such women encounter challenges with access to resources for production, including insecure and unsubstantiated land tenure as a result of continuing customary laws and weak government systems that fail to develop programmes that address the problems of secure land access and ownership by women (Thamaga-Chitja, 2012). Due to the role played by women in agriculture and the specific constraints they face, considering a value chain approach may yield long-term food security and livelihoods for women, given that the constraints are addressed. Entry into the value chain has potential to generate cash critically needed for other household (HH) requirements, and also agricultural inputs. However, studies by (Mutopo, 2010) noted that often men enter the value chain at the income earning stage and income can be lost to women and thus decrease the welfare of the household. However, women face structural challenges in accessing production resources, i.e. land and water, due to cultural practices where men hold land title and by default water rights linked to the land. Often women access the resources through association with men by marriage or birth (Thamaga-Chitja *et al*., 2010). Furthermore, historical and structural challenges that have handicapped women with less education and skill as compared to men indicate that making their voice heard at in the complex policy environment is near impossible.

2.2.6 Contribution of home gardening towards food and nutrition security in SA

Shackleton *et al.* (2019) defines home gardens as a small portion of land that is cultivated, either at the back or in front of the yard or near the residence. Most home gardens are easily accessible and can be used as a great component to reduce poverty and contribute to food security. Home gardens can sustain families throughout the year by planting different crops at corresponding times and harvesting them (Connor and Mtwana, 2018). Home gardens can include field cultivation of vegetables, fruits, crops, poultry, pigs and livestock, which produce meat, milk and eggs that can be a source of food in households and can sometimes be a source of income (Taruvinga *et al.*, 2013).

Food gardening was primarily utilized for subsistence farming, but due to increasing rates of poverty and food insecurity in SA they are now utilized for commercial farming to generate income. Nell *et al*. (2000) mentioned that when food gardening is mentioned people tend to focus on vegetables only, whereas food gardening can also include poultry, pig production, farming with rabbits and livestock. All these can be engaged in for consumption purposes and improve food security.

Home gardens serve similar interests to community gardens. They have economic benefits when they no longer only focus on food consumption and nutrient security but expand to contribute to income generation, improving, livelihoods, improving household economical welfare and promoting entrepreneurship and rural development. Social benefits include enhancing food and nutrient security in socio-economic situations, where it improves family health and human capacity, empowers women and promotes social justice and equality. It also secures indigenous knowledge and culture (Marsh, 1998).

In SA, as in several other emerging countries, food security is a worry in underprivileged households, predominantly in the rural areas. In a case study by Shackleton *et al*. (2015) it was found that food insecurity is not just about production of food. It is about production, stability of supply and access, land tenure, diversity of foods, access to food by different sectors, food cultures and preferences, distribution channels, market prices, attitudes, education and health. Consequently, eliminating food insecurity cannot be the responsibility of a single government department, tier of government or government alone. Addressing food insecurity requires a coherent, multi-sectoral and coordinated policy environment and programmes involving government, NGOs, civil society, traditional authorities and agribusiness, informed by context-specific trans-disciplinary perspectives. A continuous learning and adaptive process is imperative.

In SA, studies have shown that attempts to improve food security in households through the adoption of home gardens programmes have not yielded the desired result (Moorehead and Wolmer, 2001). Nevertheless, home gardens have been identified as an important tool in enhancing food security and decreasing vulnerability amongst households (Buchmann, 2009). In a developing country like SA, income is a determinant of household food security and home gardening activities are an essential part of family livelihood, providing sustenance and generating income throughout the year (Kirsten *et al*., 2003), and filling up the major gaps in food and vegetable supply.

Reviews of studies from various countries show that the level and combination of socio-cultural impacts on societies engaged in home gardening differ across the board. Many social benefits of home gardens include improving food and nutrient security in many socio-economic and political situations, improving family health and human capacity, empowering women, promoting social justice and equity, and preserving indigenous knowledge and culture (Mitchell and Hanstad, 2004). FAO (2015) reveals that the majority of the world's hungry people live in developing countries, where 12.9% of the population is undernourished. Sub-Saharan Africa (SSA) is the region with the highest prevalence (percentage of population) of hunger. Even though SSA is the region with the highest hunger percentage, the proportion of undernourished people has decreased and the number of hungry people has been decreasing as well in SA (FAO, 2015).

Research traces the positive links between smallholder (including home gardens) agricultural development, food and nutrition security (Wiggins and Keats, 2013). Ndaeyo (2007) reported that homestead gardens offer the potential to improve household food and nutrition security by alleviating micro-nutrient deficiencies. Corlett *et al*., (2003), Baker (2004) and Vitiello *et al*. (2009), emphasize that homestead gardening increases household and community food security through the production and sharing of food, which may also be sold from garden plots.

Frayne *et al*. (2009) and Shackleton *et al.* (2019) further posited that homestead gardens have also been reported to strengthen local control over the food system in the rural and urban areas, where home gardening may be a response to inadequate access to food through market sources. The most important benefit of home gardens stems from their direct contribution to household food security by increasing availability, accessibility, and utilization of food products. They improve food security by providing direct access to a diversity of nutrient rich foods, reducing pressure on household budgets. The majority of South African households rely largely on purchased foods (Schmidt, 2005; Baiphethi and Jacobs, 2009; Chakona and Shackleton, 2019), which makes them more vulnerable to food price inflation (Schwabe, 2004; Odeku and Meyer, 2019). Household food production becomes a reasonable intervention to reduce the effects of high food prices, while offering a fallback food provision during seasonal lean periods (FAO, 2009; Simpson *et al.*, 2019).

Most of the world's hungry live in rural areas, and depend on the consumption and sale of agricultural products for both their income and food. The amount of food produced and available in a farm household does not implicitly relate to food quality, nutrient value, or diversity of household members' diets. As documented by Berti *et al*. (2004) many agricultural development interventions, including home gardening, livestock, mixed gardens and livestock, have indeed increased food production but have not necessarily led to improvements in the nutrient status of target populations. Thus, an integrated approach and investment linking agricultural production and human nutrition is needed (Lemke and Bellows, 2011). However, the integrated approach alone in the targeted population (smallholder production; often food gardens) will have no favourable impact upon food and nutrition unless backed up by parallel investment in public infrastructure (i.e. primarily health care, clean water supply) and female empowerment.

There is a general agreement that households get food mainly through three sources. These sources are the markets, subsistence production and transfers from public programmes or other households

(Baiphethi and Jacobs, 2009). These sources are also referred to as entitlements categories: production, exchange (barter or purchase) and transfers (Baiphethi and Jacobs, 2009; Devereux, 2009). Historically, rural households produced most of their own food, whereas urban households purchased most of their food. Previous studies have shown substantial increases in dependence on market purchases on the part of both urban and rural households (Maxwell *et al*., 1998; Ruel *et al*., 1998). As a result, food expenditures can be as much as 60-80% of the total income of low-income households (Ruel *et al*, 1998).

2.2.7 Contribution of community gardens to food security

Patel (1991) defined the community garden as a piece of land that is allocated by a local authority to a group of farmers or community members to use for agricultural production. It can be either for substantial farming or commercial farming. Community gardens are mainly managed by community members in groups of five or more.

Community gardens are used for numerous aims including economic, social and environmental projects and each of these will be discussed shortly. The main aim of community gardens is no longer food production for consumption only but has expanded into a form of creating jobs specifically for women and unemployed youth. Though these jobs usually have a low income and form part of informal employment they still contribute towards food security (Ndlovu, 2007). Secondly, food security can assist people in saving money on food, particularly vegetables, and using that money for something else, like paying for school fees and other household activities. They also educate people and give them skills so that they become able to help themselves, which contribute to economic wellbeing as well as food security (London-Lane, 2004).

The social role on community gardens includes improving people's health, maintaining a healthy diet and improving nutrition, thereby increasing food security. The environmental purpose in developing community gardens includes food awareness, soil conservation and soil erosion management (Ndlovu, 2007).

All these mentioned above result in poverty alleviation, improving the quality and quantity of households' food supplies, improving nutrition, and educating people in how to manage water in households and the community. They also learn how to manage natural resources and this improves food security.

Few studies by Stimie *et al.* (2010), Ruysenaar (2013) and Lucke *et al.* (2019) have been conducted on community gardens in SA, particularly in KwaZulu-Natal, Eastern Cape and Limpopo, which clearly shows that many rural communities in SA rely on food gardens for well-being and development.

2.2.8 Contribution of school gardens to food security

School gardens play an important role by allowing children to learn how to grow different crops, how to harvest and how to preserve food. They learn skills in how to go about finding a market and sell produce (Murray, 2011). Children at school need a proper diet in order to grow well, have enough energy to concentrate and participate during classes without feeling tired and sleepy, study and be protected from diseases (FAO, 2010).

School gardens play a role in the improvement of the quality of education, enhancing the knowledge of children, parents and the community at large of food production techniques. This teaches them about nutrition and the stimulation of school, community and home gardens. All this can result in the improvement of the nutrient status of children as well as their families and ultimately it can contribute to food security as well as human capital (FAO, 2005). It is therefore very important to teach skills to children at a very young age, so they can learn how to grow and eat nutritious healthy food (Murray, 2011). A number of schools in SA have engaged and participated in food gardening.

The "hands-on" activities of cultivating and growing a vegetable garden at school seem to be enjoyed by most learners. The Department of Education needs to help schools to develop a curriculum that integrates vocational and academic work. Doing so could encourage learners to develop as many facets of their abilities and skills as possible in preparation for a demanding adult life. Matching the curriculum to the learners' aptitudes and aspiration is also likely to make the learners more willing to learn while at school.

2.3 WATER USE

The link between smallholder agriculture, water and food security is not yet clear, however, a study conducted by Thamaga-Chitja *et al*. (2010), conducted in KwaZulu-Natal, showed that farmers with access to water were more likely to engage in agricultural production throughout the whole year in comparison to those without. Food security, water security and poverty are amongst the dominant issues currently facing developing countries in Africa. In the harsh, fragile environments of these developing countries, natural resource conservation is crucial. Only 3% of land in SA is considered as fertile and only 12% of the country is suitable for rain-fed crop production, due to climate and soil conditions.

Water resource quality and quantity augmentation has become important around the world (Livingston *et al*., 2011). Within the context of SSA, it is important to note that 70% of the population relies on agriculture either directly or indirectly (Livingston *et al*., 2011). The majority of these farmers reside in rural areas, having limited to no access to agricultural subsidies or essential production resources (Molden, 2011). One of the most important production resources is water. The role of water at the start-up stage of the food value chain, for overall achievement of food security, cannot be understated. Water is essential. Its availability is the single most important factor that has limited agricultural production in SA. Furthermore, the situation is likely to become severe, due to the rapidly increasing demand from other sectors of the economy and climate change (Molden, 2011).

Water for agriculture and crop productivity plays a significant role in delivering food security goals (Mabhaudhi, 2016). This realization has stimulated discussions around the water-food nexus. Within the context of SSA, it is important to note that approximately 70% of the population relies on agriculture either directly or indirectly (Livingston *et al*., 2011). According to Singh *et al.* (2011), 95% of this agriculture is primarily rain-fed. This then highlights the link between water use in agriculture and food security, explaining why water in agriculture remains the main vehicle for addressing food security in poor rural households (Molden, 2011). There is therefore a need to enhance current water resources in order to support the livelihoods of many.

According to a study conducted by the WRC (2011), a requirement for enhancing the contribution of water resources to sustainable livelihoods, is having an institutional context which helps to create conditions whereby the resource-poor households can gain access to water resources on a sustainable basis (WRC, 2011). In order to understand the specific form of rural livelihoods in relation to water resources, action-oriented socio-economic research is needed (WRC, 2011). This is very important as people's access to water in rural areas affects their agricultural production and food security substantially.

According to WRC (2011), sustainable water resource management must be part of broader agricultural production programmes, where a balance between technical, economic and social intervention is needed. Water harvesting and conservation are key aspects to sustainable agriculture and the viability of many rural livelihood systems, even in the face of climate change (WRC, 2011).

The WRC has initiated and funded several projects where rainwater harvesting and conservation practices were introduced and applied to address food insecurity and poverty in rural communities in semi-arid areas (Botha *et al*., 2003; Botha *et al*., 2014). The main aim of these projects was to promote food security by conserving limited rainfall for longer periods, which allows villagers to grow crops in semi-arid areas with low and erratic rainfall. With rainwater harvesting rainfall is concentrated as runoff from a larger area for its productive use in a smaller target area. During a rainfall event, runoff water is channelled towards the production area and stored in manually constructed basins. After the basins had been constructed, no-till is applied on the runoff area and a crust soon develops that promotes runoff. With the IRWH technique ex-field runoff is stopped completely and evaporation loss from the soil surface is minimized by the application of mulches (Figure 2).

The IRWH technique increased agronomic productivity, reduced crop production risk, improved conservation of the natural resources and is socially acceptable. The IRWH technique was used by more than 1400 households in 42, 8 and 19 rural villages in the Free State, Eastern Cape and Limpopo province, respectively to produce a variety of cash and vegetables crops, mainly for own consumption. In a few villages in Thaba Nchu (Free State), Lambani (Limpopo) and Alice (Eastern Cape), the IRWH technique was combined with roof water harvesting to enable community members to produce throughout the year as water stored in tanks was used for supplemental irrigation during periods of drought and in wintertime.

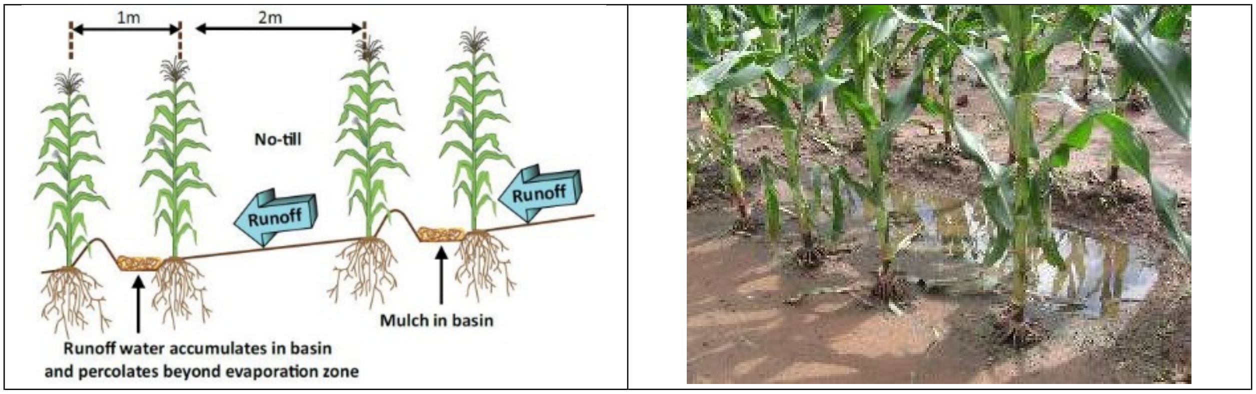


Figure 2 Diagrammatic representation of the IRWH technique.

The IPCC (2014) report on climate change has confirmed this with indications that climate change impacts in SSA will mainly be felt through changes in rainfall and water availability. This has placed agriculture in a situation where any increases in agricultural production cannot be met with corresponding increases in water use. What is concerning amongst smallholder farming is the negative impact on agricultural productivity and the adaptation or lack thereof, of water management technologies, that not only enhance adaptation to climate change effects, such as drought, but also result in an increase in productivity. The reality is that smallholder farmers might not possess the knowledge of water management technologies, making adaptation to the technologies difficult. However, in order for these challenges to be addressed, empirical evidence will be required, for the support of all efforts in designing strategies that will increase the adoption of water management technologies, that are not only profitable, but increase agricultural productivity and reduce drought-related production risks. According to Gnadlinger (2000), water management technology is known, but "*what is most needed is the moral acceptance of the technology and the political will to implement the systems*". For this purpose, the main objective of this research will therefore be to explore how smallholder farmers both utilize and manage their water at the start-up stage of the food value chain, for the improvement of their current food security status.

2.3.1 Concepts and definitions

2.3.1.1 Water security

Finding a single definition of water security is challenging. According to many authors, the definition is always dependent upon the need of the definition, be it human or environmental (WaterAid, 2012). However, for the context of this study, which encompasses both the human and environmental need of the definition, water security will be defined as reliable access to water, of sufficient quantity and quality for basic human needs, small-scale livelihoods and local ecosystem services, coupled with well-managed risk of water-related disasters (Grey and Sadoff, 2007).

2.3.1.2 Water source and water resource

It is important to note the difference in definitions, between a water source and a water resource. According to (WaterAid, 2012), a water source (or water point) is the point at which water can be accessed. Sources that are considered to be ‘improved’ are sources that have been protected from contamination. Water sources include boreholes or dug wells capped with hand pumps, protected springs, rainwater storage tanks, public tap stands or standpipes (WaterAid, 2012). Sources considered to be ‘unimproved’ include unprotected dug wells, unprotected springs, and surface water abstraction points on rivers, dams, lakes, streams, canals and irrigation channels (WaterAid, 2012). A water source depends upon a water resource. On the other hand, a water resource is the wider body of water upon which a water source depends (WaterAid, 2012). This could be surface water (e.g. rivers, streams, and lakes), ground water within an aquifer, or rainwater (WaterAid, 2012).

2.3.1.3 Water scarcity and water stress

Water scarcity is used to describe the relationship between the demand for water and its availability (Abrams, 2003). There are two types of water scarcity; physical scarcity and socio-economic scarcity. A physical scarcity exists when demand for water surpasses water supply. This usually occurs when water resources are over-exploited (Mukheibir, 2008). A socio-economic water scarcity exists when insufficient investment, skills or political will exist to keep up with growing demands for water, which overall prevents access to the resource (Grey and Sadoff, 2007). However, both forms of scarcity are derived from poor governance of water resources rather than absolute availability (Abrams, 2003 and Rockström *et al.*, 2010). Water is available but poor communities lack access to it (Abrams, 2003). On the other hand, water stress is closely linked to water scarcity. It is defined as the outcome of water scarcity (Xu and Li, 2020 and Huang *et al.*, 2020). The indicators of water stress often include conflict over water resources, poor access to water, crop failure and food insecurity (Abrams, 2003; Brewis *et al.*, 2020 and Schilling *et al.*, 2020).

2.3.1.4 Food security

Food security is defined as the condition that exists when all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life. (FAO, 2006).

2.3.2 Linking water and food security

SA has been classified as a water-scarce country (Seckler and Amaransinghe, 2000; Bwapwa, 2018; Khuzwayo and Chirwa, 2020). Research shows that if current water resources are not supplemented by 2025, the demand for water in the country will exceed supply [Local Government Budgets and Expenditure Review (LGBER), 2011]. While smallholder farming communities face a range of different challenges, access to water is the single biggest problem that they face. Water is crucial for the generation of food and livelihoods amongst the rural poor. Water is a necessity in achieving food security.

One of SA's biggest challenges is household food security, which is currently being promoted amongst a growing population. What is most concerning is the expectation of farmers to utilize the same amount of water. The most water-intensive activity in society is known to be food production, particularly local food production globally, even in SA. Yet, only a handful of studies have systematically investigated the utilization and management of water for home gardens, particularly for this water-scarce country which is currently experiencing drought. Due to water scarcity, crop systems are at risk, affecting the livelihoods of rural households (Scotcher, 2009). It is without a doubt that the rural poor are the most affected, yet no baseline information is available on the use of water by smallholder farmers and if they possess adequate skills to conserve it. This impacts household food security.

There are a number of aspects to food security, which can be disaggregated, as taken from FAO (2006);

- Food access is the ability to access available food, including the economic, legal, political and social capacity for obtaining such access.
- Food availability is the availability of sufficient quantities of food of adequate quality.
- Utilization is the capacity to safely and effectively utilize food, including having an adequate diet to maintain good nutrition, and non-food elements such as access to clean water and sanitation.
- Stability is an existing ability to acquire and use food as well as a stability of supply and safety from risk.

Taking into full consideration this definition of food security, it is important to note that the state of food security in SA is multi-dimensional. Agriculture plays an important role as a sector in the South African economy, not because of its contribution to the gross domestic product (GDP) but because of benefits such as rural upliftment and employment (Baleta and Pegram, 2014). Some parts of the country have an agricultural advantage over others, depending on the type of agricultural. Each has a demand on water as a primary input, in timing, quality and quantity. This is the reason why nationally, the country is food secure, although 20% of the population in the Northern Cape and North West is considered to be food insecure at household level. (Baleta and Pegram, 2014).

The development priorities in SA indicate the importance of agriculture in the 2030 vision. Due to the water-intensive nature of agriculture and the potential impact of climate change in SA, the projections and planning regarding food security and production have to consider the availability of water resources (Baleta and Pegram, 2014). A total of 60% of all water abstracted in SA goes towards the irrigation of crops alone (Baleta and Pegram, 2014), so an increase in water stress poses a threat to crops that are depended on irrigation or are rain-fed.

The NDP Vision for 2030 compiled in 2011, identifies key priority areas for the development of an improved SA in 2030. Many of the suggested strategies impact water availability, food production or food security in one way or another. One of the major objectives highlighted in the NDP is the support of an economy that is capable of creating more jobs (Baleta and Pegram, 2014). Labour-absorbing industries in the report, such as agriculture and agro-processing, are suggested to boost employment in the country (Baleta and Pegram, 2014).

At household level, micro-economic reforms in the area of food and many others, are suggested to reduce the cost of living for households (Baleta and Pegram, 2014). Regional and global trade targets make mention of developing regional markets for food, energy and water with neighbouring states. Overall, the report highlights that agricultural water management is generally perceived as a key step towards improving low-yielding smallholder farming systems.

2.3.3 Water availability and agricultural water requirements in South Africa

2.3.3.1 Water availability

Water resources are classified into two broad groups, green water and blue water. Green water is what enters the soil, is temporarily stored there and flows out by evapotranspiration (Falkenmark, 2006). It is essential for the growth of plants and may exist in large quantities (Falkenmark, 2006). Green water is often overlooked when water resource availability assessments are made (Falkenmark, 2006). Blue water consists of groundwater, rivers, streams, and lakes (Falkenmark, 2006). The distinction between green and blue water is a useful concept. It clearly communicates the distinct water requirements of different crops in different regions (Falkenmark, 2006; Chowdhury *et al*., 2016). It is important to note that planning, resource management and infrastructure needs of green water that is rainfall, and blue water which is irrigation, are very different from each other. It is also important to note that water resource availability can vary within a country and such is the case in SA.

In terms of rainfall, the eastern side of SA receives considerably more rain than the dry western portion of the country (Mbiriri *et al.*, 2019). Rainfall varies from less than 50 mm in the extreme northwest to more than 3000 mm in the mountains of the south-western Cape (Baleta and Pegram, 2014; Chase *et al.*, 2020). The quality of water is also important to consider in SA, apart from the quantity of water available for use. Poor quality water that is not fit for purpose successfully reduces the amount of water available (Baleta and Pegram, 2014). Evidently, across the country, water quality is not uniform, with some regions experiencing poor water quality through natural causes (Tundu *et al.*, 2018). However, water is still in demand in large quantities, particularly in agriculture for production.

2.3.3.2 Agricultural water requirements in South Africa

There is a growing demand for water in SA. SA is a semi-arid, water scarce country. Rainfall levels average 450 mm year^{-1}, compared to the world average of 860 mm year^{-1} (National Treasury, 2011). Rainfall patterns also differ between the western and eastern parts of the country, with rainfall levels as low as 100 mm year-1 in the west and as high as 1500 mm year^{-1} in the east (National Treasury, 2011). This highlights the variability in water availability. While the total annual surface run-off is estimated to be 49 000 million cubic meters, only 14 200 million cubic meters per year or 29% of the total surface run-off is available as a reliable yield (National Treasury, 2011).

Ground water resources are also not abundant, as most of SA is made up of hard rock formations that do not contain major ground aquifers that can be used on a national scale (National Treasury, 2011). It is estimated that only 20% of SA's ground water can currently be used (National Treasury, 2011). Ground water resources are used extensively in rural and arid areas and it is estimated that about two-thirds of the population are dependent on ground water for domestic needs (National Treasury, 2011).

SA's water resources are comprised of 77% surface water, 9% groundwater and 14% re-use of return flows (National Treasury, 2011). From the resources available, the demand for water is dominated by agriculture, at 60% of total demand (LGBER, 2011). The domestic demand of water accounts for 27% in total, 24% for urban areas and 3% for rural supply particularly for agricultural use (National Treasury, 2011.) The largest proportion of crop water use is green water (rainfall). This however varies for crops grown in drier regions that require larger amounts of irrigation.

The national water resources strategy (2004) estimates that at current usage and price levels, available water resources will be insufficient to meet demands by 2025 (LGBER, 2011). Projected total water requirements in 2025 will be approximately 17 billion cubic meters, versus a reliable yield of 15 billion cubic meters, which is a 98% assurance of supply level (LGBER, 2011). About one million ha of land is under irrigation while 1.3 million small-scale farmers cultivate approximately 14 million ha (Baleta & Pegram, 2014). Due to the inadequate arable land and water resources, most of the land in SA is used for grazing and livestock farming.

Overall, water is necessary to produce the agricultural products mentioned. A large proportion of SA agriculture consists of the cultivation of rain-fed crops or livestock farming (Baleta and Pegram, 2014). However, water requirements for irrigation in SA are significant, representing 60% of the total water use per sector (Baleta and Pegram, 2014). The extent of irrigation is impacted by a number of factors including crop type, climate and the level of infrastructure development in the region. Irrigation is necessary for the efficient production of crops. In SA, 1.5% of the land is under irrigation, but this area produces 30% of the country's crops. About 1.3 million ha of land are under irrigation (Baleta and Pegram, 2014).

At the other end of the scale, 1.3 million small-scale farmers use around 14 million ha with an average farm size of just over 11 ha (Baleta and Pegram, 2014). The different nature of commercial and small-scale farming in terms of irrigation, crop type and use for trade on the market and household food supply, has implications for food security. This is based on the fact that for each type of farming there is a different relationship between water and food production (Baleta and Pegram, 2014). For example, water stress and scarcity will have a lesser impact on the average household food security of commercial farmers than would be the case for small-scale farmers, who use the farm to supplement their food supply (Baleta and Pegram, 2014). The question is, then, how are smallholder farmers coping with water stress and scarcity; are they equipped with water management technology and if not, what are the constraints?

2.3.4 Water management, smallholder farming and technology adoption constraints in South Africa

One of the key solutions in achieving food security, which has not been explored amongst smallholder farmers in SA, is through increased water productivity. In its broadest sense, water productivity is the net return for a unit of water used (IFAD, 2013). Water productivity improvement aims at producing more food and income and better livelihoods and ecosystem services with less water (IFAD, 2013). There is considerable scope for improving water productivity of crop systems, which has not yet been explored by smallholder farmers, although there are a number of practices used to achieve this.

Agricultural water management in smallholder farming systems can provide a solution in the provision of opportunities to secure crop production. These practices include water harvesting, irrigation techniques and soil-water conservation practices.

In SA, some of the key agricultural water technologies available include: small power pumps, bucket and drum rip, bucket irrigation, minimum tillage which is part of conservation farming, contour ridges, gully erosion control, small earth dams, boreholes and river diversion/weirs (IFAD, 2013). This is not to say, though, that these are the only technologies that exist. Others include: treadle pumps, rope and washer pumps, elephant pumps, hand pumps, small power pumps, direct applicator hoses, bucket irrigation, clay ports, mulching, hand dug shallow wells, underground tanks, above ground tanks and roof top harvesting (IFAD, 2013).

These are biophysically and technically appropriate and economically viable. However, the low adoption of these technologies that have the potential to reap so many benefits is of concern amongst smallholder farmers. It is important to note that some of the technologies and practices have been known to the farmers for many years or are indigenous, but the extent of their use or adoption is low.

2.3.4.1 Water management technology adoption constraints in South Africa

According to research, water management practices are seldom adopted due to social, economic and biophysical constraints (Twomlow *et al*., 2008). A study conducted by Barrett in 2008, shows that other than these constraints, having limited access to improved water management technologies is also a greater reason why smallholder farmer participation in agricultural input and output markets is limited (Barrett, 2008). Not having immediate access to clean water, the time and energy required to fetch water, coupled with the negative health impacts of water-related diseases, affects the ability of smallholder farmers to farm and work (WaterAid, 2012).

The reality is that poor communities often do not have access to sufficient quantities of good quality water locally, even though water itself may not be scarce nationally. This is often because water supply services, which are needed in accessing, storing and conveying available water to communities are often unequally distributed and water resources largely go unmanaged (WaterAid, 2012). This then concludes that the problem with water access amongst smallholder farmers is largely due to the way that water resources and water supply services are governed by both service providers and the farmers themselves.

Worldwide, the lack of access to safe water is not as a result of physical scarcity, where by the demand outweighs the available supply. Socio-economic water scarcity is the biggest problem, as mentioned earlier (WaterAid, 2012). Some of the main water access constraints include; inadequate political will to improve water supply services and management of water resources; a lack of investment in water supply services and management of water resources; the lack of skills to manage water supply services and water resources; the lack of human capital to manage water supply services and water resources; and often the exclusion of certain groups, because of their inability to pay, political affiliation, disability, race, age, social status and often gender (WaterAid, 2012).

In other cases, smallholder farmers may have water resources present, but not when they are needed and where they are needed. If not the case, water resources are either located at a great distance from households, contaminated, or inaccessible because of difficult terrain; or they may have been depleted due to uncontrolled extraction.

According to a study conducted by Muchara *et al*. (2015), smallholder farmers face the challenge of having no knowledge of how to access water. Farmers have to be licensed as water users and are required to belong to a Water User Association, which regulates and manages the distribution of water, to legally draw water from rivers and dams (Muchara *et al*., 2015). They further claim that many of the smallholder farmers distrust these organizations, as they believe they are merely put in place to charge them for their water usage.

This results in smallholder farmers using water illegally (Muchara *et al*., 2015). Samakande *et al.* (2004), Muchara *et al*. (2015) and Oliver *et al.* (2020) add that there is a skills shortage when it comes to water management at smallholder level. "Water management structures at smallholder levels are too weak and the water use associations at smallholder level are not operational. Farmers do not know what has to be done and who should be responsible for it", (Muchara *et al*., 2015). While other studies (Bukchin and Kerret, 2020; Lowitt et *al.*, 2020) support that smallholder farmers often do not trust water regulatory organizations, it is important to note whether or not it is because of the lack of political will in the management and supplying of these services by relevant institutions.

Several research projects have shown that the majority of rural households perceive changes in local climates, especially in relation to the later onset of the seasonal summer rains, increased climate variability and increased severity of extreme climate events. This means that for many, the old, time-established ways of agriculture and food production will be less productive and hence food insecurity is likely to increase unless appropriate CSTs are adopted. CST promotes ways of food production that both (i) lowers emissions of greenhouse gases and (ii) increases the productivity, adaptability and resilience of food production systems in the face of climate change, whilst embedding agricultural systems in the broader landscapes and flow of ecosystem services from those landscapes.

The increasing variability and severity of local weather patterns requires that production systems need to be more adaptable and flexible and that farmers must be able to respond in shorter time periods than has been the case up until now. At the local scale, this will require greater information to farmers and households on CST, farmers and households having access to a greater variety of crop types and genetic stocks, increased use of conservation agriculture techniques, better medium-to-long-term weather forecasting and social learning regarding new approaches (Shackleton *et al*., 2015).

Weak political will and low institutional capacity to manage water resource and supply services, poor governance and/or weak political will to commit the necessary financial and human resources to water supply development and water resource management suppresses progress in water management (WaterAid, 2009). According to WaterAid (2009), even where sufficient financial resources are allocated, serious and widespread capacity constraints undermine effective implementation and equitable targeting of water services. The responsibility for managing rural water services is often delegated to communities. However, whether or not communities can manage their water supply services sustainably in the absence of external technical, managerial and financial support from local public or private sector institutions is questionable (WaterAid 2011).

In cases where major repairs are needed, external support is a requirement (WaterAid, 2011). In other cases, when investment is made in institutions tasked with water resource management, communication and enforcement of legislation and regulations can be a slow process, and there can be confusion over responsibilities at the local level (Cook and Bakker, 2010). National-level water resource management policies are also developed without consideration of existing informal and traditional institutions tasked with allocation of water resources and resolution of water-use disputes, sometimes making them irrelevant at the local level (Cook and Bakker, 2010). Such conflict within regulatory institutions sometimes creates a disinterest among users at grassroots level. These are smallholder farmers, although sometimes this is not the case.

In semi-arid developing countries, there is growing interest in the large range of low-cost agricultural water management technologies [International Water Management Institute (IWMI), 2006]. The growing interest is as a result of the vast majority of the rural poor relying on rain-fed land for their survival, which makes them vulnerable to the highly variable and unpredictable rainfall (IWMI, 2006). The growing interest is therefor in response to the observation that unreliable water supply is one of the biggest threats to the food security of resource-poor smallholder farmers.

There are a number of ways in which agricultural water management technologies may bring about desirable changes for smallholder farmers within their households. Some of these ways, as adopted from IWMI (2006), include:

- Improved cropping intensity.
- Improved productivity of water and land.
- Stabilized outputs.
- Multiple use or multi-functionality of boreholes and dams.

With so many desirable livelihood outcomes from the adoption of agricultural water management technologies, the various methods available for assessing water utilization and water management amongst smallholder agriculture are flawed. The development focus in water resources management has to a large extent focused on large scale, downstream located systems, like irrigation schemes (Rockstrom, 2000). However, there is a substantial opportunity to shift to small- scale water harvesting systems, taking advantage of the grown interest and development potential (Rockstrom, 2000). Overall, there is a need for careful assessment of the utilization and management of water, including that of governing authorities.

2.3.5 Water Policy-Governing Water Authority in South Africa

The Comprehensive Africa Agriculture Development Programme (CAADP) of the African Union (AU)'s New Partnership for Africa's Development recognized the agricultural potential and need for sustainable water management throughout Africa, by prioritizing the first of its four pillars, 'Sustainable

Land and Water Management' (CAADP, 2009). SA has also responded to the issue, through the National Development Plan (NDP), Vision 2030.

The National Water Resource Strategy (DWA, 2013) responds to SA's vision for 2030, as articulated in the National Development Plan and to the national government outcomes outlined in National Government's Programme of Action for 2010-2014 (Stevens and Van Koppen, 2015). These priorities are key drivers for change. In its Vision 2030, the National Development Plan articulates the national development goal of eradicating poverty and sharply reducing inequality by 2030 (NPC, 2010). To achieve this, the crucial role water plays in all sectors, such as agriculture, mining, energy, industry, tourism, urban growth and rural development, the allocation, development and protection of water has been recognized and placed as a crucial prerequisite for inclusive economic growth, poverty reduction and the significant reduction of inequality in the country (NPC, 2010).

SA's National Water Resource Strategy provides a framework that ensures water is protected and conserved over a longer period. It also contributes to the attainment of the social and economic goals of the country (Stevens and Van Koppen, 2015). Overall, the National Water Resource Strategy warns that meeting the growing demand for water will be increasingly difficult and costly in the country. As a result, a range of measures are initiated in the pursuit of water protection and conservation. These include the following, as listed by the DWA (2013):

- A focus on water conservation and demand management.
- Re-use of water in inland systems and the coast.
- Increased utilization of ground water.
- Catchment rehabilitation, clearing of invasive alien plants and rainwater harvesting.
- Using the most cost-effective and suitable sites for dams and transfer schemes.

Measures initiated in the pursuit of water protection and conservation have been largely influenced by water scarcity in the country. Water scarcity in the country has created a need to regulate water usage. This is to ensure the equitable, efficient and sustainable utilization of water. According to Stevens and Van Koppen (2015), the country's National Water Act clearly distinguishes permissible use, General Authorization, Existing Lawful Use (before 1998), and licensed water use (for water uptake after 1998). Benefits derived from the equitable access to water are critical for the eradication of poverty and promotion of economic growth (Stevens and Van Koppen, 2015).

The equitable utilization of water means that everyone has fair opportunities to access, use and control water resources (Stevens and Van Koppen, 2015). To balance supply requirements in a way that is beneficial to all citizens, the water allocation system uses water pricing and limited-term allocations (Stevens and Van Koppen, 2015). One of the basics of water allocation is that any form of extraction, transfer, storage or other influence on a natural stream affects the entire downstream river system (Stevens and Van Koppen, 2015). Therefore, in order to ensure effective transformation in water use, a water allocation reform programme is currently being run by the DWA (Stevens & van Koppen, 2015).

To ensure that there is one single water law system, the compulsory licensing process is used to convert Existing Lawful Uses into licenses (Stevens and Van Koppen, 2015). As a result, unused allocations or over allocations are taken away in this process, in order to reallocate water, achieving more equity (Stevens and Van Koppen, 2015). During the year 2012, compulsory licensing was initiated in three catchments in the country, namely Mhlathuze (KwaZulu-Natal), Tosca (Northern Cape) and Jan Dissel (Western Cape) (DWA, 2013).

It is important to note that farmers within the former homeland still face a number of challenges. The establishment of structures that facilitate access to water amongst smallholder farmers are still needed at the farmers' level and at the service provider level, allowing cooperation between different spheres of government and community-based organizations (DWA, 2013). This is crucial, if services are tailored to assist the production input needs of smallholder farmers. According to literature, policies are on paper but lack implementation.

2.3.6 Water as an input in the food value chain

Water is a necessity in all forms of agricultural production, including home gardens. Home gardens are often defined as gardens, which produce fruits, and vegetables, that can then be consumed (WHO, 2003). Some literature refers to home gardens as food or kitchen gardens. Home gardens serve as a starting point to assess how alternative systems might contribute to combating hunger and poverty through employment and form part of the local food movement (WHO, 2003). They represent an individual response to issues of hunger. Ultimately, farmers can rather grow their own food and in doing so, take responsibility for their own food supply. Smallholder farmers are known to produce the most food in developing countries (FAO, 2014). Studies show that Africa's food is produced by approximately 90% of smallholder farmers (FAO, 2014). Studies also show that smallholder farming's environmental footprint is small, as natural resource pressure is less, in comparison to large-scale mono-cropping. Cash-poor smallholder farmers use inputs that are natural rather than chemicals (FAO, 2014). Home gardens form part of the start-up stage of the food value chain. Value chains can be an opportunity to link smallholder farmers in developing countries to lucrative markets for consumer goods worldwide. Smallholder engagement in value chains makes sense. There are a number of components necessary to make them a successful tool for development, although they are not guaranteed success, particularly when not sustainable.

Kaplinsky and Morris (2000), define a sustainable food value chain as, *"a full range of farms and firms and their successive coordinated value-adding activities that produce particular raw agricultural materials and transform them into particular food products that are sold to final consumers and disposed of after use, in a manner that is profitable throughout, has broad-based benefits for society and does not permanently deplete natural resources"*. FAO (2010) defines a value chain as a supply chain in agriculture that identifies the set of actors and activities that bring a basic agricultural product from production in the field to final consumption, where at each stage value is added to the product (FAO, 2010). This can involve processing, packaging, storage, transport and distribution (FAO, 2010).

Water is an important input into the food value chain. There are a number of stages in this value chain and water is used at every stage. These stages include: inputs, production, processing and distribution, marketing and consuming (Baleta and Pegram, 2014). Embedded water or virtual water represents the water embodied in the inputs required to produce the final product (Baleta and Pegram, 2014). Agricultural products are generally said to have a significantly larger water footprint attributed to the crop production stage than the processing stage (Baleta and Pegram, 2014). There is little information, however, about the amount of water required at the start-up stage of the smallholder farming food value chain. Studies quantifying the amount of water used are few, if not non-existent. It is important to note the need for water at the start-up stage of the food value chain as well as the need for sustainability in the process.

Value chains hold the potential for smallholder farmers to become key players in the mainstream market while contributing to the economy and improving their livelihoods. Depending on the produce, farmer support in becoming more productive where there is a comparative advantage, could potentially improve their livelihoods in the short and long run.

2.4 NUTRITION, WATER USE, FOOD GARDENS AND FOOD SECURITY

Globally, the world population is projected at 9 billion people by 2050. The topical issue of how the 9 billion will be fed is prominent in food security discussions. In addition to feeding the growing population, poverty and food and nutrition security remain at the heart of the concern. The causal and resultant relationship between poverty and food insecurity is expressed by a non-ending cycle and pattern of malnutrition and poor societal and economic development. The high rates of malnutrition among rural communities are a stark reminder that the link between agriculture and nutrition is broken. The development of value chain systems in agriculture will not only provide healthy food to feed the increasing world population they will also create a system of employment for the rural poor who depend on agriculture for livelihood.

Malnutrition negatively affects all aspects of an individual's health and development and it limits society's economic and social development. Such complexities are more evident in rural, urban and peri-urban areas in SA. Although many households in SA are cash based, the role of subsistence agriculture and homestead gardening as a source of extra food, especially for female-headed households, has been noted. The world over, there is a growing interest in strengthening and intensifying local food production initiatives to mitigate the effects of global food price shocks (Galhena *et al*., 2013). Increasingly, home gardens are viewed as a household food security and nutrition-enhancing strategy and as important in the local food system. Homestead gardening plays an important role in contributing to the food security of poor households in developing countries, including SA.

Several studies have captured this fact over the years (Mcata and Obi, 2015). However, it is an anomaly to speak of food production, water access and water use security without relating them to security of land access, especially for women. Effective water use at the household level would mean increased production of food, which may guarantee adequate food supply and open up selling opportunities due to the surplus. There are a few success stories of urban gardening that link to the value chain, including the longstanding Abalimi Bezekaya (Kirkland, 2008). A good understanding of the food system, that delivers various food baskets and their nutrient status in rural and semi-rural areas of SA, will provide direction for appropriate, sustainable and nutrition-sensitive agricultural planning that is accepted by affected communities and provides nutrients required for human development.

2.4.1 Water, Agriculture and Food and Nutrition Security

It is an established fact that food availability relies primarily on the overall performance of the agricultural sector, while depending on a country's competence and ability in processing, importing, storing and distribution. Domestic production is supplemented by food imports directed by food consumption patterns. Unlike most southern African countries, SA is largely food secure (with increasing imports of key crops such as wheat) at a national level but has serious food access constraints at a household level, affecting more than fourteen million people as mentioned earlier (Labadarious *et al*., 2009). Domestic food production continues to be affected by factors such as land availability and access to irrigation water where activities such as mining continue to take on more agricultural land and water, thus decreasing arable land availability and irrigation capacity. Furthermore, other factors that may affect stability of supply can be related to crop storage and road and market infrastructure which are limited, especially in far flung places where government intervention may be required (NFNS, 2013).

One major challenge to consider when engaging with food production is climate change. The impact of this affects food availability, water availability and diversity of grown crops, especially for the poor. The link between water and food security is increasingly being recognized globally.

There are several correlations between water quality and food security. Below are the three most common links that have been noted for the purpose of the study. Firstly, there is a strong link between water quality and food safety in terms of production. Hence, the processing of food with wastewater or with water that is contaminated with pollutants poses many health threats to those who consume the produced food. Secondly, there are also links between water quality and inputs in the food production process, such as chemicals (fertilizers and pesticides) and livelihood assets such as soil quality. Thirdly, there are links between water consumed with health and nutrition outcomes.

Therefore, water safety is one of the most pressing development challenges of the early 21st Century; over 1.8 million people die every year from diarrheal diseases (including cholera); 90% are children under 5, mostly in developing countries. In SA, the highest killer of children under 12 has been linked to water diseases (StatsSA, 2014)

Water-use security is an important emerging concept and is currently defined by the United Nations Water Agency as the capacity of a population to safeguard sustainable access to adequate quantities of acceptable-quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against waterborne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability (UN-Water, 2013). Several studies in South African have shown a link between agricultural water, agricultural practices (husbandry) and food safety with implications for nutrition outcomes (Mdluli *et al.*, 2013; Beharielal *et al.*, 2018). Access to safe water for agricultural use, sanitation facilities and good hygiene have the potential to positively impact nutrient outcomes by addressing both the direct and underlying causes of malnutrition. Furthermore, poor sanitation has been strongly linked to poor food security outcomes (Dangour *et al.*, 2013). Therefore, the enhancement of agency and empowerment through knowledge and skills improvement of households, especially headed by women, is a critical element for improving nutrient outcomes.

Food production activities at school, homestead and community level are important, particularly for young people, inculcating a passion for agriculture. This passion is an important building block for entrepreneurial activities linked to agriculture, increasing the possibility of encouraging ownership, management and capacity for accessing land and water. The youth can be involved in the value chain when they see evidence that an income is possible, provided markets are available. Given the overwhelming evidence that more women than men are involved in production, especially at the beginning of the value chain, the following section focuses on women farmers and what hinders them from entering the value chain.

2.4.2 The role of nutrition for development of infants in the first 1000 days of life

According to Fanzo (2012), malnutrition is a broad term commonly used to describe people who are malnourished due to the fact that their diet does not provide adequate calories, protein for growth and maintenance, and micronutrients; or they are unable to fully use the food they eat due to illness or lack of safe water. In this study, literature on micronutrient deficiencies is reviewed. Micro-nutrients are substances such as vitamins and minerals that are necessary dietary components, needed in small quantities for health and wellbeing.

The main micro-nutrients are iron, Vitamin A, Iodine, and Zinc (Fanzo, 2012). The consequences of their absence are severe, impacting in particular on pregnant or lactating women and children's physical growth, mental development and immune function (Smith and Scholey, 2014). The main signs of malnutrition occur by the age of two in most children (Shrimpton *et al.*, 2001; Kar *et al.*, 2008). According to the World Health Organisation (WHO, 2013), the two main causes of malnutrition are protein energy malnutrition and micronutrient deficiencies.

It been said that when women are pregnant or lactating, their diet needs to be richer in energy and nutrients. For example, during pregnancy a woman needs an extra 300 kilocalories per day after the first trimester and 500 kilocalories more when her baby is breastfeeding (Chopra *et al.*, 2009). A lack of adequate nutrition can have a severe impact on the growth and development on the child (Aguero *et al.*, 2006). According to Nyaradi *et al.* (2013) cognition represents a complex set of higher mental functions sub-served by the brain, and includes attention, memory, thinking, learning, and perception; the process often starts in the womb and continues through at least the first two years of life (1000 days). The periods of pregnancy and lactation and the first two years present special nutrient challenges because this is when nutrition requirements are greatest.

According to Chopra *et al.* (2009) the first 1,000 days of life are a window of opportunity for health and development. Save the Children (2012) noted that good nutrition during the 1000-day period between the start of a woman's pregnancy and her child's second birthday is critical to the future health, wellbeing and success of her child. The right nutrition during this window can have a profound impact on a child's ability to grow, learn and rise out of poverty. It also benefits society by boosting productivity and improving economic prospects for families and communities. Nutrient-rich foods to the diet through food gardening could reduce micro-nutrient deficiencies.

To meaningfully incorporate nutrition elements into the concept of food security, it is important to ensure adequate protein, energy, vitamins, and minerals for all household members at all times. Going beyond just food intake to incorporate health and environmental factors, nutrition security is when a household has secure access to food linked with a sanitary environment, adequate health services, and knowledgeable child care practices. A review (Nyaradi *et al*., 2013) concluded from a study, conducted by Maleta *et al*. (2003) among 767 children in Malawi who were followed from birth through 36 months of age, that it is important to assimilate actions mentioned above throughout these early stages of life.

2.4.3 Food gardens and vulnerable groups in poor communities

Home gardens (Thuo, 2010) are socially constructed spaces that exist close to the household and are managed by various household members. They are food plots within the boundaries of the residential sites and differ in size (Veteto and Scarbo, 2009; Boone and Taylor, 2016). The term food garden encompasses two completely different things that together form such activity as gardening and human groups (households, communities and schools). The term human group(s) is a collection of individuals who have regular contact and frequent interaction, mutual influence, common feeling of solidarity, and who work together to achieve a common set of goals (Holland, 2004). Gardening, on the other hand, can be defined as an activity that involves growing plants and it varies from farming by scale and purpose.

Home gardening is an affordable, sustainable long-term strategy to complement supplementation and food fortification programmes and nutrition education (Chadha and Oluoch, 2003; Faber, 2007). Home gardening produces crops for household consumption to improve the quality, diversity and nutrient content of diets. The vegetables supply immediately accessible sources of micronutrients, as they can be cultivated throughout the year, providing vitamins, trace elements and other bioactive compounds needed by children and vulnerable household members. According to (Chadha and Oluoch, 2003) food gardens can provide direct access to a diversity of fresh foods and nutrients, as well as an important stable supply of socio-economic products, such as supplementary income, and benefits to the families that maintain them. Furthermore, food gardens can provide households with direct access to Pro-Vitamin A-rich vegetables that are not readily available or within their financial reach. As a result, the nutrient status of young children and other vulnerable groups should improve.

According to Grantham-McGregor *et al*. (2007) 200 million children in the developing world (poor households) are not fulfilling their potential for development, because of poverty, under-nutrition, micronutrient deficiencies and learning environments that do not provide enough stimulation and nurturance. These children are developing more slowly, or failing to develop critical thinking and learning skills and thus the household is locked in poverty.

However, for poor and marginalized families unable to afford expensive animal products to fulfil their nutrient needs, food gardens (either home or community) can offer a cheap source of nutritious foods.

Through gardening, households can have better access to a diversity of plant and animal food items that leads to an overall increase in dietary intake and boosts the bioavailability and absorption of essential nutrients (Galhena *et al*., 2013).

2.4.4 Water use, gender and nutrition in the value chain

Water use can lead to important changes in the livelihood and food security of households (Edame *et al*., 2011). The four food security elements: food availability, access, utilization, and stability are likely to change as a result of increased water availability for crop production and other uses. Irrigation can have a direct impact on food availability because of increased productivity and changes in cropping patterns. Furthermore, (Domènech, 2015) irrigation will probably increase the stability of the food supply because irrigation's main role is to improve water control, thus reducing or removing potentially adverse impacts on production from too little rain.

However, (Domènech, 2015) does more available food and possibly more income lead to increased food access and utilization? Greater availability of food can certainly favour greater food intake, but this might not always be real in an intra-household setting. Irrigated crops are often cash crops, and cash crops are often men's domain. If decisions regarding the crop are in male hands, including the sale and income from the sale, then intra-household food and nutrition outcomes might not improve (Coles and Mitchell, 2011). Thus, gender dynamics and women's roles in irrigated agriculture are important determinants of food access and utilization. At the same time, the consumption of more nutritious foods might not be sufficient to achieve normal growth and cognitive development in children (Nyaradiet *et al*., 2013). Nutritious diets are certainly a requirement for children's healthy growth, but other conditions such as a healthy environment are also needed. In the same way members of poor households have nutrient needs including young adults, childbearing women and the elderly. Recognizing women as independent users of water and enabling women to access water rights, regardless of land ownership; supporting women's food production systems and value chains, including in adaptation and mitigation of climate change; food production and processing and care work might address issues of gender inequalities in the value chain.

2.5 POLICY RESPONSIVENESS

Government institutions, donors and development specialists have seen the important role played by agriculture in local economic growth and food security, more particularly in countries highly dependent on the sector, but the incorporation of gender and nutrition issues in such programmes is less visible. Agricultural policies and strategies should integrate nutrition through actions targeting vulnerable populations, in order to increase food production, access to food and food diversity. Furthermore, incorporating nutrient, health and gender considerations into the design of new food production and irrigation programmes and policies would be a vital step toward realizing the full potential of irrigation interventions. Homestead food production should be encouraged, and policy collaborations between different sectors (agriculture, nutrition, health, water supply and sanitation, education) should be sought.

Water is a source of life and a natural resource that sustains our environments and supports livelihoods, but it is also a source of risk and vulnerability, and that is why formulating gender-sensitive programmes will help enhance competitiveness and gender equality (and women's empowerment) goals, thereby enabling poverty reduction and improved food security for all (USAID, 2010). It is crucial to address water security and these gender dimensions in national development plans, poverty reduction strategies, agricultural and rural development policies, and other development frameworks. Equitable water security needs to be a public policy priority.

There is a need to catalyse alliances, knowledge sharing, commitment, innovations, actions and financing to address the nexus between food security and water from a gender perspective. Gender equality and women's empowerment must be part of any blue revolution and any ‘second green generation revolution’ that seek to be launched. Specific policies that promote multiple uses of irrigation water can also be instrumental in improving nutrition and health outcomes. Evidence points to a lack of water supply and sanitation and associated environmental enteropathy as underestimated factors influencing the nutrient and health status (Domènech, 2015). Therefore, adding a water supply component to the design of irrigation interventions can be beneficial for nutrition and health.

2.6 SUMMARY AND CONCLUSION

Local policies that inform interventions that target poverty, gender and food security in SA are influenced by global and regional policies. However, to determine policy priorities to address poverty and food insecurity, and to assess the role that agriculture can play in the national effort, it is necessary to understand how people in rural areas create livelihoods (De Klerk *et al*., 2004). According to Du Toit (2011), one of the encouraging developments has been the growth in support for home gardens (Carter and May, 1999; Baiphethi and Jacobs, 2009; Du Toit, 2011), especially in peri-urban and urban areas, where small plots, of vegetables in particular, can contribute significantly to both livelihoods and nutrient standards (Cofie *et al*., 2003; Du Toit, 2011). In SA people that suffer most from food insecurity are people from rural areas and gardening have proven to be the most important way to alleviate poverty, support their families and contribute to food security. Poverty is a multi-dimensional phenomenon that needs special attention from the government, civil society organizations and business organizations.

Most communities in rural areas are very disadvantaged, which therefore hinders them in producing food in high quantities. The government needs to provide a support system to the communities with start-up capital, water for irrigation, infrastructure and fencing and give them on-going mentorship. However, much more needs to be done, especially among the poor in rural areas, to stimulate home gardening. Extension services have a major role to play in promoting production and, at the same time, encouraging householders to devote more attention to this currently neglected section of the economy by entering the local food value chain. The contribution that own production can make to alleviating rural poverty is limited, due to the factors such as the availability of land, the difficulties of obtaining water, or a lack of family labour. Employment opportunities therefore remain the most critical issue for many rural households.

If food gardening can be supported it can potentially impact on human nutrition by providing a variety of foods in sufficient quantities to enable all household members to eat a nutrient adequate diet. This demands closer cooperation between nutrition and agriculture, which thus far seems to have been limited in SA. For agricultural interventions to improve food security and nutrition, the intervention must have a well-designed agricultural component as well as a well- designed nutrient component, and these two components should be mutually supporting (Wenhold *et al*., 2007).

Water is one of the essential resources to ensure food production and feeding more people with the same amount of water (Wenhold *et al*., 2007) is an important consideration for the promotion of food security and alleviation of malnutrition. However, farmers (including food gardens) need to learn more about water management. Water management has and will continue to have a definitive influence on the generation of food and livelihoods. However, despite numerous reports on inefficient water use and poor harvesting, there remains a general lack of knowledge about how water is being used across smallholder farming systems, how much water is needed to support systems and how much will be available in the future. The literature has highlighted the weakness of water management structures at smallholder levels and the need for improvement.

In conclusion, the literature demonstrates the capacity and potential of homestead gardens and homestead farms as a way to achieve household food and nutrition security. The information presents some of the challenges that exist for the further development of homestead gardening despite its rapid increase and progress over the years. These challenges are a lack of power due to gender inequity, fewer incentives for entrepreneurial activities and less development of agency.

It is also important to note that the diversity within homestead garden participants in terms of demographic and socio-economic factors, underpins the range of motivational reasons. The literature further confirms an increase in homestead gardening (including other types of gardens and cropland) over the years and there is empirical evidence of this. However, although food gardening has gained visibility and attention from researchers and policy-makers, it has not increased in scale and investigation into scaling such garden develop and improve value chains is not well addressed. The following chapter in this research addressed this.

3 DESCRIPTION OF THE NATURAL AND HUMAN RESOURCES, FARMING SYSTEMRS AND INSTITUTIONAL ARRANGEMENTS AT SWAYIMANE AND GLADSTONE

3.1 INTRODUCTION AND CONTEXTUALISATION

Livelihoods are built around many aspects of life, including natural resources (land, water), human and social resources (gender, age) and institutions (enforced by functional institutional arrangements). The effectiveness and sustainable use of a community's natural resource base can contribute to ending deep-seated poverty and food insecurity. However, institutions that define the quality and quantity of available natural resources and their ownership and access, may influence the extent to which the resources are used effectively and sustainably (Paavola 2007; Leach *et al*., 1999). In poor rural communities there are institutional and socio-economic barriers to accessing and owning natural resources. This may lead to a non-ending cycle of malnutrition and poor societal and economic development.

Although many households in SA are cash-based, the role of homestead gardening as a source of extra food, especially for female-headed households, has been noted and warrants further exploration (StatsSA, 2016). Nevertheless, the demands on water use and secure water access come to the fore. The scarcity of water in this age of climate change effects must be taken into consideration. Water conservation and water harvesting techniques will be integral to strategies for exploring the contribution of home gardens to the agricultural value chain.

Water governance at the local level is important since the Council on Food Security's latest report on Food Security & Water use security highlights water governance failure as a contributor to poor performance of many food security initiatives (HLPE 2015). According to the National Planning Commission (2012), the South African National Development Plan (SANDP) has a strong focus on agricultural production further along the production chain, but provides no direction on water reform and water competitions issues for the beginning of the value chain. Secure access and effective water use at the household level would mean increased production of food, which may guarantee adequate nutritious food supply while yielding a surplus and thus opening up selling opportunities.

Furthermore, a good understanding of the various farming and food systems that deliver various food baskets and their nutrient status in rural and semirural areas is very important. Human capacity, skills, knowledge and awareness of diets and wellbeing in the study areas is important, given that the poor are increasingly consuming empty calories of cheap and heavily processed food with little and often harmful outcome (Shisana *et al*., 2013). An exploration of the contribution of food production in homestead, community and school gardens in urban, peri-urban or rural environments is important to inform policy to support such practices.

The final point is the role and effectiveness of institutions (workable institutional arrangements), since it is critical in setting up an environment and support for new and small producers to establish and enter the agricultural value chain (Chitja and Mabaya, 2014), thus earning an income. Kirkland (2008) showed that farmers' production quality and standards could be strengthened through teaching and supporting for all new and current producers while another entity focuses on marketing and selling. In reality, not all producers will produce for markets, since some are producing for the purpose of consumption. Every aspects of the work, despite working individually or as a team, should be conducted within the stipulated workable and functional institutional arrangements.

3.2 METHODOLOGY

This section focuses on the description of the study areas, followed by the methodology, which was used, theoretical grounding, study design, respondent selection, data collection methods and the tools used and data analysis.

3.2.1 Description of the study areas

The study was conducted in two rural areas or communities, namely Swayimane and Gladstone. Swayimane is located 13 km outside Wartburg in uMrshwathi Local Municipality (MLM) in the Midlands of KwaZulu-Natal Province (***Figure 3***). The community is under the Gcumisa Traditional Authority (Martin and Mbambo, 2011).

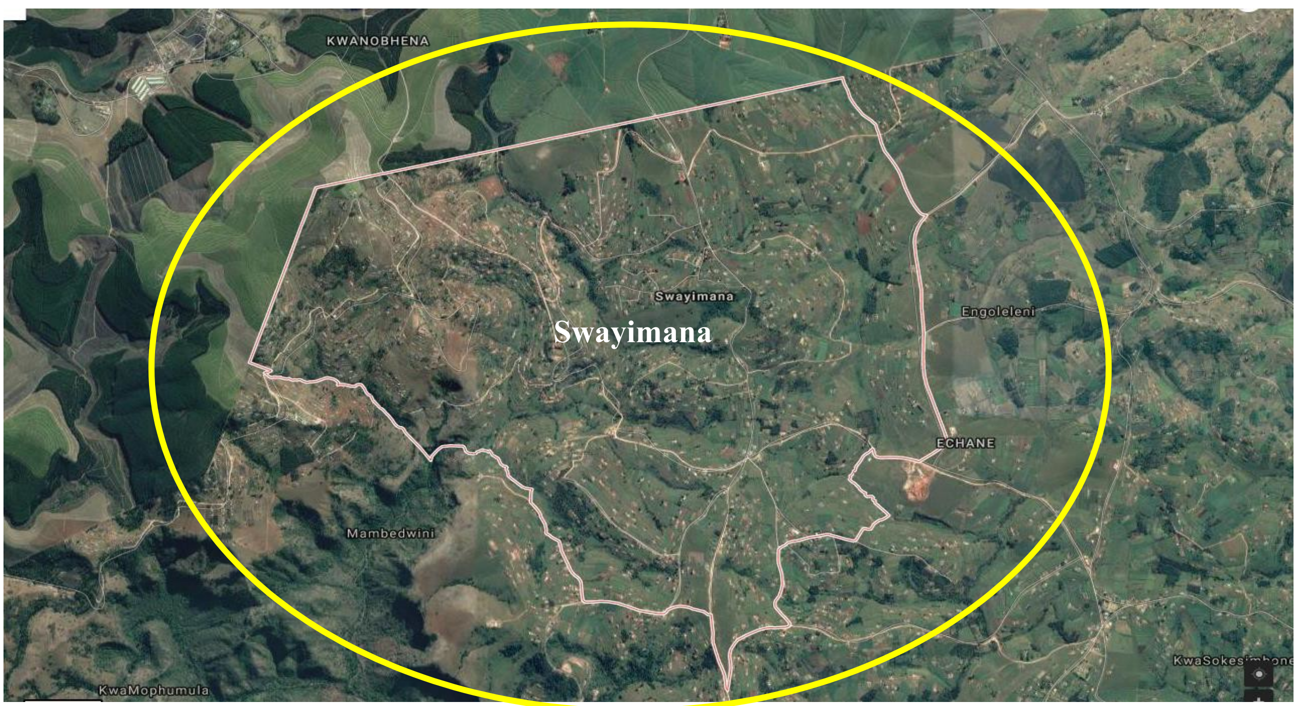


Figure 3 Swayimane Map (Source: Google Map 29.52302362°S 30.61262580°E; -29.51480680°S; 30.65391650°E; -29.53055330°S; 30. 60564540°E).

According to Zondi (2003), the area has a high rate of unemployment and subsistence agricultural production is an important livelihood activity. Zondi (2003) further alludes that agriculture is important for income generation and household consumption. Swayimane has arable soil which is in the top 2% of SA's highest potential arable soils.

Gladstone is located about 23 kilometres south of Thaba Nchu and it forms part of the Mangaung Metro Municipality (MMM). The village was established in 1933 on the Jacks Fort farm after it became part of the former Bophuthatswana homeland. The village was considered the capital of Thaba Nchu. Some villagers moved out of Gladstone and settled in the surrounding areas where they formed new communities. During the leadership of Kgosi Mangope (the then leader of the Bophuthatswana Kingdom), villagers were provided with tractors, ploughs and seeds, which the farmers used to produce different crops such as maize, sunflower, etc. In the past, community members were family oriented and always put their families first, but this has changed because the younger generation has now adopted norms and values, which centre on the individual. The village falls under the leadership of the Barolong Bo-Seleka Traditional Council.

3.2.2 Theoretical Grounding

This study was guided by the sustainable livelihoods framework (SLF), a framework which has informed many development initiatives since its introduction. In the SLF, individuals and households have five capitals which are essential for the pursuit of a sustainable livelihood (Scoones, 2009). He adds that access to these five assets is mediated by institutions, which offer households, differential access. Secure access to land and water is critical for agricultural households. Equally important is their human capital endowment as it has been shown that with training farmers are more efficient and productive (Bingen *et al*., 2003). In addition, households' human capital and agency play an important role in how they assess potential market opportunities (Vorley *et al*., 2012).

3.2.3 Research Design

The study employed a mixed methods approach, which according to Creswell (2003) involves collecting, analysing and integrating quantitative and qualitative research and data in a single study. In the mixed methods approach, quantitative and qualitative methods are combined so that a problem can be studied thoroughly (Teddlie and Yu, 2007). One advantage of using this approach is that it helps the researchers to triangulate their findings, thus providing a better understanding of a research problem than when either research approach is used alone (Creswell, 2003). The study employed the concurrent approach where both types of data were collected during the same data collection period (Ivankova *et al*., 2007).

3.2.4 Sampling Technique and Sample Size

The overarching objective of the study was to determine and describe the baseline information of the selected study areas detailing the natural and human resources, farming systems and institutional arrangement in relations to water use at the beginning of the food value chain. This was done with farmers who had food gardens, which were determined to be at the beginning stages of the value chain. The case study methodology was selected as an overarching methodology (Baxter and Jack, 2008), although actual farmers were purposively selected. The reason for this is based on their active involvement on agriculture and in previous project. Based on that, the case study approach will allow the team to select appropriate interventions. Those interventions relate to water use and models for supporting enterprise development of various value chains that are planned for later in the life of the project. Purposive sampling, a non-probability sampling technique, was adopted (Teddlie and Yu, 2007).

Although purposive sampling limits the generalisability of a study's findings, Teddlie and Yu (2007) explain that it gives the researcher access to respondents who are knowledgeable about a subject and can provide deeper insights into the subject of interest. It was therefore important to select a sample which was knowledgeable about food gardens in the selected study sites. Respondents were selected to participate in this study using the following criteria: they belonged to a household; their household had a food garden; there was active production in the garden; and willingness to participate in the study. Based on these criteria, 43 respondents were selected to participate in this study from both study areas, with 19 respondents from Swayimane and the remainder from Gladstone.

3.2.5 Data Collection

Both primary and secondary data were used in this study. The primary data was collected in early December 2016 and early January 2017, using a questionnaire and focus group discussions. Follow-ups were done on a yearly basis with the aim of comparing the progress or changes, if there were any. The questionnaire, which had eight sections, had both open ended and survey type questions. In the human resources section, the main focus was on the demographic data and household information (e.g. respondent's age, sex, marital status, education level, primary and secondary occupation, health status, income and income generated). In the rest of the sections, data was collected for the household as a unit. To measure dietary diversity and to determine household food access, the Household Dietary Diversity Score (HDDS) and the Household Food Insecurity Access Scale (HFIAS) were used.

This study adopted the HFIAS and HDDS as proxies of food security, a combination which has been used in many studies (Mvula and Chiweza, 2016; Ruysenaar 2013; Noble *et al*., 2010). The HFIAS is a tool developed by the USAID's Food and Nutrition Technical Assistance project. It can be used in different contexts and the questions used represent three domains of access, i.e. anxiety and uncertainty about household food supply, insufficient quantities and insufficient food intake and its consequences (Coates *et al*., 2007). The tool has 18 questions alternating between an occurrence and a frequency of occurrence questions, using a four-week reference period (Coates *et al*., 2007).

The HDDS, which has a strong correlation between dietary diversity and food and nutrition security, was used as a proxy measure for household food security. Briefly, dietary diversity is a measure of the variety of food groups that a household consumes and is a good indicator for a household's economic access to food (Swindale and Bilinsky, 2006). Households which can afford to improve the quality of their diet by increasing the amount of nutrient-dense food included can be assumed to have resources to purchase enough food for the household (Vellema *et al*., 2015). The HDDS manual does not have cut-off points to classify food-insecure households, and prescribes that an average HDDS in the sample be used as a bench-mark for food security in the study area (Swindale and Bilinsky 2006). Focus group discussion with participants were also held and were more focused on institutional arrangements in the study area.

It was followed by natural resources and or composition such as land holdings, soil types, rainfall, water access, household assets and production activities. A desktop review was first conducted to collect some of the natural resources data. For Swayimane, this information was largely contained in the Bio-Resource Unit (BRU) classification report (KwaZulu-Natal Department of Agriculture, 2017). For Gladstone, a desktop study was conducted using the Land Type data (1:250 000) of ARC-SCW&AE before the village was visited.

The aim of the desktop study was to determine whether the soils (clay content and depth) and climate (rainfall) were suitable for rainwater harvesting and conservation (RWH&C) practices in terms of its specifications. The area was then visited to conduct a soil survey with the main aim of improving on the Land Type data. To achieve this specific aim, a hand auger was used to drill holes within the distance of 20-40 m in order to describe and classify the soils. The soils were classified using the South African Soil Classification System (SASCS).

Knowledge of the climate in the study areas will enable decision makers to make more informed decisions, have a better base to plan from and to be able to identify the risks and opportunities that the climate holds for the intended beneficiaries. Characterization of the climate entails the analysis of rainfall, temperature, solar radiation, wind, relative humidity, vapour pressure, evapotranspiration and heat units. The Kilmarnock climate station was identified to represent the climate at Gladstone. The station is situated 14.6 km west of Gladstone and weather data was recorded at this station from 1960 until present.

3.2.6 Data Analysis

The use of the mixed methods approach for data collection produced both quantitative and qualitative data. The quantitative data was analysed using descriptive statistics in Statistical Package for Social Science (SPSS version 24) and Microsoft Excel. To determine the HFIAS, the analysis was guided by Coates *et al*. (2007) to generate the variables HFIAS conditions and HFIA Score. The calculation of the HDDS was done following Swindale and Bilinsky (2006) using a one-day reference period. Households which had a mean HDDS equal to or greater than the mean, were considered food secure (Swindale and Bilinsky, 2006). Then the qualitative data analysis was performed on the data collected using open ended questions and focus group discussions. The data was analysed using content and theme analysis to identify themes, concepts and trends and patterns (Hsieh and Shannon, 2005).

3.3 RESULTS AND DISCUSSION

The following section details baseline information of 43 cases of smallholder farmers from the selected study areas in Swayimane (KwaZulu-Natal) and Gladstone (Free State). The report details their natural resources base, human resources (livelihood assets) and institutional arrangement in relation to water use at the beginning of the food value chain. The KwaZulu-Natal data is based on the Bio-Resource Database.

3.3.1 Natural Resource

3.3.1.1 Bio-Resource Units of Swayimane

This section presents the characteristics of the Bio-Resource Units (BRU) that relate to the production potential of the five main bio-resource units applicable in Swayimane, particularly water and general soil profiles. The main bio-resource groups are TA5 (Nagle Dam), VW b5 (Valley of Thousand Hills), Xb7 (KwaGqugquma), Yb12 (Mkabele) and Yc21 (Bruyn's Hill). The bio-resources units (TA5 (Nagle Dam), VW b5 (Valley of Thousand Hills), Xb7 (KwaGqugquma), Yb12 (Mkabele) and Yc21 (Bruyn's Hill) that cover the study area in KwaZulu-Natal are shown in Figure 4. A brief discussion of each group is presented in the next sections.

3.3.1.1.1 Ta5 Nagle dam – LIGHT BLUE

As seen in Figure 4 (Map), this area covers the second-smallest area of the bio-resource. In this BRU, there are important conservation features, which would require the involvement of KZN Wildlife Ezemvelo prior to any proposed intensive cultivation or development.

3.3.1.1.1.1 General climate and soil information

The climate capability rating is C6, which means the area displays a moderately restricted growing season due to low temperatures, frost and/or moisture stress. There is a limited suitable crop choice, and even then, these frequently experience yield loss. There are three perennial rivers with noted rivers being the Mgeni and Mqeku, with no wetlands. In this BRU, there are shallow soils, duplex soils and soils of moderate to poor drainage. Without management, these present an erosion hazard. The BRU indicates that up to 48.3% of the soils are shallow, 6.8% duplex and 35.3% display moderate to poor drainage. A soil erosion hazard rating of FB 4.9 (High risk) is indicated but this can vary greatly within the BRU. Table 1 shows the climate in the BRU. Based on climatic capability, some vegetable production aimed at household food production is possible but not extensive cropping, due to the conservation restrictions that were indicated.

Table 1 Climatic attributes of Swayimane's five bio-resource units

Climatic attribute	Annual mean rainfall (mm)	Annual mean temperature (°C)
Nagle dam- Light Blue	694	19.1
Valley of Thousand Hills-Purple	836	18.4
KwaGqugquma-Yellow	889	17.4
Mkabele-Brown	889	17.4
Bruyns Hill-Dark Green	925	16.9

3.3.1.1.1.2 VW b5 (Valley of Thousand Hills-PURPLE)

As seen in Figure 4 (Map), this area covers the largest area of the bio-resource units of Swayimane. Similar to Nagle dam, there are important conservation features which would require the involvement of KZN Wildlife Ezemvelo prior to any proposed intensive cultivation or development.

3.3.1.1.1.3 General climate and soil information

The climate capability rating is C2: Local climate is favourable for a wide range of adapted crops and a year-round growing season. Moisture stress and lower temperatures increase risk and decrease yields relative to C1. Shallow soils and soils of moderate to poor drainage present an erosion hazard if not managed correctly. Similarly, this BRU has three perennial rivers with noted rivers being Mgeni and Mqeku, and it has up to 3 ha of wetland. Generally, in this BRU, there is a limited erosion hazard although some places may be prone to erosion. Table 1 indicates in brief rainfall and temperature in the BRU. The farming system in this BRU is semi-intensive. Based on climatic capability, some vegetable production aimed at household food production (limited resource farmers) and commercial production for experienced commercial farmers are applicable. Extensive cropping must be controlled due to the conservation restrictions indicated, particularly near or in the 3 ha of wetland area.

3.3.1.1.2 Xb7 (KwaGqugquma-Yellow)

As seen in Figure 4 (Map), this area covers the smallest area of the bio-resource of Swayimane. Similar to Nagle dam, there are important conservation features, which would require the involvement of KZN Wildlife Ezemvelo prior to any proposed intensive cultivation or development.

3.3.1.1.2.1 General climate and soil information

Similarly, the climate capability rating is C2: Also, the local climate is favourable for a wide range of crops that can grow year-round. This BRU experiences moisture stress and lower temperature increase risk, as well as decreased yields exacerbated by shallow soils of moderate to poor drainage, which presents an erosion hazard if not well managed. This BRU has 1 perennial river, the Mqeku, and has no wetlands.

Generally, in this BRU there is limited erosion hazard although some places may be prone to erosion. Table 1 shows the rainfall and related data in the BRU important for agricultural production. The farming system in this BRU is extensive. The land potential rating for production in this BRU has very restricted potential with regular and/or severe limitations due to soil, slope, temperature and rainfall, rendering it un-arable.

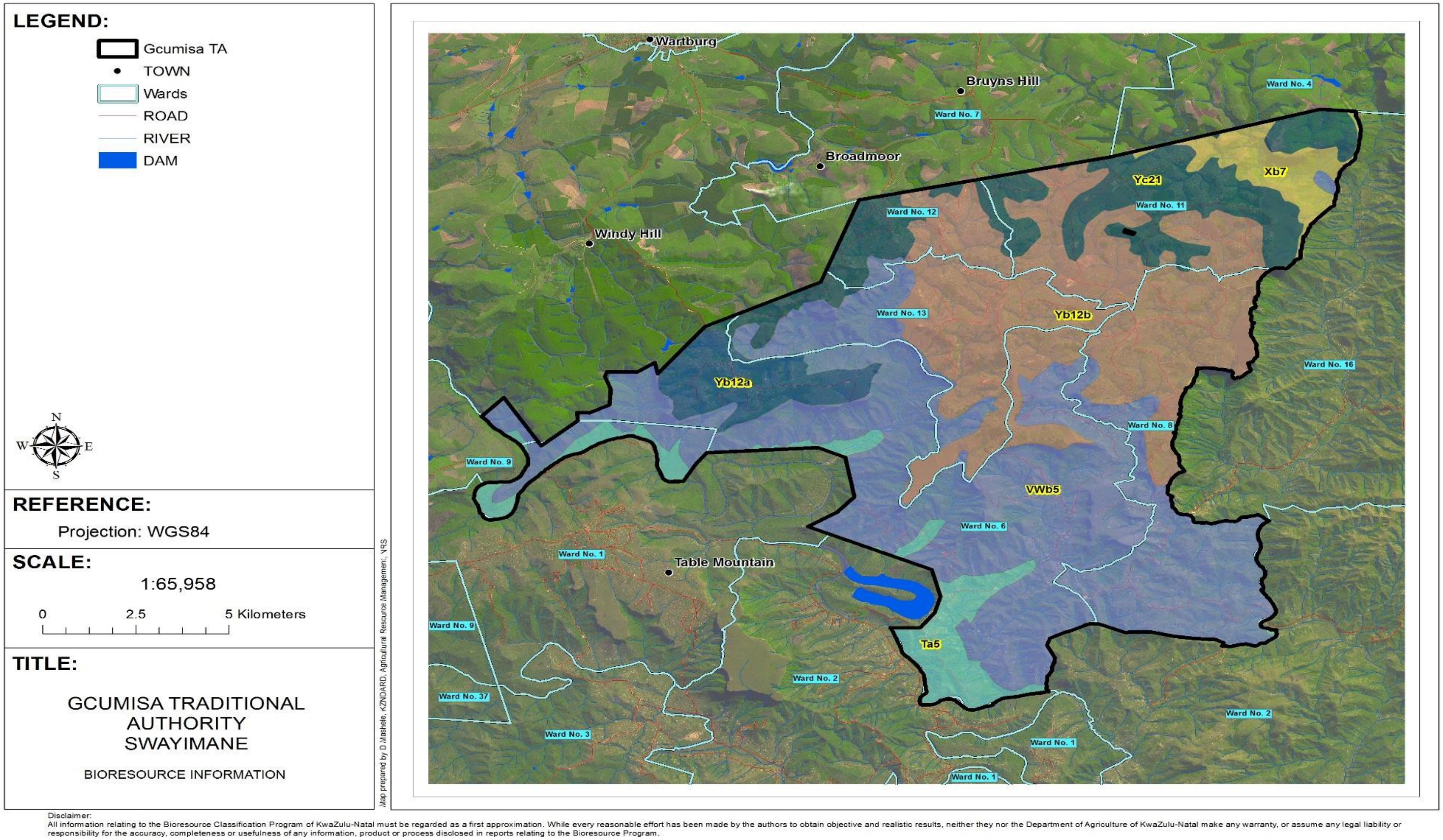


Figure 4 Map of bio-resources units of Swayimane (c21 Brown, Xb7Yellow, VWb5 Purple, Yb12 Green and Ta5 Jade lightgreen).

3.3.1.1.3 Yb12 (Mkabele-Brown)

Similar to Nagle dam, there are important conservation features, which would require the involvement of KZN Wildlife Ezemvelo prior to any proposed intensive cultivation or development.

3.3.1.1.3.1 General climate and soil information

Similarly, the climate capability rating is C2: Also, the local climate is favourable for a wide range of crops that can grow year-round. This BRU experiences moisture stress and lower temperatures increase risk and decrease yields, which is exacerbated by shallow soils of moderate to poor drainage, presenting an erosion hazard if not well managed. This BRU has 1 perennial river, the Mqeku and no wetlands. Generally, in this BRU there is limited erosion hazard although some places may be prone to erosion. Table 1 shows the brief rainfall and related data in the BRU important for agricultural production. The farming system in this BRU is extensive. The Land potential rating for production here has very restricted potential with regular and/or severe limitations due to soil, slope, temperature and rainfall, rendering it uncultivable.

3.3.1.1.4 Yc21 (Bruyn's Hill-Dark Green)

The dark green area of the bio-resource of Swayimane depicts YC21. Similar to Nagle dam, there are important conservation features which would require the involvement of KZN Wildlife Ezemvelo prior to any proposed intensive cultivation or development.

3.3.1.1.4.1 General climate and soil information

Similarly, the climate capability rating is C2: Also, the local climate is favourable for a wide range of crops that can grow year-round. This BRU experiences moisture stress and lower temperatures increase risk and decrease yields. This is exacerbated by shallow soils of moderate to poor drainage, presenting an erosion hazard if not well managed. This BRU has one perennial river, the Mqeku, and no wetlands. The soil erosion hazard rating is FB=5.4 depicting limited risk, although big variation could occur within the BRU. There is limited erosion hazard although some places may be prone to erosion. The rainfall and related data in the BRU important for agricultural production are presented in Table 1. The farming system in this BRU is extensive with the highest rainfall potential at 925 mm mean annual.

3.3.1.2 Natural resources of Gladstone

There is a constant interaction between the natural resources (climate, soil and plants), which determine the productivity of the system, while the management of the system determines its sustainability. The soil is the link between the atmosphere (climate) and production (plants or crops). Food production is fundamentally a product of the atmosphere-plant-soil (APS) system and how it is being utilized by the human resources. Optimal management of the APS system requires that its functioning is well understood and therefore proper integration of the three disciplines (climate, soil and plants/crops) and the socio-environment with its human resources is very important. The characteristics, productivity and stability of the APS system and the socio-environment depend on the natural resource factors (climate, topography, soil and the crop) and the human resources in a particular area. Therefore, it is very important to describe and understand the natural and human resources in a particular area, especially when that information is going to be used for planning or as baseline information.

3.3.1.2.1 Climate

The representative climate station falls within a homogeneous climate zone, as characterized by the Koppen classification system. The climate of Gladstone is classified as semi-arid with summer rainfall and cool winters. The mean annual precipitation for the Gladstone area is 599 mm. A minimum of 342 mm rainfall was received in 1984 and a maximum of 1055 mm in 1988. Gladstone receives approximately 85% of its annual rainfall between October and April. February is the month with the highest average rainfall (97 mm) and July the month with the lowest average rainfall (10 mm). Maximum monthly rainfall values range between 367 mm (February) and 61 mm (June) and minimum monthly rainfall values range between 18 mm in March and 0 mm from May to October. Typical of a summer rainfall area, January is the warmest month and July the coldest month with average temperatures of 20.9°C and 6.9°C, respectively. The solar radiation is at its minimum in the winter months during June, with 3410 W m^{-2} day^{-1}. A maximum of 7319 W m^{-2} day^{-1} is reached in December. Both minimum and maximum relative humidity is at its lowest during September with values of 22.8% and 81.8%, respectively. Relative humidity peaks during April with a maximum of 95.7% and a minimum of 38.1%. A minimum evapotranspiration of 2.0 mm day^{-1} occurs in June and a maximum of 6.7 mm day^{-1} in December.

3.3.1.2.2 Soils

The slope in Gladstone varies between 0 and 12%. The slope for most of the lands is less than 3% with small areas having slopes between 3% and 4%. The community of Gladstone occurs in the upper four lower three position of the landscape. The parent material of the soils is mainly derived from the sandstone, shale and mudstone of the Beaufort Group with dolerite intrusions. Gladstone community completely falls within Land Type Dc17, which makes up 53% of the total area of Thaba Nchu. Dominant soil forms in this community suitable for RWH&C are Sepane, Swartland, Arcardia and Bonheim. The effective rooting depth was found to be between 700 and 900 mm. Soils found to be unsuitable for RWH&C are of Mispah, Glenrosa, Mayo, Klapmuts and Escourt forms, and shallow members of Swartland soil form. The clay content of some soil forms ranged from 34 to 54% in the topsoil and from 60 to 73% in the subsoil.

3.3.1.2.3 Rangelands

A rangeland survey was done as a means of assessing the vegetation condition in the communal rangeland. The condition of the rangeland was determined to assess the livestock production potential and the potential for rehabilitation if needed. The rangeland of Gladstone is divided into four portions by roads. The border fences of the area are in a poor state and need to be fixed as a priority before any other measures can be undertaken. There are no inter-camp fences in any of the camps. Small areas close to the community have been overgrazed due to the animals staying close to the community and being housed in kraals at night. Lack of a grazing system, veld management knowledge, camps and water supply for animals are the reasons for the degradation of the rangeland. Overall Gladstone’s rangelands are in good condition because the bulk of the rangelands are not grazed. This is due to the distance from the community. Closer to the community, where the animals normally graze, there are signs of overgrazing. Even though certain areas of the natural veld are in a good condition there are areas suffering from major sheet erosion.

In Gladstone there are several old cultivated areas that have not been utilized for crop production for more than 30 years. The ecological state of these areas is currently in a sub-climax stage. This is an advanced stage between bare cultivated land and prime climax rangeland. The plough furrows/contours can still be seen and in these areas and different ecological stages could also be identified. It ranges from waterlogged soil with Eragrostis plana grass species that is associated with waterlogged vlei areas to Themeda triandra which is associated with climax rangeland.

These areas differ due to the grazing applied by the animals, which differ from sheep to cattle. The sheep were found on the low grass cover area and on the shrubs on the old cultivated areas. The cattle were in the Themeda-Cymbopogon-dominated areas that were not ploughed previously. The shrub that is dominating the area, Felicia muricatus is very palatable and is a shrub that is high in protein. In the Free State it is very important for sheep production. With good veld management practices, the rangeland could be increased by approximately 11% and the old lands by 31%.

3.3.2 Human Resources

Section 3.1 above showed that the two communities possess very different natural resources, particularly where climate and soil are concerned. It is expected that these different natural resource endowments will provide the farmers with different opportunities to engage in agricultural production at the beginning stages of the food value chain. This section presents the farmers' human resources data (their ages, gender, education level), followed by their household food and nutrition security and vulnerability at the time of data collection.

3.3.2.1 Demographic Data

Information contained in Table 2 shows the information of Swayimane. The majority of farmers were women (78.9%) and the average age of the respondents was 55.47 years. The sampled farmers had attended school for an average of 6.79 years, and had no formal tertiary qualification. Instead most had years of farming experience, had attended some training programmes and had learnt from extension. The majority of the respondents spoke IsiZulu only, compared to 26.4% of the respondents who spoke at least two languages including IsiZulu. The Swayimane sample's households had an average of 5.95 household members. Of the respondents interviewed, 52.6% were the household head. Furthermore, 52.6% of the respondents identified farming as their primary occupation. The majority of respondents earned some income from their primary occupation, and 63.2% estimated their income to be in the R1001-R5000 range.

Table 2 Demographic information of Swayimane and Gladstone

Description	Swayimane (%) n=19	Gladstone (%) n=24
Sex of Respondent		
Male	21.1	70.8
Female	78.9	29.2
Relationship to Household		
Household head	52.6	62.5
Spouse	15.8	12.5
Child	5.6	20.8
Sibling	26.3	-
Grandchild	-	4.2
Age of Respondent in years	55.47 (13.91)	53.2 (13.41)
Years in School	6.79 (4.91)	8.96 (4.33)
Marital Status		
Single	42.1	29.2
Married	31.6	33.3
Divorced	-	8.3
Widowed		4.2
Language spoken		
IsiZulu	73.7	8.3
Xhosa	-	12.5
Sesotho	-	16.7
Other	-	62.5
2 or more languages	26.4	-
Primary Occupation		
Farming	52.6	47.8
Pensioner	21.1	17.4
Livestock	-	4.3
Business	5.3	4.3
Monthly Income earned from Primary Occupation		
No income	8.3	8.3
<R1000	36.8	50.0
R1001-R5000	63.2	41.7
Household size	5.95 (6.5)	3.3 (4.5)

Figures in parentheses (brackets) are standard deviations.

For the Gladstone sample, the majority of the respondents were male (70.8%) and had an average age of 53.23 years. Unemployment had added to their miseries since the majority of the villagers were unemployed. Some villagers mentioned that they are farming, but the fact of that matter is that they have few livestock and some crops planted in their backyards; and that does not classify them as farming, therefore they can be regarded as unemployed.

From the data collected from the sample, the Swayimane sample has more female respondents than the Gladstone sample. The composition of the Swayimane sample is consistent with literature on smallholder agriculture in SA (Baiphethi and Jacobs 2009). The prevalence of female respondents in Swayimane compared to the Gladstone sample could be attributed to male migration, which may not have been the case in Gladstone. Furthermore, this data shows that there were limited livelihood activities in the two study sites as most respondents depended on subsistence agriculture and social grants. That the majority of households in both study sites earned at most R5000 a month from their primary occupation which indicates that these households may be income poor.

3.3.2.2 Gender Dynamics

The two study areas were both patriarchal communities, however this meant different things for the two samples. Land rights were largely held by men in Swayimane but all the respondents in this sample said that women could also hold land rights. Women could go directly to the Chief (31.6%), their male relatives or buy land (21.1%). These claims were further substantiated by showing that some pieces of land were registered in the names of female household members and this shows that in Swayimane land access is not restricted to male household members only. This is supported by some other research on rural land access in SA (Claassens, 2013).

The study also shows that although women can access land individually, their male natal and marital relatives are an important source of land for women. This is consistent with some studies on women and land access in patriarchal communities (Rose, 2002; Yngstrom, 2002), which show that while some cultural practices may disempower women, there are some practices which protect them. An interesting finding in this study is that land can be sold in these communities. The results also show that although men held most land rights, women were actively engaged in agriculture in Swayimane and can be assumed to have some decision-making powers in the work they do. This would imply a higher contribution in crop choice decisions, and how the money would be used in pursuit of household goals, possibly resulting in improved child welfare and food and nutrition security.

In the Gladstone community, it appeared that while men were the main decision-makers in the household, women were the ones largely responsible for the homestead gardening. Even when women wanted to plant anything in those gardens, they have to consult men before buying any seeds or seedlings. This shows that female farmers in this sample were not responsible for the agricultural decisions made in the household. This is consistent with what has been reported in patriarchal households, where gendered household roles are clearly defined and women may just implement the male household head's ideas (Ambunda and de Klerk, 2008). This raises questions about the extent to which these female farmers could influence use of produce and if it was sold, how the money generated would be used, as this has implications for overall household welfare including food and nutrition security (Sraboni *et al*., 2014).

3.3.2.3 Household Vulnerability to Food Insecurity

There are occurrences of the food insecurity access conditions in the sample regardless of severity (Table 3). It shows that in both Swayimane and Gladstone many households are vulnerable to food insecurity. For instance, in Swayimane, nearly three in every ten households had either consumed smaller meals or fewer meals at some point in the preceding month. The incidence of these events is higher in Gladstone with 45.5% consuming smaller meals, while 40.9% had consumed fewer meals. What is of importance is that despite all these challenges, none of the villagers and farmers spent the whole day and night without eating something, despite some having gone to sleep hungry (23.8%). There are those who did not have food at all (31.8%), but neighbours were able to help in such a situation.

Table 3 Households with HFIAS-related conditions regardless of severity

HFIAS conditions (N=43)	Swayimane (%)	Gladstone (%)	Total
Worried about enough food	31.58(6)	40.9(9)	36.59(15)
Could not eat preferred food	42.1(9)	40.91(8)	41.16(17)
Food had limited variety	31.58(6)	40.91(9)	36.59(15)
Ate food they did not want	36.84(7)	45.45(10)	41.46(17)
Had smaller meals	42.11(8)	45.45(10)	43.90(18)
Had fewer meals	36.84(7)	40.91(9)	39.02(16)
Had no food at all	21.05(4)	31.82(7)	26.83(11)
Went to sleep hungry	21.05(4)	22.73(5)	21.95(9)
Did not eat the whole day and night	21.05(4)	22.73(5)	21.95(9)

Figures in parentheses are frequencies.

In Table 4, most respondents in both samples felt that their village were moderately poor and this may worsen their vulnerability. This perception was likely informed by the level of development in their communities and the respondents' analysis of their financial resources compared to other communities. Literature has shown that different communities value different resources and how these contribute to the communities' sense of wellbeing (Mushongah and Scoones 2012). In addition, most respondents felt that they were like most of the households in their community, while 31.6% felt that they were slightly better than most households. As highlighted above, these comparisons were based on a locally established and accepted ranking system. It may be helpful to conduct a wealth ranking exercise in the communities to determine what these labels translate to in the community. Regarding the adequacy of household money to clothe the household, only 36.8% of the respondents belonged to households that always had enough money for clothing.

Table 4 Household wealth

	Swayimane	Gladstone
Village wealth		
Moderately poor	68.4	72.7
Not too poor	26.3	27.3
No response	5.3	-
Household wealth status		
Poorer than most in the community	5.3	9.1
Like most in the community	57.9	68.2
A bit better than most	31.6	9.1
I don't know	5.3	13.6
Enough money for clothing		
Yes, always	36.8	9.1
Yes, sometimes	57.9	54.5
No, never	5.3	36.4

Figure 5 Gladstone clinic and Jojo tanks installed for rainwater harvesting.

3.3.2.4 Food and Nutrition Security Status

Table 5 shows that the average HFIA Score for the Swayimane respondents was 3.72, indicating that most households were food secure as their score was very close to 0. In addition, their dietary diversity score based on a 24-hr recall was 6.95 food groups out of 12. Using this average as the minimum required for a household to be considered food secure, 42.1% of the households were food secure. The average of 6.95 is more than double the 3 food groups which are considered to indicate that a household does not receive adequate dietary diversity (Kennedy *et al*., 2010).

Therefore, we can assume that for this sample, most households could access different groups, which is indicative of a good diet. The effect of seasonality on prevalence of food security in these studies may need to be tested to ensure that the high levels of food security were not influenced by the season. Some studies have shown that the month of data collection has an influence on the prevailing food security in a community (De Cock, 2013). Administering these questions to the respondents at another time will provide more information and may allow for the study to show how seasons affect food security in the study areas.

The households were likely to have insufficient food between January and March in the Free State, while the KwaZulu-Natal sample experienced food insecurity between January and March and July-September (Table 5). As depicted in Table 5, January to March coincides with the period before harvest when supplies have run low and households may not have the resources to buy food, while the period July to September may represent a time at which households with small harvests run out of their produce stores, resulting in food insecurity. As mentioned in the preceding paragraph, administering a short question will allow for this data to be collected and validated and present the team with an opportunity to probe the respondents about their experiences of food insecurity. The Household Dietary Diversity Score (HDDS was computed using a list of 17 foods, the number of days they were consumed in a week and the main source of the food. Dietary diversity is a measure of the variety of food groups that a household consumes and is a good indicator for a household's economic access to food (Swindale & Bilinsky 2006). Following Swindale and Bilinsky (2006) households were considered food secure if their HDDS was greater than or equal to the mean HDDS for the community. A nine-item food insecurity scale, the HFIAS, developed by USAID's FANTA Project as adopted Knueppel *et al*., (2010) was used to measure household food insecurity. The measurement instrument follows a progression that begins with anxiety about food supply, followed by a decrease in the quality of food, a decrease in the quantity of food, and finally going to sleep hungry and going all day and night without eating. The HFIAS module covers a recall period of 30 days, and consists of two types of questions: nine "occurrence" and nine "frequency-of-occurrence" questions. The respondent is first asked if a given condition was experienced (yes or no) and, if it was, then with what frequency (rarely, sometimes, or often).

Table 5 Food security indicators for Swayimane and Gladstone

Food security indicator	Swayimane	Gladstone	Food groups consumed
HFIA Scale Score	3.72 (5.27)	3.57 (3.97)	
HDDS	6.95 (7.53)	7.77 (8.11)	
	%	%	
Food secure households (HDDS)	42.1	63.6	Cereals
Sufficient food in the household			Roots and tubers
Yes, always	57.9	45.5	Vegetables
Yes, sometimes	36.8	54.5	Fruits
No, never	5.3	-	Meat products
Food insufficient months			Eggs
No	22.2	-	Fish
Jan-arch	27.8	50	Pulses, legumes and nuts
April-Jun	-	4.5	Milk
Jul-Sept	22.2	4.5	Oils and fats
Oct-Dec	5.6	-	Sugar and honey
Other months	11.1	36.4	Miscellaneous
Every month end	11.1	-	
October-March	-	4-5	

Figures in parentheses are standard deviations. Means and standard deviations were only computed for non-categorical variables.

3.3.3 Farming Systems

In KZN, Swayimane farmers are primarily smallholders, cultivating the majority of their land for household consumption and selling several commodity crops when possible. Farmers generally did not know the exact size of their land, but they estimated that their gardens ranged from 0.025 ha to 1 hectare, while when combined, their fields could be as large as 6 ha. Most farmers had two areas of land under cultivation; a small garden next to the homes, and larger fields adjacent to the homestead's living and storage buildings (Shackleton *et al.*, 2019). It was common for farmers to have a small garden they used to grow a variety of vegetables such as onions, carrots, beetroot, and spinach for household consumption. A few farmers were commercially producing cabbage and several other vegetable crops. The home gardens cultivated by most farmers were more characteristic of diverse polyculture systems.
Farmers relied on pesticides, such as Supreme (for stalk borer), Karate EC, Basagran and Roundup to control pest outbreaks. The sample reported that access to pesticides and fertiliser was limited because the village shops did not stock them. Farmers interested in purchasing pesticides and fertiliser and other agricultural inputs had to travel to Wartburg or Durban to purchase inputs. Due to the distance of these places, the farmers had resolved to pool their purchasing. These findings are supported by other researchers who show that access to improved agricultural inputs is limited for smallholder farmers, particularly in sub-Saharan Africa (Tittonell and Giller, 2013; Poulton *et al.*, 2010; Chirwa, 2005).

Several farmers reported that some pests no longer responded to pesticide application, and pest outbreaks occur even after treatment. This has also been observed in other studies (Nyantakyi- Frimpon g *et al.*, 2016). It indicates the possible build-up of pesticide resistance in local pest populations and greater chance of extreme crop loss due to outbreaks. In response, farmers may increase the application dosage beyond the recommended levels, however, improper application of pesticides and fertilizers can also have environmental implications, such as eutrophication and negative effects on biological pest populations.

In the Free State, farmers are also smallholders but with a mixed farming system (crop and animal production). Crop production has been the main survival strategy for Gladstone villagers for years because the crops are essential or their daily consumption. Normally they plant crops such as potatoes, cabbage, beans, maize, butternut, beetroot, onions and maize. Those crops are mainly for own consumption purposes, but those who have more than enough (surplus) either sell or exchange with fellow villagers or even donate/give to their extended families or relatives. The price of the produce is determined and agreed between the seller and the buyer. Production in backyard gardens has been taking place at the village for a very long time. The size of the backyards in the village are more than twice the size of those in the urban areas, although the sizes of the gardens differ depending on where the homestead is located.

Despite all their efforts and hard work, their farming has been constrained by the current serious drought, which is being experienced across SA. Unfortunately, some of the backyards are not yet planted due to drought. Although the homesteads had municipal taps, they were mostly dry most of the time and this prevented the farmers from growing their vegetables. Every household in Gladstone had once had fields which had been allocated by the then government of Bophuthatswana, however, these were last used in 1989 due to the interference of politics. Despite being located close to the homesteads; most of these fields are now being used as rangelands. Due to lying fallow for a long time, these fields can no longer be told apart from rangelands.

Villagers are also involved in livestock production and they believe that it contributes significantly towards their livelihoods. It also contributes to employment and poverty relief, integrates with and complements crop-production, embodies savings and provides a reserve against risks. The animals even have special roles in traditional culture. They have livestock such as cattle, goats, pigs, sheep, poultry, horses and others, including turkey and ducks in numbers. Cattle and sheep are closest to the hearts of African people since they can be used for many ceremonial occasions such as a dowry (lobola) and in traditional events.

The dominant livestock in the village of Gladstone is sheep. Their rangelands are in poor condition despite them being divided into four portions by roads. The small areas close to the village have been overgrazed due to the animals staying close to the village and being housed in kraals at night. Certain areas were identified where the veld has not been managed properly for years. Lack of a grazing system, poor veld management, poor camping systems and shortage of water supply for animals are the reasons for the identified degradation of the rangeland. There are two windmills that were repaired and revived by the government, but according to the villagers and or farmers, water capacity coming from those windmills is extremely poor.

3.3.4 Water use and land tenure

Water use by individual households for crop production was investigated in both Swayimane and Gladstone. In Swayimane, the sample of farmers had access to the following water sources: in house tap water, communal tap water, river or stream, borehole, well, spring, rainfall, water truck and other sources. One or more combinations of these sources are used for crop production practices and household use. The degree of utilisation is presented in Table 6, and the most common sources of water are the in-house taps, rain, rivers and streams. The water resources are generally shared by the community for crop production, as farmers indicated during discussions, however, utilisation of water takes place on an individual basis.

3.3.4.1 Water sources used

From the list of water sources given above, the sample of farmers were asked to indicate sources of water they had access to. In Swayimane, 95% of the sample had access to tap water and it was their main source of water, while another 79% used rainfall as well. According to the BRU report (2017), the study area receives 450 mm of mean rainfall annually. The report defines the mean rainfall as total rainfall values averaged, of a particular month that is taken over a number of years. River or stream water was also an important water source for the sampled households as 74% of them used it. The sampled area consists of three perennial rivers, namely: Mgeni, Mqeku and Mombeni.

There were differences between water availability and actual water use for (i) tap water, where 95% of the sample had access to tap water but only 84% reported using this water and (ii) river and spring water (Table 6). For tap water, the farmers interviewed said that it was not always available, thus farmers had to use alternative water sources. The erratic supply of municipal water in some rural villages has also been observed in Limpopo (Chitja *et al*., 2016). Springs and wells are another source of water, with 37% of farmers using springs and only 5% using wells. For river and spring use, the issue of quality perception may have been an influence. Few farmers felt that the water was of a good quality (Table 6).

The percentage of farmers that have access to rainwater (roof harvested) and those that actually use it remains the same at 79%. This is evidently the most depended-upon natural source of water. The municipality also delivered water using water trucks in Swayimane, however only 53% of the respondents had access to this water. The sample informed the research team that the municipal water truck only travelled to certain areas in the community. As a result, only households situated near the roads along the water truck's route had access to this water. While water for household use seems accessible from the available sources, it is not guaranteed that the sample always has water to use for agricultural purposes as well. This may lead to a reduction in gardening activities (Thamaga-Chitja *et al*., 2010). Thamaga-Chitja *et al*. (2010) established that farmers with access to water were more likely to engage in agricultural productivity throughout the year, in comparison to those without

Table 6 Sources of water available in Swayimane, their usage and perceptions of good quality

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
Spring	42	37	11
Water truck	53	53	26
Borehole	-	-	-
Well	5	5	-
Other	16	16	-

Fifty three percent of the sample irrigated their crops using water buckets, but the majority of the system is rain fed. It was difficult for the sample to give the exact volumes of water used per day on their household garden because most of the farmers were over the age of 50 years. Thus, many gave an estimation of the volume of the water they use on a daily basis and the values ranged from 5-1000 litres on a watering per day, with an average of 167 litres. From their water use, four distinct groups of farmers at different levels of water use and production intensity are shown (Table 7).

A farmer typology characterizing farmer in relation to farming intensity and water usage was developed and the word "*dlondlobala*" was chosen as a descriptor of the various categories. The term "*dlondlobala*" means to flourish in IsiZulu. The table shows that the amount of water used by each respondent can be positively correlated to the number of water sources they have access to. Farmers stated that volumes of water used daily are determined by the availability or lack thereof.

In the Swayimane sample, very few households produced for household consumption only, while the majority produced enough to sell. The land size for both garden and fields was shown to not have a great influence on water use, suggesting that water availability limited the farmers from intensifying production. Water use typologies are going to be matched to farmer typologies later in the study, in order to inform intervention technologies and strategies.

Table 7 Water-use and farmer typology applied in household gardens

Farmer Category	**Description land size/irrigation/purpose**	**Water volume and description of sources**	**Number of farmers**
Dlondlobala-lite	Total land size below a hectare, their gardens ≤0.25 ha. They irrigate, but only produce 2-3 crops for household consumption	≤10 L of water a day which comes from 2 or 3 sources	2
Dlondlobala-midway	Total land size varies from below a hectare to more than a hectare, gardens ≤0.25 ha. They irrigate, produce an average of 4 crops which are consumed in the household and sold	1-50 L a day Water from usually 3 sources	5
Dlondlobala-cash	Land size varies, gardens ≤1 ha. They irrigate, produce an average 4 crops which are sold and consumed by the household	5-200 L a day, from about 4 sources	8*
Dlondlobala- business	Land size varies, gardens ≤1 ha. They irrigate, produce an average of 4 crops which are sold and consumed by the household.	>200 L a day, from 5 sources	3

*one farmer had nothing planted yet

About 58% of the farmers in Swayimane identified water shortages as affecting vegetable production, saying that they usually adopted the following coping strategies in the event of limited water availability:

- They used polluted sources of water for household and agricultural use (47%);
- They changed the crops they planted (37%);
- They stopped cultivation altogether (11%);
- They bought water (5%).

The use of polluted water sources may be unhealthy if the water contains microbiological organisms and dissolved heavy metal compounds. It may also render the produce unfit for human consumption and this would reduce the farmers' access to higher-level value chains. Some researchers have shown that it is necessary to conduct more than physical tests on fresh produce before accepting it for resale (Jaffee *et al.*, 2011).

All the households in Gladstone had a tap in the backyard garden and the water was supplied by BloemWater (Figure 6). Piped water was always available, although its use was restricted to household consumption (drinking, cooking and washing) only. Villagers were not allowed to use this water to irrigate their gardens or to give it to their livestock for drinking. If households do not adhere to these regulations a penalty can be imposed by the village headman. Where an individual household fails to pay the penalty, the matter is referred to the chief. The chief will then make a final decision about the individual. Failure to still pay the penalty will result in water being cut to that specific household. Several households had two 5000 litre water tanks to use as supplemental irrigation for their backyard gardens that were provided the Department of Water and Environmental Affairs through ARC-SCW&AE.

Other households had also installed water tanks using their own resources or using drums to collect rainwater from the rooftops. The collected water was either used for supplemental irrigation or as drinking water for their animals. Some homesteads had very old hand pumps in their backyards, but most of these pumps were either broken or the rods were rusted and too short to reach the water table. There is also a large cement reservoir, but it has cracked and was never maintained or renovated. There is a river which passes close (about 500 m away) to the village, but it often runs dry during winter and prolonged drought in summer. Livestock (cattle and sheep) from Gladstone homesteads drink this water.

Figure 6 Different household water sources in Gladstone.

3.3.4.2 Land tenure and security

Land tenure and security is one of the most critical elements in eliminating poverty, promoting social equality and developing sustainable agriculture. In SA, small-scale farmers in rural areas do not own property as it is owned by the area’s tribal authority (TA). In Swayimane and Gladstone land is owned by the Gcumisa Traditional Authority and Barolong Bo-Seleka Traditional Council, respectively, while the community has Permission to Occupy (PTO) documents which give them limited control and user rights to the land.

Another aspect which contributed to the sample's land use security was that the gardens were situated near the homestead and the land is usually part of the homestead and belongs to the household. Some studies have shown that smallholder farmers struggle to access credit as they have no documentation to show that a piece of land belongs to them (Chikozho, 2005; De Soto, 2000).

Land in both villages (Swayimane and Gladstone) is accessed through the tribal leadership who work closely with both the municipality and the local government. To access land, the applicant would consult the village headman/headwoman and inform them about their intention to apply for a piece of land. If land is available, the headman/headwoman will then consult with the tribal council, which will take a decision about the application. If the application is successful, a stand number is then recorded, so that the information can be passed on to the municipality for the allocation of basic services. Prices for land differ according to the village and its purpose, e.g. residential versus business.

The Swayimane farmers' fields were on average less than a hectare, while their home gardens were 0.49 ha (SD ±1.34). This land size is consistent with the land that smallholder farmers use in SA. This is supported by some literature which has found their arable land to be below two hectares (Ortmann and King, 2010). Although fields of this size usually limit smallholder farmers from producing for markets, there is evidence that farmers with much smaller plots have been organised for market production in other countries (Herbel *et al*., 2012). Most farmers in this sample produced enough to eat and sell in Swayimane. Of those who had identified agriculture as their primary occupation, 53.8% of the respondents earned between R1001-R5000. These farmers sold their produce to hawkers (53.8%), while the rest of the produce was sold to individuals locally.

3.3.5 Institutional Arrangements

Since the collapsed of the then government of Bophuthatswana after 1994, lawlessness has become a serious problem in the village (Chaskalson, 2016; Pillay, 2018). All those institutional arrangements that used to be practised and adhered to vanished. Very few villagers shared some of the institutional arrangements that used to exist in the village (Table 8). According to them, everyone respected those institutional arrangements, but everything changed due to political influence. The respect of the elders has changed since the government passed the law preventing parents and teachers from administering corporal punishment to children. Crime in the area has increased due to unemployment and the current food insecurity situation in the country. Villagers say they seldom see police officers in their village. Fences have been stolen on most of the borders of the village including the rangelands and, in the croplands, there is nothing.

Table 8 Various institutional arrangements in the village of Gladstone

Rule	Formal/ informal	Range, Crop or both	Enforceable / Not enforceable	To which organization does it belong & who enforce it?	Consequences / Penalty	How do you resolve conflict?	Functional/ Dysfunctional	If dysfunctional, how was production suppressed?	Evaluate: Stay/ Remove or improve
1. Access to land is open to anyone provided they pay what is needed by the Tribal Council.	Formal	Village at large including both range- and croplands	Enforceable	Tribal council. Both government and tribal council enforce the law.	Forceful removal & illegal squatter, who is fined. Police are called to stabilise the situation if the person is not cooperating.	Conflict over land disputes is resolved by the tribal council. If conflict persists police and magistrates are called to assist in finding the solution.	Functional.	Even though the law is functional, authorities take time to approve an application for a piece of land and sometimes farmers miss the planting season because of the delay.	Stay, but let the application be dealt within a short time so that planting season cannot be missed. Give title deeds to all landowners.
2. No one is allowed to consume alcohol in public places.	Formal/ Informal	Village at large including both range- and croplands	Enforceable	Tribal council and Police.	Fine is posed on the individual. If fail to pay immediately, offender will be kept in police holding cells.	The matter will be addressed by the headman; if not resolved police get involved.	Used to be functional before 1994, afterwards became dysfunctional	Does not suppress production as men (if they are unemployed) are forced to work on their fields and assist their families.	Improve as an effort to control lawlessness and encourage people to do something for themselves. It will decrease high rate of unemployment.
3. Cutting or stealing fences is prohibited.	Informal	Village at large including both range- and croplands	Enforceable	Tribal council & the Department of Agriculture are the custodians of the law.	Anyone who is caught stealing is referred to the police, even though tribal council has powers to preside over case.	Livestock destroyed other people's crops & that lead to many cases brought to the tribal council for adjudication.	Functional/ Dysfunctional	It does not suppress agriculture, but helps to improve the safety of both animals and livestock.	It should stay, but be improved by introducing tough measures against those who steal fences.
4. Only rangers will patrol both rangelands & croplands	Formal	Both range- and croplands	Enforceable	Tribal council & the Department of Agriculture. They are also custodians of the	Magistrates were responsible for penalties. It could either be a	Those caught destroying or stealing both livestock and fences were	Used to be functional before 1994.	Now is dysfunctional as it was abolished after 1994 and there	Rangers should be brought back so that villagers are able to produce enough

Rule	Formal/ informal	Range, Crop or both	Enforceable / Not enforceable	To which organization does it belong & who enforce it?	Consequences / Penalty	How do you resolve conflict?	Functional/ Dysfunctional	If dysfunctional, how was production suppressed?	Evaluate: Stay/ Remove or improve
(especially during the night).				law therefore, they enforce it.	fine, prison sentence of lashes.	given to law enforcement agencies to give them proper sentences.		are no more rangers. It suppresses production because fences are stolen, stock theft has increased and crops are destroyed.	for themselves and their livestock is secured at all times.
5. No one is allowed to stay in the house that was built for the extension officer of the area.	Formal	Village at large including both range- and croplands.	Enforceable	Department of Agriculture with the help of the tribal council (including the headman).	Anyone found occupying the house illegally will be forcefully removed and fined.	There were no conflicts as it was known that the house was for the use by the extension officer, but now somebody is occupying it illegally.	Used to be functional before 1994. But now is dysfunctional.	Law is now dysfunctional as somebody is occupying it illegally and no one tried to remove him. That suppressed production because people have to travel long distances to access what they use to get from the extension officer.	Improved it as it will improve agricultural production within the village. An extension officer will be easily accessible at all times by the village.
6. Everyone is obliged to make sure that his/her livestock is branded with his/her own mark.	Formal	Rangeland s (including livestock owners)	Enforceable	Department of Agriculture and the tribal council	Law enforcement agencies enforced the law.	Conflicts were resolved by tribal council in consultation with the law enforcement agencies.	Functional	Not all people brand their livestock and once their livestock is stolen, it is difficult to identify it & causes conflicts with neighbouring	6. Everyone is obliged to make sure that his/her livestock is branded with his/her own mark.

Rule	Formal/ informal	Range, Crop or both	Enforceable / Not enforceable	To which organization does it belong & who enforce it?	Consequences / Penalty	How do you resolve conflict?	Functional/ Dysfunctional	If dysfunctional, how was production suppressed?	Evaluate: Stay/ Remove or improve
7. Water in the tanks should only be used for household consumption	Formal	Both range- and croplands.	Enforceable	Former government of Bophuthatswana	No water supplied for a certain period of time.	Tribal leaders were most of the time responsible for dealing with the issue.	Dysfunctional	There are no water points within the rangelands; two windmills are drawing enough water. People fear to leave that livestock unattended in	Be removed as it hampers the development of agriculture in the area. Village members cannot even water their homestead gardens due to harsh penalties.
8. Only village members who have livestock can use dipping tanks	Formal	Rangeland s	Enforceable	Department of Agriculture	Fine		Used to be functional, but now is not.	Not everyone who owns livestock can afford to pay the fee.	It should be improved and government should subsidise farmers

3.4 SUMMARY AND CONCLUSION

Different methods of data were used with the aim of understanding both villages in detail. Both primary and secondary data was used. The data collected played a critical role in the study since it indicated the natural resources base is somewhat capable of production in various capabilities. With regard to natural resources, detailed soil tests were conducted to ascertain the current condition of the plots in order to recommend a specific soil management plan for both areas. In KwaZulu-Natal, the BRU information shows what crops are possible for production and also provides yield potentials. The rainfall data is encouraging with BRUs that receive up to 900 mm in mean annual rainfall. The Free State site, although drier, has similar potential. The SASCS played a vital role in understating the situation in the area. Although encouraging, the data is predictable as a 10-year average for commercial production and that resource-limited farmers will have to be engaged differently to bring about such yield potentials.

In human resources various demographics were looked at and analysed. The demographics indicated that mostly men were respondents in the Gladstone area, compared to Swayimane. The reason behind this might be the fact that men return home after they have lost their jobs, either due to old age or tough economic times. Many young people have moved to urban areas to search for greener pastures, leaving their elders behind.

A great concern is the health status of everyone (especially elderly people and children) which is not good shape because they do not have access to good-quality nutrition. This lack of access to proper food, impacts negatively on their lives and agricultural production because they are unable to take their medication due to the fact that they don't have anything to eat. Additionally, many households in this baseline study were either vulnerable or food insecure in spite of having gardens, indicating that food insecurity may be related to the households' inability to access food from markets. There is a need to investigate this further over the duration of the project.

There were differences in the farming systems in part due to water availability, thus water interventions will need to be tailored to address this. This was further demonstrated by the four typologies which emerged, based on water used in the study. In Gladstone, water access was more of a challenge compared to KwaZulu-Natal's Swayimane. In Swayimane, all households have very big "gardens" (more than 1 ha) that can be classified as cropland, based on their size, and they are using them effectively.

Unfortunately, the land usage with regard to agricultural activities in Gladstone is extremely poor. The croplands in the village have not been used for almost thirty years due to lack of resources or machinery such as tractors and other implements; this was caused by political interference. The smallholder farmers and villagers are only using their homesteads gardens for agricultural production activities, since their sizes range from half to one hectare. A variety of crops are planted in the homestead gardens in both villages.

Both villages are still governed by traditional leadership. Only Gladstone was part of the former self-governing states of Bophuthatswana. The traditional authority in Swayimane facilitates and manages access to and the use of communal tenure land at both sites in Swayimane. They are by far the most important role-player in this regard; hence the discussion below will focus on the traditional authority. All traditional leaders fall under King Zwelithini (‘iNgonyama’ – ‘Lion’ or ‘King’) who is the sole trustee of the iNgonyama Trust, which holds all communal tenure land in KwaZulu-Natal. As for Gladstone, the land was and is still under the leadership of the Barolong-Boo-Seleka Traditional Council, despite the area being integrated into the new government of SA in the 1990s. If the municipality wishes to do anything in that area, they have to consult with the traditional council for.

Municipalities in both villages have the responsibility, together with other government departments, to provide services that are not only limited to access to clean water, roads, schools, clinics, electricity, safety (police), etc. Through their democratically-elected councillors and in consultation with the traditional council represented by a headman from the village, the provision of social services is facilitated. These services include assisting residents with electricity, helping them to access social grants and making sure that they have access to water by bringing in tankers when there is a shortage of piped water. This does not, however, happen reliably, and two weeks can pass with villagers not having water. The bottom line is that land allocation is solemnly in the hands of the Traditional Council. One important thing that should be mentioned is that in both villages no one has ownership of land and the areas are still using the permission to stay (PTS) system.

Such arrangements and their implications on interventions in the food gardens must be considered. The institutional arrangements in place related more to access to land and management of land use and keeping the peace. Loose and non-identifiable arrangements were found for water use in both study areas, indicating a need for intervention. The institutional arrangements were also weak for enterprise development and great intervention will have to be embarked on, based on the findings. There were no marketing committees and crop scheduling was not a concept that was understood.

Much will still need to be understood about the value chains of various crops that are being grown, based on this report. On the other hand, accessibility of water within both study areas is not clearly defined since there are no proper or functional working institutional arrangements that can be used as a guideline for all community members. All these challenges impact negatively on the utilization of water resources in the area. For example, wells and boreholes that have been fixed by the government are not accessible to everyone in the community.

4 PARTICIPATORY APPROACHES AND PROCESSES IDENTIFICATION AND SELECTION OF CSTS

4.1 INTRODUCTION

The need for improved agricultural methods required to meet the growing global food and nutrition security demands has been amplified by the changing climate and rapid population increase (Shivakoti *et al*., 2016). Ward and Pulido-Velazquez (2008) show that *"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"*. Evidently, the small-scale farmers whose livelihoods depend on farming are at greater risk.

Innovative and CSTs are critical to address water shortages for food production, particularly by vulnerable communities who may not be able to purchase as much food as desired. Many rural African and Asian households practise subsistence-oriented agricultural production and it is their main source of household food and nutrition security. The per capita demand for food is growing exponentially and efficient, smart and environmentally-friendly crop production techniques are required. Faced with competing non-food demands for agricultural production and declining agricultural productivity due to weather variations, the complexity of climate change impact calls for collaboration by different experts. Vulnerable farming communities must also be involved to inform on the appropriateness of the technologies for farmers at the production level, as they are the ones who face the reality of climate change (Regmi and Meade, 2013).

CSTs are an alternative to CON, which show that agricultural systems can be developed and implemented to concurrently improve food security and rural livelihoods in a changing climate. This can be achieved through enabling climate-change adaptation and offer mitigation benefits (Scherr *et al*., 2012).

There are various ways to promote adaptation and mitigate climate change, e.g. enhancement of soil quality to produce vibrant regulating services that buffer, filter and moderate the hydrological cycle. Soil quality enhancement involves improving soil biodiversity and regulating the carbon, oxygen and plant nutrient cycles, promoting resilience to drought and flooding, and carbon sequestration (Campbell *et al*., 2014). Scherr *et al*. (2012), further added that CSTs include many field-based and farm-based sustainable agricultural land management practices, including conservation tillage, agro-forestry and residue management. CSTs can increase and conserve natural capital by means of generating productivity increases, cost decreases and higher stability of production (Branca *et al*., 2011).

This will be achieved through improving soil fertility and structure, adding biomass to the soil, causing minimal soil disturbance, conserving soil and water resources, enhancing the diversity and activity of soil fauna and strengthening the mechanisms' elemental cycling (Branca *et al*., 2011). This will result in better plant nutrient content and improved water retention capacity and soil structure, leading to higher yields and greater resilience, which will directly improve food security and rural livelihoods.

The term CST emerged in 2010, informed by the work of the United Nations Food and Agricultural Organisation (FAO), the World Bank and other international institutions (Scherr *et al*., 2012). However, Branca *et al*. (2011) have observed that the adoption of CST has been relatively low globally, thus there is a considerable interest in understanding the benefits, costs and barriers to adoption of these practices in the context of changing climate. The focus around this concept has been mainly on the implementation of field- based and farm-based sustainable agricultural land management practices.

In addition to these, CSTs are aimed at ensuring optimum food production. Homestead, school and community gardens have been neglected in food production system, in spite of the fact that they have been proven to positively contribute to household food security and better livelihoods. Galhena (2002) suggested that the consideration of these institutions (homestead, community and school gardens), as part of agriculture and food production systems, will positively contribute to alleviating hunger and malnutrition.

The objective of this chapter is to review various CSTs for increased crop production and identify those that are relevant to the current conditions of the selected study sites for implementation purposes.

4.1.1 CST: definitions

Numerous definitions for CSTs are given in the literature. A few examples are provided below:

"CST is defined as agricultural practices that sustainably increase the productivity and system reliance while reducing the emissions of greenhouse gases." (Sullivan *et al*., 2012).

"CST refers to the integrated planning of land, agriculture, fisheries and water at a multiple scale which includes local, watershed and regional." (Scherr *et al*., 2012).

Both these definitions consider landscapes as a key component of the climate-smart conceptual framework. In this regard, any definition that captures the management of soil and water resources is accepted since these are major resources that CSTs aim to protect and to reduce their degradation (McCarthy *et al*., 2011).

4.1.2 Broader categories of CSTs

Various CSTs were identified from the literature, but only those CSTs that have the potential to improve the adaptive capacity or mitigation potential of different agricultural systems within the study area are summarized in Figure 7.

The adaptive options that are discussed includes a wide variety of approaches that are designed to reduce the vulnerability while enhancing the adaptive capacity of agricultural systems to climate change (Harvey *et al*., 2014). These options include a range of farm management practices, which include soil and water conservation practices, crop diversification as well as improved tillage practices that will enhance agricultural systems to become more resilient to change in climate, diversifying farmer livelihoods and ensuring the continued supply of ecosystem services (Harvey *et al*., 2014). CSTs are divided into practices that can be applied to soil or water under dry-or irrigated lands, as shown in Figure 7.

The main purpose of some of these systems is to conserve depletion of the natural resources, e.g. soil and water while improving the productivity of agricultural lands for improved crop production. Included in Figure 7 also are management practices relevant to areas experiencing water logging problems, e.g. wetlands or areas receiving high amount of rainfall that exceeds the infiltration potential of the soil. As a result, management practices relevant to dryland and irrigated lands are summarised for both soil and water resources.

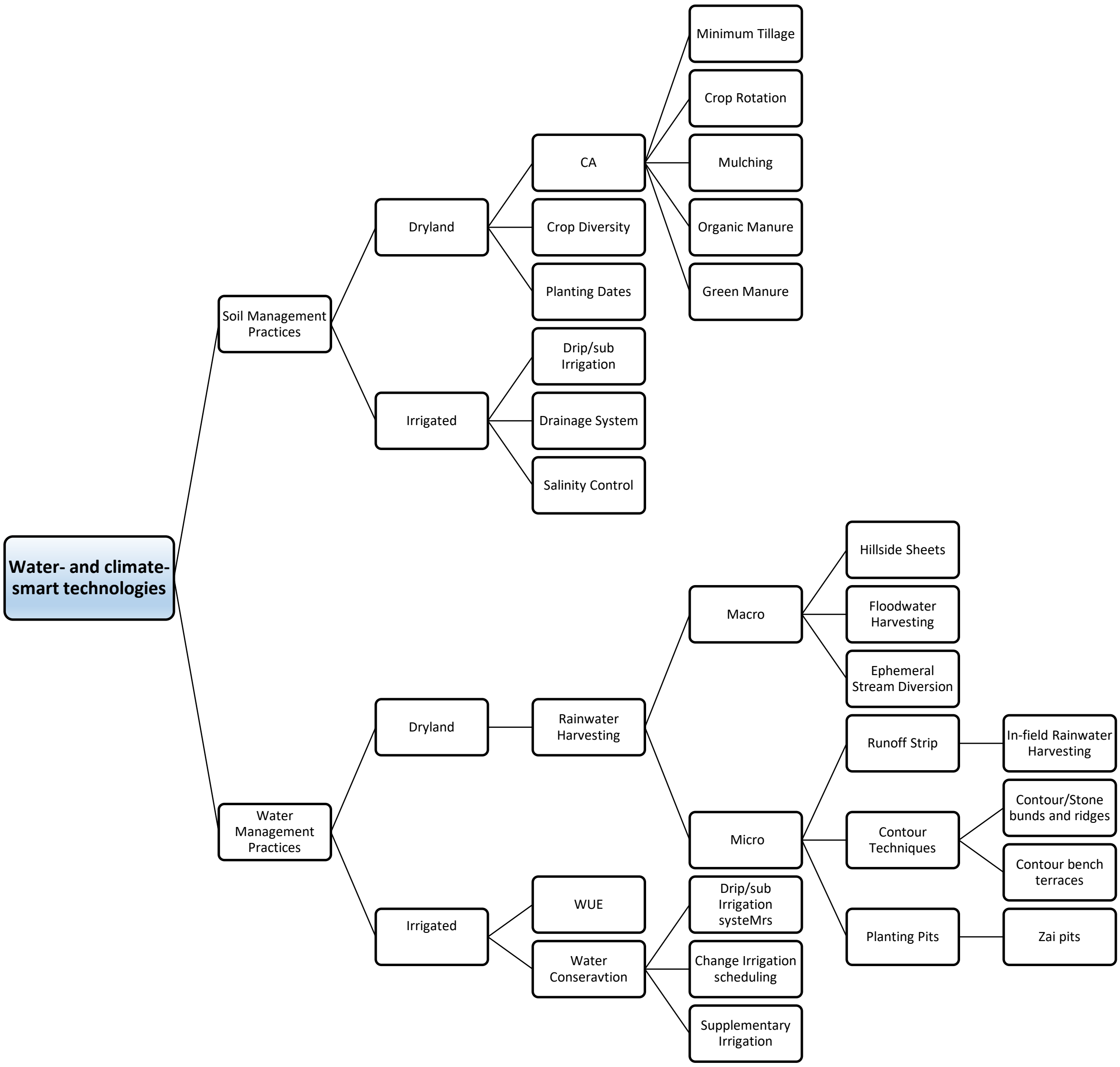


Figure 7 Different CSTs for improved adaptation and mitigation of climate change on agricultural systems.

Table 9 summarizes the different CSTs as presented in Figure 7. It describes their main uses and descriptions of each technology or practice, where they are appropriate, their advantages and limitations as well as relevant sources where the information about each technology was obtained from the literature.

Table 9 Uses, description, appropriateness, advantages and limitations of potential CSTs

CST	Main use	Description	Where appropriate	Advantages	Limitations	Sources
Conservation Agriculture • Minimum tillage • Crop Rotation • Mulching • Cover Crops • Organic manure • Green manure	Crop Production/ Soil conservation	Agricultural methods that aim at preserving and improving crop yields and resilience against drought while protecting and stimulating the biological functioning of the soil. It is also considered as a practice for carbon sequestration.	Areas experiencing severe drought coupled with severe soil erosion. Areas with infertile soils that results in poor yields. These systems can work better in any slope gradient. Areas dominated by sandy soil texture (Clay % <10) may not yield better results.	Higher yields due to improved soil moisture coupled with improved soil characteristics such as structure and porosity. Improves soil fertility through improving nitrogen content of the soil. Improves water-holding capacity of the soil and reduces evapotranspiration (Es). Active in carbon sequestration	Does not work better in too sandy soils. Does not work well in dry areas where water is a limiting factor to the production of sufficient biomass to maintain a permanent soil cover and for significant amount of crop residue.	Thomas, (2008). Branca, (2011) McCarthy *et al.*, (2011). Haynes & Naidu (1998) Steiner *et al.* (2007). Bogdanski (2012).
Crop diversification (e.g. agroforestry)	Crop production and soil conservation	This system provides the link between stress and resilience since the diversity of organism is required for the ecosystem to function and provide services. This system is good for adaption or mitigating changes in climatic conditions.	Suitable for area under arid and semi-arid regions. Can be employed in areas dominated by steeper slopes, e.g. hillside. Not suitable for establishment in areas dominated by shallow soil with	Reduces Es and therefore results in higher yields. Reduces soil and water erosion. Improves water management and reduces crop output variability.	Availability of range of suitable seeds and bush seedlings and seeds. Limited knowledge and information of types of agro-forestry options, mainly those suited to local conditions. Requires labour or additional investments to ensure the trees and bushes receives adequate	McCarthy *et al.* (2011). (Lin, 2011).

CST	Main use	Description	Where appropriate	Advantages	Limitations	Sources
			clay percentage <10%		water until roots of the trees are firmly established for survival.	
Change in planting dates	Crop production	This system is considered as the leading strategy to cope with poor crop production in the agricultural sector. Changes in planting dates usually differ from one area to another depending on climatic conditions of that particular area, since different areas experiences different climatic conditions.	Suitable under arid and semi-arid regions. Also suitable for any soils that have agricultural potential.	Crops are planted when rainfall is possible. Reduces chances of crop failure due to limited rainfall.	Depends on the accuracy of predictions as to when the changes of rainfall will occur. If predictions are not corresponding to real life situations, chances of permanent crop failure are high.	Deressa *et al*. (2009).
Drip- or sub-irrigation	Crop production	This refers to an application of water below the soil surface through emitters. This system is considered as one of the water saving agricultural practices. Save about 25-50% of the water compared with other irrigation systems.	This system can be utilised by farmers in arid and semi-arid regions who have access to irrigation. Suitable for areas that experience a decline in the availability of water resources.	This system increases crop yields, higher quality of vegetable crops, ability to apply chemicals such as fertilizers and pesticides through sub- or drip irrigation tubes as well as the reduction of plant diseases. Increases water use efficiency (WUE), reduction of nitrate leaching as compared to other surface irrigation. Applies water and nutrients to the most active root zone,	Not suitable for coarse textured soils. Smaller crop root zones may be insufficient to avoid diurnal crop water stresses even when the root zone is well watered. Some crops might require a very close dripline spacing that might be economically unfeasible.	Thompson *et al*., (2009) Lamm & Trooien, (2003) Santamaria *et al*. (2003)

CST	Main use	Description	Where appropriate	Advantages	Limitations	Sources
				protection of drip lines from damage due to cultivation and other operations.		
Drainage Systems (e.g. surface or subsurface drainage systems)	Crop production	This system is aimed at reclaiming soils that are experiencing waterlogging problems for improved agricultural production. It controls the level of the water table.	This system is usually applied in relatively flat lands that have soils with a low or medium infiltration capacity. Perform well in areas with high-intensity rainfalls that exceed the normal infiltration capacity. This system is applied in arid and semi-arid areas, which normally experience waterlogging conditions.	Reduces the amount of water stored in the soil while inducing drier soil conditions during waterlogging. Promotes aeration of the soil and also stabilizes the soil structure. Promotes nitrogen availability in the soil and higher or more diversified crop production. Earlier planting dates.	The system is too expensive and is not viable for resource-poor farmers who reside in rural areas. This system requires technical skills and is not feasible for farmers who are illiterate. Pipes that are used can release heavy metals that will contaminate the water table thus compromising the quality of water.	Zucker & Brown (1998) Skaggs *et al*. (1994)
Control salinity	Crop production	This system involves controlling the salinity of the soil, not necessarily to the lowest possible level but rather keeping it within acceptable limits adequate for sustained productivity.	Irrigated fields in arid and semi-arid areas. Areas that are periodically experiencing waterlogging conditions.	Improves yields and promotes the availability of essential elements such as phosphorus Corrects the soil pH in a range that is suitable for crop production.	If not controlled can reduce yields and the fertility status of the land.	Rhoades (1993) George & Frantom (1990)

CST	Main use	Description	Where appropriate	Advantages	Limitations	Sources
Water use efficiency/ Water conservation	Crop production	This system involves efficient use of irrigation water in order to conserve more water for other environmental uses. This mean irrigating at the right time and correct amount of water as required by the crop need.	Arid and semi-arid regions where farmers have access to irrigation facilities.	Conserve more water for use in the coming future. Supply crop with the correct amount of water as per its requirement. Improve yields and household food security	Only applicable to farmers that have access to irrigation facilities.	Schaible & Aillery (2012) Caswell *et al*. (1990) Ward & Pulido-Velazquez (2008)
IRWH	Crop and vegetable production	This system stimulates rainfall runoff on a 2 m wide strip between alternative crop rows and stores the runoff water in the basin. Collected water in the basin infiltrate deep in the soil beyond the surface evaporation zone.	This system is appropriate in areas with slope < 8%. Soil depth should be at least 700 mm. Soils must have clay percentage greater than 10%. The area must receive a rainfall between 450-700 mm.	It improves crop production especially in areas that are located in arid and semi-arid regions. Farmers located in areas that are marginal for crop production are able to produce crops using this system. Prevent soil erosion and surface evaporation. Improves household food security and better livelihood.	Avoid areas with low percentage of clay (<10%), i.e. sandy soils. Does not perform well in areas receiving the rainfall that is less than 450 mm. Avoid shallow soils.	Botha *et al*. (2007) Botha *et al*. (2003). Everson *et al*., (2011) McCosh *et al*. (2017)
Contour bunds and ridges and stone bunds	Crop, rangeland and trees production	Improves the mechanical protection of arable land from rill and gully erosion. This system can entail either bunds or ridges	Contour ridges/bunds are suitable for slopes of between 1% and 5%.	The advantages of this system are that contours are built once and there is no need to rebuild them unless they are damaged.	The disadvantage of this system is that failure to align the ridges with the contour line will result in the system becoming ineffective due to	Hagmann (1996) Kahinda *et al*. (2007)

CST	Main use	Description	Where appropriate	Advantages	Limitations	Sources
		constructed along a contour line, and separated from each other by a space of 5-20 m.	This system is suitable for arid and semi-arid regions where the rainfall is not too high to cause extreme runoff and soil loss.	Contours can be built using stone and will be referred to as stone bunds.	overtopping and breaking of bunds.	Li *et al*. (2008)
Contour bench terraces	Crop, rangeland and tree production	It can be used for both soil and water conservation practices	This system can be applied in steeper slopes (>8%) as it has a potential to slow down the velocity and erosive force of water. Suitable for arid and semi-arid regions. Clay percentage must at least be greater than 10%.	This system provides erosion control and retains, spreads and infiltrates surface runoff	It is only effective on steeper slopes and cannot be used in flat areas. Does not perform well on sandy soils	Mhizha *et al*. (2009)
Zai Pits	Crop and vegetable production.	This system involves the digging of the small planting pits measuring 20-30 cm in width, 10-20 cm in depth and are 60-80 cm apart.	Suitable for dry fragile lands as a way of managing land degradation, soil infertility and low soil moisture. Organic materials such as compost and manure can be added into the planting holes to	It concentrates both fertility and moisture in the rooting system of the crop.	The disadvantage of this system is that high rainfall amounts could cause water logging of the pits which may promote soil salinity.	Kaboré & Reij (2004). Kahinda *et al*. (2007)

CST	Main use	Description	Where appropriate	Advantages	Limitations	Sources
			improve the soil fertility.			
Hillsides sheet or rill runoff utilisation	Crop, trees, bush and rangeland production	This system includes natural collection of runoff water from hilltops, sloping grounds, grazing land and/or highland areas to low lying flat areas.	Appropriate in areas where the runoff must travel over a long distance before reaching the cultivated area. Can be applied on sloping sites.	Enhances soil infiltration rate. Improves the production of crops. Reduces soil erosion by water.	Requires special skills to ensure the success. Cannot work on soils that are too sandy.	Rosegrant *et al*. (2002). Hatibu & Mahoo (1999)
Floodwater harvesting with stream bed	Crop production	This system uses barriers such as permeable stone dams to reduce water flow and spread it on the adjacent plain	It is suitable for areas receiving high volumes of rainfall only.	Improves land management due to silting up of gullies with fertile deposits. Increases crop production and erosion control because of harvesting and spreading of floodwater. Enhances groundwater recharge. Reduces runoff velocities as well as the erosive potential of water.	Requires high labour costs during implementation. Not suitable for areas receiving low rainfall	Jiang & Li (2013)
Ephemeral stream diversion	Crop Production	This system involves diverting water from its natural ephemeral stream and then conveying it to arable cropping areas	Where runoff generating areas can be used to supplement rainfall falling on micro-catchment systems.	Increases water availability in micro-catchment systems.	Requires proper design to prevent deposition if slope too shallow and erosion gradient is too steep. Not suitable for highly erodible soils.	McCosh *et al*. (2017).

4.1.3 Methodology

This chapter sought to outline proposed CSTs for the project's two study sites; Swayimane (KwaZulu-Natal) and Gladstone (Free State), based on the data collected and described in Chapters 2 and 3. The data presented in this chapter emanate from Chapters 2 and 3 as well as a review of secondary literature on the two study sites. Climate, soil, water, human resources and socio-economic data were extracted from Chapter 3. Chapter 3 showed that Swayimane and Gladstone communities have different climatic and relief properties, indicating that different CSTs and soil management practices would be needed.

4.2 SITUATION ANALYSIS OF SWAYIMANE VILLAGE FOR THE IMPLEMENTATION OF CSTS, PRACTICES, CROPS AND FARMING SYSTEMRS

This chapter gives the results of a situation analysis conducted in Swayimane to assess the biophysical- and socio-economic conditions of the village so that appropriate CSTs can be proposed. The biophysical and socio-economic data for Swayimane was supplemented with information from Chapter 2 (Literature review) and Chapter 3 (Description of the natural and human resources, farming systems and institutional arrangements at the selected areas – Swayimane and Gladstone).

The aim of this chapter was to prepare the shortlisted technologies, farming systems and crops that were communicated to relevant stakeholders and community members at a stakeholders' forum/workshop.

4.2.1 Situation analysis of Swayimane

A summary of the situation analysis used to identify appropriate technologies from the basket of technologies based on literature is given in Appendix 1.

4.2.1.1 Climate

Swayimane has three distinct climate capability ratings: first, the climate in Valley of a Thousand hills and KwaGquggquma bio-resource units favours the production of a wide variety of adapted crops, which can be grown all year-round. However, moisture stress and lower temperatures, could increase risk and decrease yields relative to C1. Second, Mkabele and Bruyn's Hills have a slightly restricted growing season because of the occurrence of low temperatures and frost. Communities under this climate capability rating have the potential to produce good yields for a moderate range of adapted crops. Finally, the Nagel dam area has a moderately restricted growing season due to low temperatures, frost and/or moisture stress. In addition, this area is suitable for limited crops, which frequently experience yield loss. Thus, any agricultural developments for Swayimane would be guided by this information and consideration of the crops, which are suitable for the area.

4.2.1.2 Soil

As discussed in Appendix 2 Swayimane soils vary as per the five bio-resource units. The general soil profiles and origin vary from young to alluvial and duplex. The areas have some steep slopes of up to 35% but also have areas of low erosion categories.

4.2.1.3 Human Resources

Most farmers interviewed were able-bodied. They have received at least six years of primary school and are literate, although most of them are largely monolingual. They have the physical capacity and varying means to produce both for household consumption and for sale. Their yields and income have the potential to increase; however, the farmers need appropriate training to improve product quality and value chain readiness.

4.2.1.4 Infrastructure

The community has robust information and transport infrastructure, which makes it possible for the farmers and other community members to travel to other towns and cities and allows traffic into the community. The communities have access to municipal tap water but the taps are often dry. Although there are some rivers in the communities, there is little evidence of irrigation infrastructure in the community. Instead, the farmers have their own creativity and labour to irrigate their crops. As a result, the farmers can produce with the infrastructure currently available to them; however, implementing water technologies, which increase efficient water use, could improve farmer output.

4.2.1.5 Farming system

Appendix 1 shows that the farmers in this community are largely smallholder farmers who in addition to owning larger plots of land often have homestead gardens to cater for household consumption. The production in these gardens seems to be an extension of their broader agricultural activities and is limited by the difficulties in accessing seeds, fertiliser and other improved inputs, which are found outside the community. This is a mixed farming system characterised by resource scarcity. Farmers practise either subsistence or semi-commercial small-scale production.

4.2.1.6 Water use

The farmers reported having access to water from several sources, e.g. municipal taps, rivers and springs as shown in Appendix 1. Due to the preceding drought, there was less water from rivers and springs as a result and water availability was a challenge in these communities. It was generally perceived that municipal water had a higher quality than the other water sources and this determined the uses of water from other sources. It is possible that their perceptions of water quality resulted in farmers limiting the range of uses for water from other sources. Given the prevailing water scarcity, avenues of processing ‘polluted’ water sources need to be explored so that its use on food crops does not compromise their quality and safety.

4.2.1.7 Food and nutrient security status

Most households experience different levels of food insecurity as shown by the common occurrence of consuming smaller or fewer meals, etc. in Appendix 1. Although some coping strategies were observed, the respondents in Swayimane consumed at least six of the twelve food groups in question. It is important to determine the food environment of communities in Swayimane and to determine patterns of food availability and scarcity throughout the year. It is possible that local production and nutrition knowledge could lead to an improved food and nutrition security outcome.

4.2.1.8 Access to inputs and marketing

The farmers accessed most of their inputs from Wartburg and neighbouring cities and towns. Similarly, most of their buyers came from these neighbouring cities and towns. The lack of farmer organisation in these communities indicates that the farmers interacted with these markets as individuals and this resulted in them being price-takers. Some farmers made a profit through the sale of green mielies and potatoes, therefore a market for other produce could be developed.

4.2.1.9 Challenges

Most of the farmers' challenges stemmed from their resource poverty and water shortages due to inadequate infrastructure and water harvesting. If farmers could access more agricultural water and better markets, it is likely that these challenges would be addressed.

4.2.2 Proposed CSTs

Due to the presence of rivers and springs and the steep nature of Swayimane's fields, these CSTs could be appropriate for the area:

- Conservation agriculture
- Crop diversification
- Change in planting dates
- Drip-irrigation
- Water conservation
- IRWH (slope <8%)
- Contour bench terraces
- Zai pits
- Stone bunds

4.3 SITUATION ANALYSIS OF GLADSTONE VILLAGE FOR THE IMPLEMENTATION OF CSTS, PRACTICES, CROPS AND FARMING SYSTEMS

The situation analysis is summarized in Appendix 2 and thus assisted to make informed decisions on what might have been the most suitable technologies from those identified from the literature to be implemented in Gladstone village.

4.3.1 Situation analysis of Gladstone

4.3.1.1 Climate

The climate of Gladstone village is typical of semi-arid regions, which are characterized by cold winters and hot summers with low and erratic rainfall. In Gladstone, most of the rain occurs in the form of high-intensity thundershowers, resulting in high water losses due to runoff. During mid-summer, it is extremely hot with high evaporation losses. Frequent mid-summer droughts are also experienced. Although the long-term annual rainfall is constant, villagers have observed that there has been 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 greater and with higher intensity. The occurrence of floods is now more frequent than in the past. Gladstone is situated on a flat area surrounded by small hills, resulting in it being much colder than surrounding villages. Temperatures below 0ºC and frost during the winter are common.

The unfavourable climatic conditions will have a huge impact on agricultural technologies that can be applied and crops that can be planted. All technologies will have to be geared to minimizing unproductive water losses and increasing the effective rainfall. This can, for example, be achieved by applying rainwater harvesting where runoff water is either stored in the soil profile or in a container (e.g. JoJo tank) for later use. Apart from having to introduce strategies to cope with the limited rainfall it will also be necessary to control the temperature during extreme cold and heat. This can for example be achieved by placing a mulch blanket on the soil surface to cool down the soil during the summer and heat the soil during winter.

4.3.1.2 Soil

Gladstone community falls entirely within Land Type Dc17, which makes up 53% of the total area of Thaba Nchu. The largest portion of Gladstone is covered by clay soils. The slope in Gladstone varies between 0 and 12%. The slope for most of the lands is less than 3% with small areas having slopes between 3% and 4%.

The dominant soil forms in this community suitable for RWH&C are Sepane, Swartland, Arcardia and Bonheim. These clay soils (34-54% clay in the topsoil) tend to easily form a crust that promotes runoff. The infiltration rate is low, but the clay soils have a high water holding capacity, meaning that the water can be retained for a longer period. The soils are shallow and the effective rooting depth seldom exceeds 1 m. There are many bare patches due to overgrazing and poor veld management, meaning that the soil surface is exposed to erosion. Valuable topsoil has been washed away and dongas are increasing fast.

The crusting properties of the clay soils could be put to good use by applying IRWH where the crust promotes in-field runoff toward the basin area, where runoff water is stored in the basins beyond the surface evaporation zone. This will result in increased plant-available water and thus increase crop yields. The slope of the soils in Gladstone is not too steep (less than 4%) and it is clayey (more than 30% clay), which makes it ideal for IRWH.

4.3.1.3 Human resources

There are many child- or female-headed households in Gladstone. This is because either the parents have passed away or young children are left alone or with grandparents while parents are working in Bloemfontein or the Goldfields. In some child-headed households, older children have even had to leave school to look after their younger siblings. The majority of the adult population is unemployed and most households depend on pensions and other government grants for survival. The majority of the workforce in Gladstone is either very old (older than 60 years) or very young (under 18 years), as most of the youth has left the village and moved to urban areas to increase their education and employment opportunities.

Since the workforce mainly consists of old people with poor health assisted by young children and teenagers, it will be necessary to implement techniques and practices that can be mastered by this weakened workforce. It will thus not be possible to advocate techniques and practices that require hard labour with these limited human resources. In the case of child-headed households, techniques and practices will be implemented in the homestead gardens where they can work after finishing their schoolwork and other chores around the house while looking after the siblings.

The techniques need to be simple enough, so that the principles thereof can be understood by all the family members and that all the family members can work together in the garden. Responsibilities will also be divided between the family members, where, for example, the young boys can do the construction of the water harvesting basins while the small children and old women can assist with planting and pulling out weeds. Due to the high unemployment rate and low household income the selected techniques and practices need to be affordable, so that they can be implemented by the poorest of the poor and do not require huge capital investments. An example of such a practice might be the use of animal manure as an alternative to expensive inorganic fertilizers.

4.3.1.4 Infrastructure

The lack of proper infrastructure is a serious problem in Gladstone. The gravel roads in and around the area are in an extremely poor condition and are inaccessible during the rainy season. It is thus difficult to move from Gladstone to Thaba Nchu and Bloemfontein. There is no taxi service in Gladstone and most residents travel by bus to Thaba Nchu and Bloemfontein, which has stipulated times. The bus service is also unreliable and buses are only available early in the morning, around lunchtime and late afternoon. This is mostly to carry scholars to the high school in Thaba Nchu and women that are working as domestic workers in Bloemfontein.

It is thus difficult to transport inputs to Gladstone and any produce to the markets. Fences are also in a very poor condition and even the border of Gladstone is unfenced. No crop and rangelands are fenced and fences around homestead gardens are also in a poor condition, so chickens and other livestock can easily enter gardens and destroy the crops. This make it impossible to implement good farming practices such as rotational grazing without proper fencing. There is a community hall, church and clinic but they in a dilapidated condition. Villagers are thus deprived of basic services, which all contribute to low morale and lawlessness.

The lack of or poor infrastructure needs to be taken into consideration when suggestion are made on potentially suitable technologies and practices to be implemented in the village. The involvement of other relevant stakeholders should be encouraged and government departments should deliver on their mandate of service delivery, in order to create a conducive environment for the implementation and widespread application of new technologies and practices.

4.3.1.5 Farming systems

All residential stands that were allocated prior to 1994 were also issued with a piece of a cropland. Households that received residential stands later were not given any croplands. This means that every household has the opportunity to establish a homestead gardens but not everyone has access to the croplands. Due to lack of tractors and implements the croplands have not been used for more than 20 years. Only a few of the households are making use of their homestead gardens to produce mainly maize and some vegetables crops for own consumption. In most cases less than half of the garden is utilized, so there is considerable room for expansion. None of the crops are irrigated since water from the taps is only used for domestic purposes (cooking, drinking and laundry).

Some households own livestock, which roam freely in and around the village. Due to the lack of fences, there is no camping system to allow for rotational grazing, with the result that the veld especially close to the residential area is heavily overgrazed. Livestock theft is a serious problem in Gladstone village so owners kraal their animals at night at their homesteads.

Although expansion to the croplands might be problematic due to lack of implements, the homestead gardens can be used more productively to produce a variety of vegetable crops. The kraaling of animals provides the opportunity to apply cow dung as organic fertilizer since the collection thereof is concentrated.

4.3.1.6 Water use

Every household has a tap in the homestead. However, these taps are often without water for days and sometimes even for weeks. If there is water during the day, it is only for a few hours, so villagers have to fetch a much water as they can. Some homesteads have JoJo tanks to collect rainwater from the rooftops during the rainy season. There is a small river close to the village but it only has water after good rains. Water from the taps and tanks is only used for cooking, drinking and laundry purposes. Animals drink water from the river when there is water, otherwise buckets of water are placed in the kraal at the homesteads.

Due to the scarcity of water, it needs to be used more productively. Since no water is available for supplemental irrigation, production techniques that increase water use efficiency should be encouraged, meaning that the principle of “more crop per drop” is applied.

4.3.1.7 Food and nutrient security status

Since the unemployment rate is very high and household income is low, villagers do not have money to buy food to cater for all the essential food groups. Villagers hardly ever have a nutritious plate of food. Most of them only eat pap and marogo (word used in the local language to described cooked leaves of an edible *Amaranthus* spp.) and some only eat pap. Those who own cattle can milk the cows and eat pap and milk. Cattle are sometimes slaughtered for funerals and other cultural ceremonies and villagers then eat meat too. Those who make use of their homestead gardens plant maize, spinach, cabbage, beetroot, onions, tomato, beans and pumpkin so that they have access to a larger diversity of food.

The food and nutrition nutrient security status has deteriorated over the last few years, which has contributed to poor health among villagers. With rising food prices villagers are forced to have smaller portions and some go to bed hungry. Where possible, neighbours or friends help those in need and in parents sacrifice their food so that their children have something to eat.

The villagers are in dire need for greater quantities of nutritious food. This could be addressed by using their homestead gardens more productively, by producing a variety of vegetable crops that would supply more nutrients. The water shortage makes it difficult to produce vegetables using traditional cultivation practices but by applying RWH&C practices villagers would be able to produce a variety of vegetables. Water collected from rooftops and stored in tanks could also be used for supplemental irrigation during periods of drought and water stress. Production could be boosted further by applying a mulch cover to minimize evaporation losses.

4.3.1.8 Access to inputs and marketing

There are no government projects in Gladstone that can assist villagers with free seeds and fertilizer and they have to buy their own inputs. Villagers do not purchase their inputs collectively and individuals have to buy their own seeds in small quantities at the shops in Thaba Nchu and Bloemfontein. With their limited funds, they do not have enough money to buy enough seeds to produce enough food that will last them for a whole season.

Production in the homestead gardens is mainly for own consumption, but those who produce surpluses do not have access to markets to sell their goods. Surplus produce is often sold at prices much lower than prevailing market prices within the village, as villagers cannot afford to pay market-related prices. The profit that is made from the selling of vegetables is hardly enough to buy seeds and fertilizer for the next season. Villagers will have to be equipped with the necessary knowledge and skills to produce large quantities and be assisted to enter the formal markets where they can sell their produce collectively at better prices.

4.3.1.9 Challenges faced by villagers

Villagers are faced with numerous challenges that hinder them from improving their production and rural livelihoods. Many of their challenges originate from the current unemployment and poverty status. Due to a lack of finances, villagers do not have money to buy much needed fencing material, garden tools, inputs (seeds and fertilizer), implements, etc. Villagers also struggle with their health, unemployment and crime (especially stock theft) within the village.

Lack of knowledge about agricultural production, poor service delivery and the absence of extension services also poses a threat for improved production and vibrant rural livelihoods. The situation is aggravated by unfavourable climatic conditions (low and erratic rainfall) and poor shallow soils. However, if villagers were assisted with inputs and had access to an uninterrupted water supply, many of these challenges could be overcome, as they would have the means to create their own employment opportunities by improving production in their homestead gardens and crop-and rangelands.

4.4 PROPOSED CSTS AND PRACTICES

Due to the poverty status and limiting natural resources (low rainfall and poor soils) it is suggested that the following CSTs be implemented at Gladstone village:

- IRWH

- Roof water harvesting
- Supplemental irrigation
- Mulching
- Organic fertilizers
- Integrated weed- and pest control
- Crop diversity
- Crop rotation

4.5 SUMMARY AND CONCLUSION

4.5.1 Swayimane

As earlier mentioned, Swayimane is a village located in the KwaZulu-Natal Midlands. It is regarded as having high agricultural potential, as it has fertile soils and mean annual rainfall of 694-994 mm in the five BRUs. Swayimane is steep and many fields are on slopes. This results in high water losses due to runoff. 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. Agriculture in Swayimane is largely rain-fed and farmers have observed some changes in the rainfall patterns and the drying up of springs and small streams. This increasing water scarcity has affected household production, possibly worsening food and nutrition insecurity in affected households.

Interventions that decrease the amount of water lost as runoff are therefore required. The farmers in this community are mostly able-bodied and will be able to implement any interventions, including those that are labour intensive. Most farmers indicated that some household members also participated in production, and it is likely that they would participate in implementing the decided on CSTs. The farmers have basic farming equipment and there were tractors for hire in the community that could be used to construct different structures during the implementation of the interventions. Currently, field produce is sold to informal and formal traders and where excess produce is harvested, it can also be marketed locally and to informal and formal traders. The technologies implemented in Swayimane will largely be informed by the terrain of the community and the type of soils. The following are potential innovations:

- Conservation agriculture
- Crop diversification
- Change in planting dates
- Drip-irrigation
- Water conservation
- IRWH (slope <8%)
- Contour bench terraces
- Zai pits

4.5.2 Gladstone

As highlighted earlier, Gladstone village is located in an area with low, erratic rainfall with a mean annual precipitation of less than 600 mm. The soils are shallow with inherent low fertility. This makes the area marginal for crop production. The situation is aggravated by rainfall events that occur in the form of heavy thundershowers, resulting in high water losses due to runoff on the clayey soils that are characterized by crusting. Further water losses occur due to high evaporation during the summer.

In these unfavourable conditions crop failures are common when using traditional farming practices, and many community members have abandoned crop production. Some community members are still making use of their homestead gardens to produce a variety of vegetable crops and maize by making use of CON. These gardens are mostly used by old women who depend on pensions and other government grants for survival. The majority of the workforce in Gladstone consists of these women, whose husbands have either passed away or work elsewhere, leaving them to take care of the household and the grandchildren.

With this in mind, it is recommended that techniques or practices be implemented in the homestead gardens that will enable community members to prepare a nutrient meal for their families. This can be achieved by making use of various RWH&C techniques, especially the IRWH technique to produce crops in the homestead gardens with limited resources. Most community members have a spade, rake and garden fork and with these basic garden tools, they would be able to construct water harvesting structures in their homestead gardens. Without much effort, even an old woman would be able to implement and manage this system. Although most of the youth have left the village there are still small children and a few youths who could assist with weeding and other maintenance tasks in the garden. With limited resources and man-power the remaining community members in Gladstone would be able to easily convert their homestead gardens into a productive enterprise.

Crops grown in the homestead gardens would mainly be for household consumption, but in cases where surpluses were produced, community members would be able to sell their produce in the village to those who are not utilizing their gardens. However, since most of the community members are unemployed and household incomes are extremely low, they do not have funds to buy inorganic fertilizer, herbicides and insecticides, so yields would still be low. Therefore, alternative management practices such as the use of animal manure as organic fertilizer and the use of cultural practices to control weeds and insects would be introduced to the community members.

Conservation practices, such as mulching, would also be promoted as they can help minimize evaporation losses. Furthermore, the collection of water from rooftops would be encouraged, as the collected water can be applied as supplemental irrigation to the crops grown within the IRWH system during periods of drought. The merging of roof water harvesting with IRWH would further enable the community to produce throughout the year, as water that is collected and stored during the summer rainfall period can be used to water the garden during the dry winter period.

The project aims to improve water use for improved crop production in homestead, community and school gardens. Unfortunately, Gladstone does not have a community garden. The village does have a clinic but the space around it is also too small to make a garden. Fortunately, there is a big space at the Maserona Intermediate School in Gladstone that is already ploughed, where a school garden can be established. The windmill at the school has been built in such a way that the children can play on it, and, in the process, pump water to a nearby storage tank. There is thus a sufficient supply of stored water that is potentially available to be used as supplemental irrigation, should any crops be planted in the school garden.

Once again, it would be advisable to implement IRWH at the school garden as it is a simple technique that can even be implemented, planted and maintained by the learners. This will also encourage them to help their parents in their homestead gardens.

To conclude, it is recommended that the following CST/P or WST be considered for implementation at Gladstone to boost water use for improved crop production:

- IRWH
- Roof water harvesting
- Supplemental irrigation
- Mulching
- Organic fertilizers
- Integrated weed and pest control
- Crop diversity
- Crop rotation

5 PARTICIPATORY DEMONSTRATION AND IMPLEMENTATION OF CSTS

5.1 INTRODUCTION

The discourse on smallholder agriculture in SA usually focuses on farmers who produce field crops, and how their aspirations, particularly to access agricultural markets, can be realised. Little, if any, attention is given to households who garden, yet they made up 83.8% of agricultural households in SA in the 2016 Community Survey (StatsSA, 2016).

Most household gardens are managed by female household members and their produce, a combination of leafy and root vegetables, tubers, legumes and other crops, supplements food purchases (Hart and Aliber, 2015). Their socio-economic status is similar to that of the traditional smallholder farmer (Hart and Aliber, 2015), and it likely that they face similar constraints (e.g. land size, access to inputs, extension knowledge, water access) and aspirations (i.e. accessing agricultural markets and earning income from their work).

Water access is a major constraint to smallholder agricultural production in most developing countries, including SA, where the majority of smallholder agriculture is rain fed (Jayne *et al*., 2010). SA is a water-scarce country, which receives an average of 450 mm of rainfall each year. Many smallholder farmers in SA are in the former homelands, which are characterised as arid and semi-arid, and having soils with low agricultural potential (Mathis, 2007).

Although smallholder farmers may farm close to rivers, dams and other water sources, they do not have water use licences and this restricts them from extracting substantial amounts of water for production (Van Koppen and Schreiner, 2014). Increasingly, South African households have had to cope with drought, mid-season drought, flooding, etc. and these incidents have been attributed to climate-change-related events, sometimes reducing their already limited access to water (Maponya and Mpandeli, 2012). These challenging natural conditions and farmer resource poor make it difficult for them to farm profitably.

The farmers in Swayimane (KwaZulu-Natal) and Gladstone (Free State) have no access to irrigation infrastructure and facilities, and Chapters 3 and 4 show that they largely rely on frequently unpredictable rainfall for their crop production. The increased occurrence of droughts and floods has further reduced their low yields and could result in the following unfavourable consequences in poor agricultural households: (i) the loss of livelihood security; and (ii) the reduction of crop diversity, further lowering dietary diversity (Jones *et al*., 2014) . This reduction in dietary diversity could lead to worsening malnutrition in poor households, which cannot afford to replace lost diversity through purchasing vegetables on the market. Adopting CSTs could improve the capacity of gardening households to respond to these challenges and maintain or increase production levels, possibly positioning themselves to enter the value chain.

Baseline information on the natural and human resources for Swayimane (KwaZulu-Natal) and Gladstone (Free State) was presented in Chapter 4. This exploration of their resources and how they used them in pursuit of agricultural livelihoods, informed the identification of the proposed CST for Swayimane (KwaZulu-Natal) and Gladstone (Free State). These proposed

CST can improve water access in intervention communities, and the approach used to introduce them is equally important.

Literature has numerous examples of good interventions that failed to achieve their intended goals because the top-down approach was used to introduce technology to beneficiary communities with little consultation. Informed by this and other development literature, this research proposes to use a participatory approach to select the technology and use demonstration plots to show its effectiveness.

Participatory approaches are adopted because it is recognised that communities are more knowledgeable about the challenges they face and have possible solutions to address them. By adopting these approaches, the agency and aspirations of the respective communities are also acknowledged, and so are their opinion of the proposed interventions and the reasons why they may or may not succeed. The first step in such a process would be gaining stakeholder buy-in, which is important if any intervention is to be successfully adopted.

The team has therefore adopted a participatory approach to select and then demonstrate the use of the selected technologies in partnership with the communities. The second step involved showing the farmers evidence that the interventions would address their water access problem. Demonstration plots have been used by agricultural extension officers for decades (Burney and Naylor, 2012; Baudron *et al*., 2012; Machete *et al*., 2004). They have the added advantage of making it possible for the farmers to see how the intervention works and the extension workers can transfer scientific principles to their clients (Kondylis *et al*., 2017).

The objective of this chapter is to present: a) stakeholder engagements; b) sites selection and description of sites for demonstrations; c) implementation of demonstrations.

5.2 PROCEDURE

Introducing CST was an integral part of the project, especially when the implementation phase was entered, which required project management principles in order to achieve desired outcomes. The following section will discuss the process of project management in as far as it related to the implementation of the objectives by the various stakeholders. The pros and cons of each stakeholder was an important aspect for gaps to be identified and addressed.

A project has activities that must be coordinated in order for its objectives to be reached. A strengths-weakness-opportunities-and-threats (SWOT) analysis for project management is an effective and simple process. With correct feedback, it allows the coordinator to identify areas for improvement. Implementation of correct methodologies for analysis and assimilation of feedback is critical to ascertain that a project will be completed on time and within all resources (Lim, 2012).

Effective use of the SWOT analysis improves the efficiency of the whole project, while mitigating risks and allowing better use of resources and limiting duplication of tasks and processes. For example, Government Departments are known for working in “silos’ and thus tasks and processes may be duplicated if all stakeholders are not well assessed using a SWOT. Ideally, the SWOT analysis should be conducted at the beginning of project implementation to ascertain roles and perform the analysis, in order to provide a solid backbone to the project plan.

5.2.1 SWOT analysis process

Once stakeholder identification is concluded, it is important to have clear objectives for the SWOT analysis so that each stakeholder understands what is expected of him/her and that what they commit to is within their mandate and resources. Indeed, all stakeholders need to come together, identify roles and commit to the process. Further, along the process another SWOT can be conducted to assess the budget, progress and cost benefit. In terms of assessing the SWOT certain questions are pertinent. Once stakeholders are satisfied with the process of identification of strength, weakness, opportunities and threats and have committed to solutions in each aspect, the project can go ahead (Lim, 2012).

Chapter 4 showed the list of proposed CST for Swayimane and Gladstone, selected based on their suitability to the two different communities. In this section, the procedure followed by the team in both communities is given below. This section details the process of community engagement and implementation.

5.2.2 Community engagement

5.2.2.1 Introduction and raising awareness

Building relationships between development agents and the local community is time-consuming, and the results may not always correlate smoothly with the stated objectives of the project; however, its importance cannot be underestimated. Ideally, the inclusion of a variety of stakeholders should result in a process which acknowledges and integrates local knowledge, values and norms into the project (Talley *et al*., 2016). It is believed that doing this particularly early in a project will result in a sense of ownership among beneficiary stakeholders, and higher levels of adoption of the new technology (Newton and Elliott, 2016). Where stakeholder engagement processes are practised in earnest, they have the potential to empower the different stakeholders.

The project was therefore reintroduced to the communities of Swayimane and Gladstone by conducting community meetings. The main aim of these meetings was to give them a background of the project and information on the different CSTs. Presentations, which included examples of potential CSA technologies, were made to raise their awareness of the technologies in existence. This information was useful when the communities selected CSA techniques that were demonstrated. These meetings also aimed at discussing the processes that were followed when demonstration sites and CSA techniques for demonstrations were selected. The meetings also clarified work arrangements.

5.2.2.2 Community workshop

The research team selected community workshops as the tool for engaging with the people of Swayimane and Gladstone. The team selected workshops because: (i) they allow the facilitators to involve, collaborate with and empower the stakeholders; (ii) they are interactive, allowing for facilitators and stakeholders to engage in discussion; and (iii) they allow feedback to be obtained from participants (Durham *et al*., 2014; Yang *et al*., 2011). The research team first presented the aims and objectives of the overall project, and then spoke in detail with the community members about the proposed CSA techniques in the basket of technologies for Swayimane and Gladstone, respectively.

5.2.3 CSA techniques

The CSA techniques identified by the project team (Chapter 4) were finalized at the community workshops. Here community members with input from stakeholders selected the most suitable and preferred CSA technologies that complement their natural and socio-economic conditions from the shortlisted basket of technologies. These selected technologies were then implemented at the selected demonstration plots.

5.2.4 Parameters to be measured

The identification of parameters to be measured and the individuals responsible for measurement were finalised at the community workshops. Community and all relevant stakeholders gave input in selecting the relevant and important parameters.

5.2.5 Role, responsibilities and Memorandum of Understanding

Roles and responsibilities of each party (project team, community members, demonstrators, and relevant stakeholders) were clarified at the community workshops. This culminated in drawing up a Memorandum of Understanding (MoU) between the project team and the communities, project team and demonstrators, as well as project team, stakeholders and communities in the selected provinces.

5.2.6 Implementation

Before the project was implemented, it was important to do an analysis of the strength, weaknesses, opportunities and threats (SWOT). The use of SWOT analysis allowed the project team to improve the project or individual tasks and seek better efficiency implementation.

5.2.7 Site selection for demonstrations

The selected CSA techniques were demonstrated in homestead, community and school gardens to improve production and water use for food and nutrition security at the start-up stage of food value chains. Criteria for selecting homestead, community and school gardens were developed by the project team. These guidelines were discussed with the project's participants and were used for final site selection.

The project team conducted preliminary field visits to get an understanding of the lay of the land and interacted with community members. Extension officers who work in the earmarked communities selected potential sites from local homestead, school and community gardens, and the project team assessed them during the field visits.

These criteria used to select final homestead/community/school demonstration sites at both Swayimane and Gladstone were:

- Soil, preferably clay-loam textured soils, must be at least 700 mm deep
- Annual rainfall should be between 500-900 mm.
- The site should be in an area where the slope does not exceed 8% on non-erodible soils.
- The site should be well fenced, and the owner/members/scholars should be actively

involved in the utilization of the site.

- The site should have a form of rooftop rainwater harvesting, e.g. JoJo tank.
- The site should be big enough to practise agricultural production.
- The household/members/scholars should also own basic gardening tools (spade, rake, and hosepipe).
- Able and willing bodies at the site that can work in the garden/field.
- Members of the homestead/community garden/school should be passionate about producing food for themselves or generating income from their produce.
- Should have access to potential markets.
- Members/scholars should be willing to adopt new technologies.
- Access roads should be in a good condition.
- Access to relatively clean water is available nearby for spraying of herbicides and insecticides.
- The site has livestock and a kraal, e.g. cattle, goats, pigs or even chicken, etc. (optional)
- Access to irrigation water and equipment (optional).
- Access to tractor and implements (optional).

5.2.8 Finalization of CSA techniques

Each demonstration plot was treated and assessed on its own merit. The research team and the owner of the demonstration site made a final selection of the most suitable CSA technique from those shortlisted during the community workshop. The selected CSA techniques complemented the demonstration site's natural conditions and the farmers' socio-economic status.

5.2.9 Lay-out and maintenance of demonstration plots

The research team and the demonstration site owner finalized the lay-out of each demonstration. They also agreed on the terms and responsibility of each party. The demonstration site owner was responsible for maintaining the demonstration with the guidance of the project team.

5.2.9.1 Training and capacity building

Capacity building at community level with individuals and households took place during the project through discussions, interviews, workshops, training and farmers' days that the research team and other stakeholders were involved in. Training sessions included training on the following aspects; CSA principles; implementation and maintenance of selected CSA techniques; crop management practices; food and nutrition security; food value chains, etc.

5.3 OUTCOME

5.3.1 Stakeholder engagements

The stakeholder engagements of KwaZulu-Natal: Swayimane are used as the example.

5.3.1.1 Stakeholders workshop

The stakeholder workshop in KwaZulu-Natal took place on 20 November 2017 and was attended by representatives from the national 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. During this workshop, the following were identified as important stakeholders: KwaZulu-Natal Department of Social Development, Umgeni Water, uMshwati Municipality and uMgungundlovu District Municipality. The senior leadership of the School of Agriculture Environment and Earth Sciences' was represented by the Dean, Professor O. Mutanga.

Figure 8 Photo of stakeholder workshop attendees and signing of MOUs at UKZN for Swayimane (KwaZulu-Natal).

5.3.1.2 Stakeholder analysis, roles, responsibility and MoU

Five stakeholders inclusive of the research team attended the stakeholder workshop. The agenda (Appendix 3) focused on sharing each organisation's programmes and identifying synergies in the interest of the programmes' sustainability.

The deliberations showed synergies and resources available where areas of support and investment were outlined. Each stakeholder articulated their support and each representative from four stakeholders signed the MoUs. Their proposed roles and responsibilities are presented in Table 10.

Table 10 Stakeholder proposed roles and responsibilities

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 produce 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.

Co-ordination is a critical component in stakeholder management and implementation. However, the co-ordination needed to be strong in order for activities to yield results towards the desired outcome. The following section shows results on a SWOT analysis of all stakeholders in order to inform the co-ordination (Table 11).

Table 11 SWOT Analysis – readiness of stakeholder for implementation at Swayimane

Strengths	Weaknesses
• The existence of a strong coordinating forum	• Weak commitment by other members
Opportunities	**Threats**
• Link to projects and initiates that are organized, assessed and poised for success.	• Sustained commitment (meeting attendance and financial)

5.3.2 Community engagement: Swayimane

The research team conducted several re-introductory meetings to remind the community members about the objectives of this project during the week ending 01 December 2017. The meetings were largely attended by farmers from wards six, eight and thirteen in Swayimane, where the demonstrations were implemented.

Farmers from other wards were also welcomed to attend the meetings. Firstly, the research team presented the project objectives, which included improving food security through homestead, community and school gardens and resilient livelihood strategies. Secondly, the team introduced the different CSTs and management practices to the farmers. After the presentation, the farmers engaged the research team on the different types of CSA techniques and a robust discussion ensued.

From the ensuing discussions, it was evident that the community members felt that the project was timely and would help to address the challenges that they were facing at that time. In addition, they were eager to test the different CSA technologies in their homestead, community and school gardens to determine if they would improve production, food security and lead to better livelihood outcomes. The proposed CSA techniques were so popular that even the farmers from other wards, were interested in testing them in their homestead gardens.

Figure 9 Photos of farmers from ward 6 and 13 attending the CSTs and management practices workshop.

After the re-introductory meetings, the team visited five homesteads, three schools and three communities in the three wards of Swayimane to conduct a detailed inspection of their gardens.

5.3.3 DEMONSTRATION SITE SELECTION: SWAYIMANE

Homesteads in rural Swayimane can accommodate the homestead and pieces of land over a hectare, which can be used for agricultural production. One community, one school garden and a couple of homestead gardens were preliminary selected in each ward for potential demonstration of CSA techniques and management practices. The final site selections for demonstrations were conducted at a later stage. Since it was not possible to demonstrate all three production units (homestead, community and school gardens) in each ward, it was decided to at least select one production unit in the earmarked wards for demonstration purposes.

5.3.3.1 Homestead gardens

The purpose of the visits was to identify the basic biophysical properties, which included soil depths, soil texture, slope aspects, climate, etc. in the different wards of Swayimane. Hutton soils, which are very deep, were the dominant soil form (Figure 10) in the Swayimane sites. Final site selection for demonstration purposes was conducted at a later stage.

Figure 10 Photos of Hutton soil form in one of the selected sites for demonstration in Swayimane.

Most farmers in Swayimane operate under dryland conditions and were therefore interested in testing CSA techniques and management practices that would conserve soil and water in their fields. Two homesteads were selected for demonstration sites, belonging to Mrs Nxusa (Site 1) and Mr Khanyile (Site 2). He only irrigates a small portion of his land. The team discussed different water-saving methods with Mr Khanyile, who was eager to try new CSA techniques and management practices under dryland conditions. Mrs Nxusa operates on a huge area by making use of dryland farming. During the meeting and workshop, she offered to host a demonstration plot, so that she could test CSA techniques that could work under dryland conditions. Further consultation with the senior extension officer resulted in final site selection

5.3.3.2 School and Community gardens

Vuka Primary School, Sbongumusa High School, Inyaninga Primary School and Mbhava Lower Primary School were identified and shortlisted as possible school demonstrations in wards 6, 13 and 8 respectively. These schools were shortlisted because of their active involvement in agriculture and the willingness of their principals to test CSA technologies in their school gardens. Figure 11 shows the principal from Vuka Combined Primary School signing the attendance register after showing the research team the school garden that might be used for demonstrations. Inyaninga primary school was selected during the 2017/18 season but was replaced by Mbhava Lower Primary School during the 2018/19 season due to rabbits that destroyed the crops and lack of participation by the farmers.

Figure 11 Photo of principal at Vuka Combined Primary School signing the attendance register.

5.3.4 COMMUNITY ENGAGEMENT: GLADSTONE

The project re-introductory meeting was conducted in collaboration with the Free State Department of Agriculture under the Directorate of Extension Services on November 14, 2017 in Gladstone Community Hall. The main aim of this meeting was to introduce the project to the community and give them background and information about different possible CSA technologies. The presentation also included the examples of different CSA technologies. This meeting discussed the site selection processes that was going to be followed for demonstration of CSA technologies and clarified the work arrangements. Members from the Agricultural Research Council, the Institute of Soil Climate and Water & Agricultural Engineering (ARC-ISCW&AE), Free State Department of Agriculture and Rural Development's Extension Services, Community Work Programme (CWP) personnel, as well as 67 community members and the headman of the community, attended the meeting (Figure 12). Amongst the attendees, about 75% were women who are actively involved in agriculture.

Figure 12 Photos of Gladstone community members (left) and presentation of CSTs and management practices (right).

After presenting different CSA technologies and management practices, the specific aims of the project were discussed with the attendees. At this meeting it was emphasised that the project aimed at implementing CSA technologies at homestead, community and school gardens as these production levels are viewed as a stepping stone into the food value chain. The community was made aware that another detailed presentation and discussion of the CSA technologies would follow where they would select from a basket of CSA technologies those that they think would work in their current conditions to improve production. After the presentation, members were given an opportunity to ask questions and comment on the presentation of these technologies. Before the meeting was dissolved, the attendees were made aware that the research team, together with the extension officer, would visit the local schools and identified community gardens to see how the potential sites looked. Information about soil depth, texture (especially the clay percentage) and soil forms would also be captured at the school and homestead gardens at a later stage.

5.3.5 DEMONSTRATION SITE SELECTION: GLADSTONE

Preliminary field visits were conducted in order to get an understanding of the lay out of the land and interact with community members. During the field visits, potential homestead, school and community gardens were visited.

5.3.5.1 Homestead gardens

During the preliminary site selection and evaluation, the research team went further to evaluate potential homestead gardens. It was observed that the majority of the community members were actively involved in agriculture, as the majority of homestead gardens were used to plant different crops. Two homesteads were selected for demonstration of CSAs in homestead gardens. The homesteads of Mrs Moswaka (Site 3) and Mrs Setoute (Site 4) were selected.

5.3.5.2 School gardens

Maserona Intermediate School (Site 5) was visited for the research team to meet with the principal and introduce the project to them (Figure 13). The school seemed to be actively involved in agriculture, the principal welcomed the team, showed interest in the project and gave permission for them to proceed with the inspection.

Figure 13 Photos of potential school (left) and its water source (right) in Gladstone.

The principal then introduced the team to an individual who would have acted as liaison officer between the school and the project team, if the school was selected. The team together with the extension officer proceeded to the school garden for site characterisation of soil depth, soil form and field estimation of clay percentage (Figure 14). After all the evaluations Maserona Intermediate School was selected as the school garden demonstration plot.

Figure 14 Photo of site characterisation for basic soil properties at Maserona Intermediate School.

5.4 SITE DESCRIPTION

5.4.1 Swayimane

Swayimane (Figure 15) lies from latitude -29.431277º S to -29.513402º S and from longitude 30.582431º E to 30.649214º E. It falls under uMrshwathi Local Municipality. According to Hiteyeza (2016) the area has an annual precipitation ranging from 521 mm (1992 records) to 1120 mm (2006 records). The temperature ranges from 28ºC (summer maximum) to 3.2ºC (winter minimum). Both soils at the homestead demonstration plots were classified as Griffin (Orthic A / yellow brown apedal B / red apedal B) soil forms, while the soil at Inyaninga primary school was classified as a Valsrivier (OrthicA / pedocutanic B / Unconsolidated material without signs of wetness) soil. The soil at Mbhava Lower Primary School was classified as an Oak Cliff (OrthicA / neocutanic B / Unspecified materials) soil.

5.4.2 Gladstone

Gladstone (Figure 15) lies between latitude -29.2056175º S to -29.361088º S and longitude 26.819347º E to 26.839956º E. According to Somers (2008), Gladstone has a mean annual precipitation of 599 mm with a minimum precipitation of 342 mm, recorded in 1984, and a maximum precipitation of 1055 mm, recorded in 1988. Typical of this summer rainfall area, January is the warmest month and July the coldest month, with average temperatures of 20.9°C and 6.9°C, respectively.

The slope in Gladstone varies between 0 and 12%. The slope for most of the lands is less than 3% with small areas having slopes between 3% and 4%. The community of Gladstone occurs in the upper four lower three position of the landscape. The parent material of the soils is mainly derived from the sandstone, shale and mudstone of the Beaufort Group with dolerite intrusions. Gladstone community completely falls within Land Type Dc17. Dominant soil forms in this community suitable for rainwater harvesting and conservation (RWH&C) practices are Sepane, Swartland, Arcardia and Bonheim. The effective rooting depth was found to be between 700 and 900 mm. Soils found to be unsuitable for RWH&C are of Mispah, Glenrosa, Mayo, Klapmuts and Escourt forms, and shallow members of Swartland soil form. The clay content of some soil forms ranged from 34 to 54% in the topsoil and from 60 to 73% in the subsoil. All the soils from the demonstration plots at Gladstone were classified as Valsriver soil forms (OrthicA / pedocutanic B / Unconsolidated material without signs of wetness).

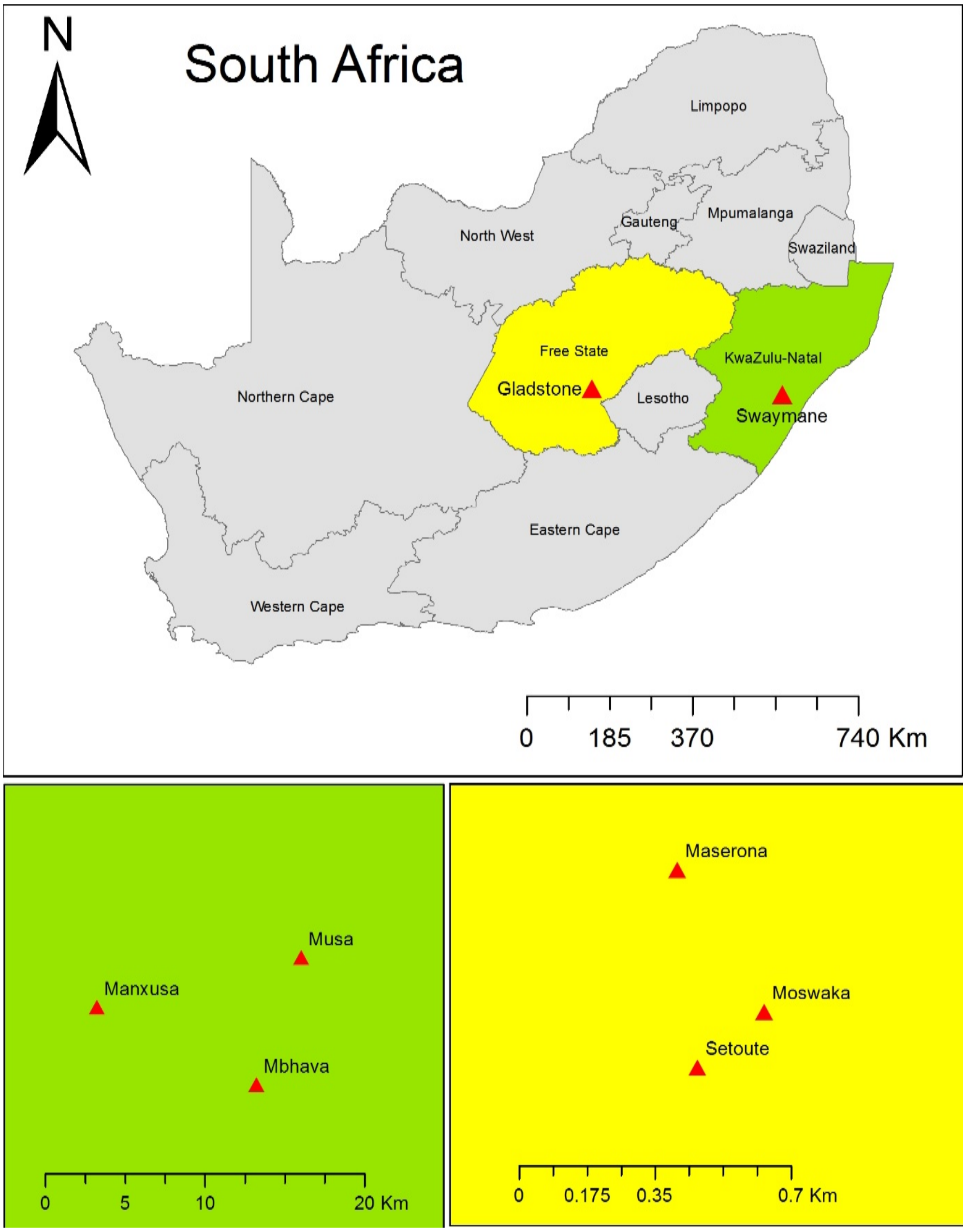


Figure 15 Site location for Swayimane and Gladestone.

5.5 EXPERIMENTAL DESIGN: SWAYIMANE

5.5.1 Swayimane: 2017/18 summer growing season

5.5.1.1 Homestead

Two homestead gardens (Site 1 and Site 2) were selected for demonstration during the 2017/18 summer growing season in Swayimane. The selected appropriate CSTs for these homesteads were IRWH, mechanized basins (MB) and No-Till. These CSTs were compared with CON as the control. The design at Site 1's garden is presented in Table 12.

Table 12 Experimental design and layout at Site 1 in Swayimane during the 2017/2018 summer growing season

	16.67 m	16.67 m	16.67 m	16.67 m	16.67 m	16.67 m
	REP 1	REP 2	REP 3	REP 1	REP 2	REP 3
25 m	**IRWH**	**IRWH**	**IRWH**	**MB**	**MB**	**MB**
	REP 1	REP 2	REP 3	REP 1	REP 2	REP 3
25 m	**CON**	**CON**	**CON**	**NT**	**NT**	**NT**

The experimental plan for the demonstration plot at Site 2 is presented in Table 13.

Table 13 Experimental design and layout at Site 2 in Swayimane during the 2017/2018 summer growing season

	30 m	30 m	30 m
	REP 1	REP 2	REP 3
15 m	**IRWH**	**IRWH**	**IRWH**
15 m	**MB**	**MB**	**MB**
15 m	**NT**	**NT**	**NT**
15 m	**CON**	**CON**	**CON**

Treatment implementation took place during January 2018 (Table 13). Only maize was planted in the homestead gardens on 09 February 2018, with a plant population of 28000 plants ha^{-1}. MAP and LAN fertilizer were applied at planting at rate of 140 kg ha^{-1} as a standard application rate for this area, since planting was conducted before soil samples were taken for fertilizer recommendation.

Figure 16 Photos of implementation and planting of demonstration sites in Swayimane.

5.5.1.2 School

Inyaninga primary school was selected during the 2017/18 summer growing season and IRWH was selected as the appropriate CST. This was combined with various management practices to get the different treatment combinations:

- IRWH+Fert only
- IRWH+Fert+Supplementary Irrigation (IRWH+Supp Irr)
- IRWH+Fert+Mulch in basins (IRWHm+Fert)
- IRWH+Mulch in basins + Supplementary Irrigation (IRWHm+Fert+Supp)

The design in the school was a complete randomised block design comparing the CST and management practices with CON, which was referred to as control (CON+Fert). Cabbage, spinach and beans were planted at the school on 06 February 2018. Samples for fertilizer recommendation were not yet collected by the time when planting was done, therefore a standard application of fertilizer was followed, guided by the Water harvesting and Conservation manual. Consequently, 3:2:1 was applied at a rate of about 3.57 g planting station^{-1}, as recommended by Botha *et al* (2011). The neighbouring group of farmers together with the scholars were tasked with monitoring the experimental plots. However, due to low commitment of both farmers and the school, there was a complete crop failure at this site and for this reason results for this site is not included in this report.

Table 14 Experimental design and layout at the school site in Swayimane during the 2017/2018 summer growing season

		3 m	3 m	3 m	3 m
6 m	CON+Fert	Spinach	Cabbage	Beans	Beans
6 m	IRWH + Fert	Spinach	Cabbage	Beans	Beans
6 m	IRWHm + Fert	Spinach	Cabbage	Beans	Beans

5.5.2 Swayimane: 2018 winter season

Following the harvesting of 2017/18 summer crops, the project team organised an information sharing day, which was intended to allow farmers to share their observations and perceptions of demonstrated CSTs, while the research team presented the preliminary results obtained from the summer season. Farmers were also invited to participate in the selection of crops to be planted during the winter at the selected demonstration plots that would meet their preferences and dietary requirements. Consequently, Umkhumbi ka Noah community garden was selected and added for the demonstration of winter crops in addition to already existing demonstration plots (Site 1 and Site 2) during 2018. The section below outlines the experimental layout and crop planting of these selected sites for winter planting.

5.5.2.1 Homestead

As transpired in the preceding section, Site 1 and Site 2 were also selected for the demonstration of winter vegetable crops. A complete randomised block design comparing IRWH with sound management practices with CON was considered. Cabbage, beetroot and green pepper were planted at Site 1 (Table 14) on 16 and 17 July 2018. At Site 2, cabbage was planted as represented in Table 15. The fertilizer application rates were also applied, following the rainwater harvesting and conservation manual as recommended by Botha *et al* (2011). Several applicable agronomic management practices as treatment combinations were incorporated in the IRWH. These included:

- IRWH + Inorganic Fertilizer (IRWH+Fert)
- IRWH + manure (IRWH+Manure)
- IRWH + Organic Mulch + Inorganic Fertilizer (IRWHm+Fert)
- IRWH + Inorganic Fertilizer + Supplementary Irrigation (IRWH+Fert+Supp)
- IRWH + Inorganic Fertilizer + Manure (IRWH+Fert+Org)
- IRWH+ Mulch + Inorganic Fertilizer + Manure (IRWHm+Fert+Org)
- IRWH + Mulch + Inorganic Fertilizer + Manure + Supplementary Irrigation (IRWHm+Fert+Org+Supp).

These treatment combinations were compared with normal conventional tillage practice (CON+Fert).

Table 15 Experimental design and layout at Site 1 in Swayimane during the 2018 winter growing season

	3 m	3 m	3 m	
CON+Fert	Cabbage	Beetroot	Green pepper	6 m
IRWH + Fert	Cabbage	Beetroot	Green pepper	6 m
IRWH + Manure	Cabbage	Beetroot	Green pepper	6 m
IRWHm + Fert	Cabbage	Beetroot	Green pepper	6 m
IRWH + Fert + Manure	Cabbage	Beetroot	Green pepper	6 m
IRWHm + Fert + Manure	Cabbage	Beetroot	Green pepper	6 m

Table 16 Experimental design and layout at Site 1 in Swayimane during the 2018 winter growing season

	3 m	
CON+Fert	Cabbage	6 m
IRWH + Fert	Cabbage	6 m
IRWH + Manure	Cabbage	6 m
IRWHm + Fert	Cabbage	6 m
IRWH + Fert	Cabbage	6 m
IRWH + Fert + Manure	Cabbage	6 m
IRWHm + Fert + Manure	Cabbage	6 m

Figure 17 Photos of planting of vegetables in the homestead gardens in Swayimane during the 2018 winter growing season.

5.5.2.2 Community garden

The additional site, Umkhumbi ka Noah community garden, was planted with cabbages, spinach, beetroot and peas. The treatment layouts and experimental design were similar to that of the homestead gardens discussed in the preceding section. The crops were planted on 18 July 2018 at this site. Unfortunately, the soil was very acidic, and liming had to take place first in order to correct the pH.

5.5.3 Swayimane: 2018/19 summer growing season

The same treatments as discussed in Section 5.5.1 were planted with maize in the homestead gardens at Site 1 and Site 2 for the 2018/19 summer season.

5.6 EXPERIMENTAL DESIGN: GLADSTONE

5.6.1 Gladstone: 2017/18 summer growing season

5.6.1.1 Homestead

In Gladstone two homestead gardens were selected for the demonstration of CSAs during the 2017/18 summer growing season. The IRWH was selected as an appropriate CSA for both homestead gardens with sound management practices. Spinach and beetroot were planted, following the rainwater harvesting and conservation guideline manual as transpired in the preceding sections. The planting dates for these crops were 24 and 25 January 2018, respectively. The experimental design was also a complete randomised block design comparing applicable CSAs and their management practices with CON. The treatment combinations and layout for Mrs Moswaka (Site 3) and Mrs Setoute (Site 4) are shown in Table 17.

Table 17 Experimental design and layout at Site 2 and Site 3 during the 2017/2018 summer growing season

	3 m	3 m	3 m	
CON+Fert	Spinach	Beetroot	Spinach	6 m
IRWH+manure	Spinach	Beetroot	Spinach	6 m
IRWH+Fert	Spinach	Beetroot	Spinach	6 m
IRWHm+Fert	Spinach	Beetroot	Spinach	6 m
IRWHm+Fert	Spinach	Beetroot	Spinach	6 m

5.6.1.2 School

The Maserona Intermediate School in Gladstone was selected for the demonstration of CSAs. The dimensions of the school garden were 30 m x 15 m and beetroots, spinach, carrots and maize were planted. However, carrots completely failed during this season (2017/18) and only beetroot, spinach and maize completed their life cycle. Beetroot was planted on 05 February 2018, while spinach was planted on 07 February 2018. The experimental layout and treatment combinations are presented in Table 18. However, the planting and fertilizer application at this site was also done following normal standard application as recommended by Botha *et al.* (2011) in the rainwater harvesting and conservation manual.

Table 18 Experimental design and layout at Site 5 during the 2017/2018 summer growing season

	3 m	3 m	3 m	3 m	3 m	3 m	
CON+Fert	Beetroot	Spinach	Carrot	Maize	Maize	Maize	6 m
IRWH+Fert	Beetroot	Spinach	Carrot	Maize	Maize	Maize	6 m
IRWH+Fert+NWC	Beetroot	Spinach	Carrot	Maize	Maize	Maize	6 m
IRWHm+Fert	Beetroot	Spinach	Carrot	Maize	Maize	Maize	6 m
IRWHm+manure	Beetroot	Spinach	Carrot	Maize	Maize	Maize	6 m

5.6.2 Gladstone: 2018 winter growing season

5.6.2.1 Homestead

For the 2018 winter planting no site was added for Gladstone and only existing sites were considered for the demonstration during the season. Similar CSAs and management practices as for the summer season were selected. However, only peas and onions were planted during the winter period. Due to extremely cold weather conditions, the peas did not even germinate. Only a few onion seedlings survived the cold and the onions did not perform well. The treatment combinations and layout for the winter planting are shown in Table 19 for Site 3 and Site 4.

Table 19 Experimental design and layout at Site 3 and Site 4 during the 2018 winter growing season

	3 m	3 m	
CON+Fert	Spinach	Beetroot	6 m
IRWH+Org	Spinach	Beetroot	6 m
IRWH+Fert	Spinach	Beetroot	6 m
IRWHm+Fert	Spinach	Beetroot	6 m
IRWHm+Fert+Irr	Spinach	Beetroot	6 m
IRWHm+Fert+Cover+Irr	Spinach	Beetroot	6 m

5.6.2.2 School

At the school, the same treatments were used as in the 2017/2018 summer growing season. The same crops (onion and pea) that were planted in the homestead gardens were also planted at the school. However, due to farmers' lack of commitment to maintain these crops, coupled with unfavourable winter climatic conditions in Gladstone, both crops completely failed. Consequently, the results for these crops will not form part of this report

Table 20 Experimental design and layout at Site 5 during the 2018 winter growing season

	3 m	3 m	3 m	
CON+Fert	Spinach	Beetroot	Maize	6 m
IRWH+Fert	Spinach	Beetroot	Maize	6 m
IRWH+Fert+NWC	Spinach	Beetroot	Maize	6 m
IRWHm+Fert+Irr	Spinach	Beetroot	Maize	6 m
IRWHm+Fert	Spinach	Beetroot	Maize	6 m
IRWHm+Org	Spinach	Beetroot	Maize	6 m

5.7 IMPLEMENTATION AND TRIAL LAYOUT

Following stakeholder engagements, trials were implemented at Maserona Intermediate School (Site 5). In KwaZulu-Natal implementation took place during January 2018. The main purpose was to implement CSTs within the village, community and school gardens. Initially, during the first engagement with the smallholder farmers and villagers, a presentation of different CSTs and management practices was shown and discussed. The study was designed as complete randomised block design, which compared IRWH with the CON as the control at Site 5. The crops planted were carrot, beetroot, spinach, tomato and maize. The plot size per crop was maintained as 3 x 8 m, which is equivalent to 0.0024 hectares in the IRWH, while it was actually 6 x 6 m, which is equivalent to 0.0036 hectares in the control, i.e. CON. These plots per crop were replicated three times and the number of replicates will be used as the blocking factor during the statistical analyses of data.

Treatment combinations used in this study were infield rainwater harvesting and kraal manure in basins, IRWH and fertilizer in basins and IRWH with neither fertilizer nor kraal manure. The control plot was only treated with fertilizer only with no IRWH. The treatment combinations are illustrated in Table 21, while the crops that were planted are presented in Table 22, indicating them in their order of appearance in the field.

Table 21 Treatment combinations at Site 5

Conventional Tillage Practice, i.e. control (Fertilizer Only)
IRWH + Fertilizer + mulching in basins and in runoff area
IRWH + no fertilizer
IRWH + fertilization and mulching in basins
IRWH + fertilization and Irrigation
IRWH + Kraal manure in basins

Table 22 Experimental layout of the trial plots under IRWH and CON

Carrot	Spinach	Carrot	Tomato	Maize	Maize	Maize	Maize
Spinach	Beetroot	Tomato	Carrot	Maize	Maize	Maize	Maize
Tomato	Carrot	Spinach	Beetroot	Maize	Maize	Maize	Maize
Spinach	Tomato	Beetroot	Carrot	Maize	Maize	Maize	Maize
Beetroot	Carrot	Tomato	Spinach	Maize	Maize	Maize	Maize
Carrot	Beetroot	Spinach	Tomato	Maize	Maize	Maize	Maize

After the experimental plots designs were done at the school garden (Maserona Intermediate School, is the only school in the village) and the principal had given the go-ahead for it to be used for the project, different crops were planted (Figure 18).

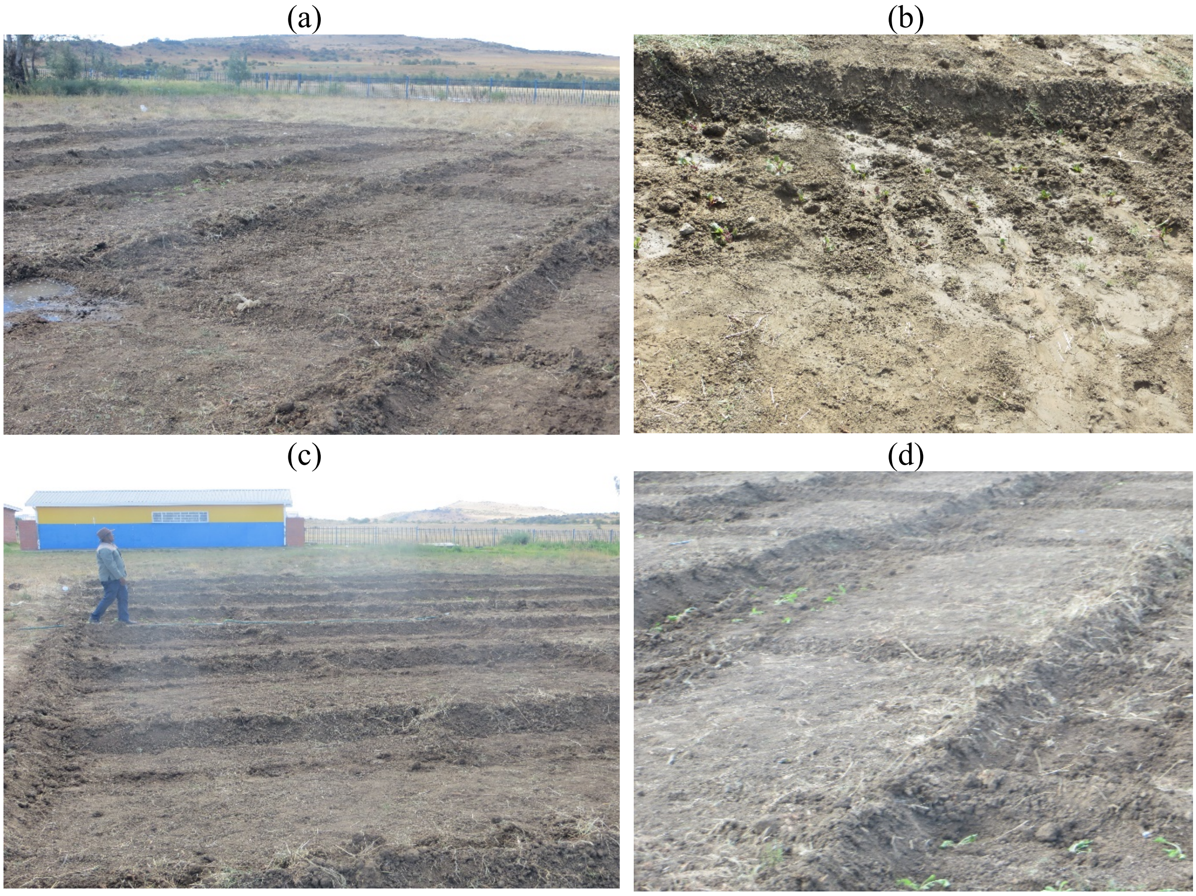


Figure 18 Photos of CSTs implemented at the school garden.

Those crops included as spinach, beetroot, maize, cabbage, onion and butternut. They were planted using CSTs and management practises at the school garden. It was agreed with the smallholder farmers and villagers that they would monitor and take care of the crops during the December holidays.

5.8 COMMUNITY GARDENS

During the community meeting, only one community garden was identified as a potential site for the implementation of CSA techniques. The site is well fenced, but does not have access to water. The preliminary site selection and evaluation trip ended at the community garden where the basic soil properties were evaluated. The research team met with the members of the community garden and it was agreed that there would be a possible follow-up meeting with the members involved in this garden, to discuss the way forward and working arrangements.

As part of site selection and evaluation, the research team went to the local old age and care centre, and met with the centre's senior management (Figure 19). The team re-introduced the project to the management team and they expressed interest in both the project and the opportunity to test the selected CSA techniques and management practices. The site characterisation for basic soil properties was done after the project team was given the go-ahead. The research team established that the centre had a thriving garden which was fenced and had tap water. They mentioned that in case of low rainfall, they used water from the tap to irrigate their crops.

Figure 19 Photo of community old age home and care centre (left) and members of the centre (right) in the garden.

5.9 SUMMARY AND CONCLUSION

Water scarcity for food production is a serious problem for many rural communities, especially those situated in semi-arid areas. In these areas, communities depend on heavily dryland crop production for household food production. Under these conditions, production is often poor resulting in poor dietary diversity and leading to malnutrition in many poor households. However, through the adoption of CSTs poor rural households could improve their household food production and possibly position themselves to enter the food value chain. Therefore, the project has aimed to introduce CSA technologies to the communities of Swayimane (in KwaZulu-Natal) and Gladstone (in the Free State province).

Participatory approaches were used to select and demonstrate the use of selected CSA technologies in partnership with the identified communities. The second step was to show the communities that the interventions can be used in a sustainable manner to improve homestead production and address their access to water problem. Therefore, demonstration plots have been implemented at selected homestead- and school gardens.

Stakeholder workshops with relevant role players were conducted to get the buy in of those who could contribute to the successful application of the CSA technologies and assisting community members to enter the food value chain. At these workshops, the stakeholders come together to identify their roles in the project and to commit to the process.

The project was introduced to the communities of Swayimane and Gladstone by conducting community meetings. At these meetings background information on the project and presentations of the various CSA technologies were provided. Community members were allowed to select suitable CSA technologies that complimented their natural and human resources.

In each community, two homestead gardens and one school garden were selected where the CSA technologies were demonstrated. The selected sites had to meet the biophysical criteria in terms of soil depth, soil texture, slope and climate. Swayimane has large plots exceeding one hectare, compared to the small homestead gardens at Gladstone. At Swayimane community members have chosen to plant a variety of vegetable crops close to the homesteads, while planting maize on the larger plots. At Gladstone, the need was to have access to a more nutrient diet, so community members preferred to plant various vegetable crops. Because the CSA technologies have the ability to collect and store water, it was possible to plant vegetable crops throughout the year. Vegetable crops like spinach, cabbage, beans, beetroot and green peppers were planted. On the larger plots where maize was planted IRWH, mechanized basins (MB) and minimum or no-till (MIN/NT) were compared to normal CON. In the homestead- and school gardens, only IRWH was used in combination with various management practices such as fertilizer application, manure, mulching and supplementary irrigation. At the demonstration sites, trial plots were laid out as a complete randomised block design with three replications.

In order to overcome hunger and poverty vulnerable communities are encouraged to adopt and apply suitable CSA technologies for household food production. This will enable community members to produce more than what is needed for household consumption and be able to enter the food value chain by selling surplus produce.

6 MONITORING AND EVALUATION OF SELECTED TECHNOLOGIES

6.1 INTRODUCTION

This chapter will outline the crop water-related parameters that were collected during the course of the project period. It will further describe and discuss the results obtained, comparing the different CSTs that were selected and applied to see if there were significant differences between the treatments.

6.2 METHODS AND MATERIALS

6.2.1 Agronomic information

As already stated in previous sections, beneficiaries were selected in the respective villages where the CSTs were implemented and demonstrated. The understanding was that the structures should be constructed with the help of technical assistants who have been working on similar projects for many years. They were also assisted with the planting and maintenance of the demonstration plots. The crops that were planted were done in consultation with the beneficiaries, who had their own preferences.

Crop details for the two growing seasons in Swayimane (2017/2018 and 2018/2019) are presented in Table 23. The treatments were implemented by making use of specialized implements in the case of IRWH and MB. Planting was done in all cases by hand. The same maize cultivar was used every year. The maize cultivar CS701 is preferred by the farmers as they sell the produce as "green mealies". Two plantings took place during 2018/2019, an early planting and a late planting. Site 2 decided to plant butternut as his early planting during the 2018/2019 season. Site 1 decided to plant only maize as she was earning good income from selling green mealies. Rainfall during the seasons differed, with the highest rainfall occurring during 2017/2018, followed by 2018/2019 early planting and then 2018/2019 late planting. It must be kept in mind that although total rainfall during a growing season is important, the rainfall distribution and rainfall amount per rain event have a much higher effect on the yield.

Table 23 Agronomic information for crop production during three summer growing seasons in Swayimane

Season	Locality	Crop	Cultivar	Planting date	Harvest date	Rainfall growing period (mm)
2017/18	Site 1 Site 2	Maize	CS701	02/02/2018	16/06/2018	395
2018/19 Early planting	Site 1	Maize	CS701	23/09/2018	19/01/2019	337
	Site 2	Butternut		23/09/2018	19/01/2019	337
2018/19 Late planting	Site 1 Site 2	Maize	CS701	09/02/2019	16/07/2019	315

An inventory of the plantings done at the three sites in Gladstone is presented in Table 24.

Table 24 Agronomic information for crop production during three summer growing seasons in Gladstone

Locality	Season	Crop	Planting date	Harvest date	Rainfall during growing season	Comments
Site 3	2017/ 2018	Peas	25/6/18	-	-	Nothing harvested
		Spinach	26/2/18	28/3/18	145	
		Beetroot	26/2/18	28/3/18	145	
	2018/ 2019	Onion	5/06/19	20/11/19	21	
Site 4	2017/ 2018	Peas	10/7/18	-	-	Nothing survived
		Onion	9/7/18	-	-	Nothing survived
		Spinach	21/2/18	28/3/18	150	
		Beetroot	21/2/18	28/3/18	150	
Site 5	2017/ 2018	Maize	21/2/18	7/5/18	265	
		Beetroot	5/2/18	2/4/18	246	
		Tomato	7/2/18	-	-	Poor growth. Nothing harvested
		Carrots	8/2/18	-	-	Poor growth. Nothing harvested
		Peas	21/2/18	-	-	Poor growth. Nothing harvested
		Spinach	6/2/18	6/3/18	84	
	2018/ 2019	Onion	7/6/19	-	-	Poor growth. Nothing harvested
		Spinach	7/6/19	-	-	Poor growth. Nothing harvested
		Cabbage	7/6/19	-	-	Poor growth. Nothing harvested

6.2.2 Plant sampling and analyses

To determine the maize aboveground biomass and grain yields, three replications of 12 plants were harvested in each treatment in Swayimane and Gladstone. However, only sub-samples (6 plants) were taken for analyses. Maize plants were dried at 60ºC until a constant mass was reached for the determination of biomass. Cobs were separated from the stalk and grains were separated from the cobs for the determination of grain yield. Spinach was also harvested as above-ground biomass, while beetroot and cabbage were recorded as the mass of total heads per treatment. Furthermore, for the spinach and beetroot, the number of bunches obtained and their mass was recorded per treatment for the determination of economic yield. Beans were harvested as above ground biomass before it reached maturity.

6.2.3 Rainwater productivity

The rainwater productivity (RWP) that describes the effectiveness with which rainwater is converted into grain, seed or any other edible product by different treatments was calculated by dividing the economic yield harvested from a specific area by the volume of water (in this case rainfall, as all crops were produced under dryland conditions) the crop has during its growing period. The RWP was expressed as kg ha^{-1} mm^{-1}.

6.2.4 Weather data

Across all demonstration sites, the nearby representative automatic weather station was used to obtain weather data such as rainfall that was a major weather parameter required in this study.

6.2.5 Statistical Analysis

Measured parameters from different treatments were subjected to an analysis-of-variance (ANOVA) test using Genstat 17^{th} edition (VSN International, UK). Treatment means were separated using the least significant difference (LSD) at 5% probability level.

6.3 Results

6.3.1 Swayimane

6.3.1.1 Summer production

Green mealie yields for the different treatments over three seasons in two different homesteads are presented in Table 25. Green mealie yields varied between 8711 and 18433 kg ha^{-1} over the two years (Table 25) with a very strong yield trend of IRWH >MB > NT ≈ CON (Table 26). Results from Table 25 indicate that higher yields were obtained during 2018/2019 early as compared to 2017/2018 and 2018/2019 late where very similar yields were obtained. Smaller differences between the four treatments occurred during the first growing season (2017/2018 season). The reason for this might be that demonstration implementation was almost immediately followed by planting, which eliminated the opportunity to conserve water. The IRWH treatment induced over all three seasons the highest yield at Site 1, followed by MB and then CON and NT with very similar yields. The IRWH treatment managed to increase green mealie production at Site 1 with 4185 kg ha^{-1} as compared to CON. This increase in green mealie yield will result in an increase of R26997 ha^{-1} as compared to CON.

Table 25 Green mealie (cobs covered with husks) yields (kg ha^{-1}) on two homesteads for different treatments in Swayimane during three summer growing seasons

Locality	Treatments	2017/18	2018/19 Early planting	2018/19 Late planting	Average
Site 1	CON	11423	14467	8711	11534
	NT	11670	12600	10267	11512
	MB	12209	15000	12667	13292
	IRWH	14491	18433	14233	15719
	Average	12448	15125	11469	13014
Site 2	CON	11414	-	11900	11657
	NT	11751	-	11667	11709
	MB	10992	-	12289	11641
	IRWH	11400	-	13667	12534
	Average	11389	-	12381	11885
Combined mean of two sites		11919	15125	11925	12450

At Site 2 on average over the two seasons the IRWH induced the highest yield followed by NT, CON and MB, all three treatments with very similar yields. IRWH increased green mealie yields by 7.5%, which will result in an increase in income of R4152 ha^{-1} as compared to CON. On average, the IRWH treatments produced 24.7% more green mealies that CON (Table 26). This increase in green mealie yield will result in an increase of R20015 ha^{-1} as compared to CON.

Results in Table 26 further indicate that the IRWH managed to produce overall 14.4 and 24.6% more green mealies that MB and NT, respectively. Reasons for this phenomenon might be due to the ability of IRWH to stop ex-field runoff and to minimize evaporation from the soil surface.

Table 26 Mean "green mealie" (cobs covered with husks) yields (kg ha^{-1}) in Swayimane during three summer growing seasons

Treatments	Average green mealie yield	Advantage of IRWH (%)
CON	11583	25
NT	11591	25
MB	12631	14
IRWH	14445	

Butternut yields during the 2018/2019 early planting at Site 2 are presented in Table 27. Butternut yields varied between 269 and 775 kg ha^{-1}, with a pattern of IRWH > NT ≈ MB > CON. The relatively low butternut yields were due to poor weed control. The IRWH treatment induced on average 13% higher butternut yields as compared to NT and MB and 88% higher than CON. By changing from CON to IRWH the farmer has the opportunity to earn with butternut R1709 ha^{-1} more as compared to CON.

Table 27 Mean butternut yields (kg ha^{-1}) for different treatments in Swayimane during the 2018/19 summer growing season

Locality	Treatments	2018/19 Early planting
Site 2	CON	269
	NT	695
	MB	676
	IRWH	775
	Average	604

RWP data for green mealies are presented in Table 28. The results at Site 1 revealed that the IRWH increased water productivity with 37.2, 37.2 and 18.1% as compared to CON, NT and MB, respectively. At Site 2, it was found that the IRWH increased RWP with 8.3, 8.2 and 8.1% as compared to CON, NT and MB, respectively. Overall mean results indicated that the IRWH treatments managed to use the rainwater much more productively to produce green mealies. On average the IRWH used rainwater 19.5% more effectively to produce green mealies as compared to the mean of MB, NT and CON.

Table 28 Mean rainwater productivity (kg ha^{-1} mm^{-1}) results for "green mealies" (cobs covered with husks) for different treatments in Swayimane during three summer growing seasons

Locality	Treatments	2017/18	2018/19 Early planting	2018/19 Late planting	Average	Advantage of IRWH (%)
Site 1	CON	28.9	42.9	27.7	33.2	37.2
	NT	29.5	37.4	32.6	33.2	37.2
	MB	30.9	44.5	40.2	38.5	18.1
	IRWH	36.7	54.7	45.2	45.5	
	Average	31.5	44.9	36.4	37.6	30.3
Site 2	CON	28.9	-	37.8	33.3	8.3
	NT	29.8	-	37.0	33.4	8.2
	MB	27.8	-	39.0	33.4	8.1
	IRWH	28.9	-	43.4	36.1	
	Average	28.8	-	39.3	34.1	8.2
Mean		30.2	44.9	37.9	35.8	19.5

RWP results for butternut production at Site 2 during the 2018/2019 early planting season are presented in Table 29. RWP results of butternut varied between 0.8 and 2.3 kg ha^{-1} mm^{-1}. This is an indication that for every 1 mm of rain that occurred during the 2018/19 season the IRWH treatments produced 2.3 kg of butternut yield per hectare compared to the 0.8 kg from CON. This result indicated that all the IRWH treatment was almost three times more effective than CON in converting rainwater into butternut yield. This is a remarkable difference especially in a semi-arid environment where every drop of rainwater must be utilized to produce food. The superiority of the IRWH treatment is the result of its ability to stop ex-field runoff and induces in-field runoff within the system and therefore utilizes every drop of rainwater far better than CON. Comparing the different treatments, water productivity results reveal a trend of IRWH > NT ≈ MB > CON.

Table 29 Mean rainwater productivity (kg ha^{-1} mm^{-1}) results for butternut for different treatments in Swayimane during the 2018/19 summer growing season

Locality	Treatments	2018/19 Early planting
Site 2	CON	0.8
	NT	2.1
	MB	2.0
	IRWH	2.3
	Average	1.8

6.3.1.2 Winter production

6.3.1.2.1 Site 1

Mean green pepper yields from different treatments obtained at the demonstration at Site 1 during the 2017 winter season are presented in Figure 20. Results from Figure 20 indicate a trend of IRWHm+Fert+Manure > IRWHm+Fert > IRWH+Fert > IRWH+Manure > CON+Fert. Comparing green pepper yields from IRWH+Fert with CON+Fert indicate that IRWH increased green pepper yields with 512 kg ha^{-1} (191%) as compared to CON. This increase in green pepper yield means an increase of R5120 ha^{-1} by switching from CON to IRWH. Comparing inorganic fertilizer with manure (IRWH+Fert vs IRWH+Manure) indicates that inorganic fertilizer performed slightly better. The results indicate that much higher green pepper yields were obtained by applying a mixture of inorganic fertilizer and manure with organic mulch (IRWHm+Fert+Manure), on average an increase of 741 kg ha^{-1} (170%) as compared to IRWH+Fert and IRWH+Manure. Comparing bare with mulch (IRWH+Fert vs IRWHm+Fert) indicate that green pepper yields increased by 316 kg ha^{-1} (41%) by adding mulch which suppressed evaporation from the soil surface and increased infiltration rate. By changing from CON+Fert to the best treatments, IRWHm+Fert+Manure a farmer will be able to earn R17350 ha^{-1} more with green peppers. Green pepper prices (R10 kg^{-1}) from Mkhondeni Fresh Produce for 30 January 2020 were used.

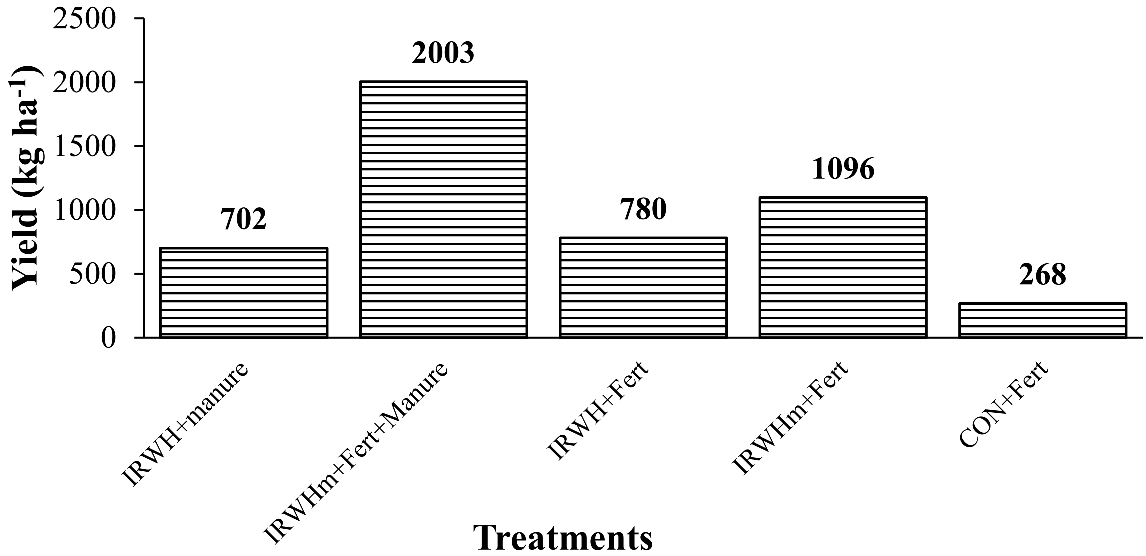


Figure 20 Mean green pepper yields from different treatments at Site 1 in Swayimane during the 2018 winter season.

Similar trend for the cabbage as that of green pepper was discerned during the 2017 winter season as shown in Figure 21 where IRWHm+Fert+Manure > IRWHm+Fert > IRWH+Fert > IRWH+Manure > CON+Fert. The IRWH produced 1326 kg ha^{-1} (7%) more cabbages as compared to CON (IRWH+Fert vs CON+Fert). This increase with IRWH will result in an increase of R3315 ha^{-1} as compared to CON. Inorganic fertilizer (IRWH+Fert) performed slightly better (599 kg ha^{-1}) than manure (IRWH+Manure). By adding mulches to the IRWH (IRWHm+Fert) it increased cabbage yields with 1342 kg ha^{-1} as compared to the bare IRWH treatments (IRWH+Fert). IRWHm+Fert increased cabbaged yield with 2668 kg ha^{-1} (13%) as compared to CON+Fert. Once again, the mixture of inorganic fertilizer and manure combined with the application of organic mulch on IRWH was the best treatment and increased cabbage yields with 3446 kg ha^{-1} (17%) as compared to CON+Fert. By changing from CON+Fert to the best treatment (IRWHm+Fert+Manure) a farmer who produces cabbage will be able to earn R8615 ha^{-1} more. Cabbage prices (R2.50 kg^{-1}) from Bloemfontein Fresh Produce for 30 January 2020 were used.

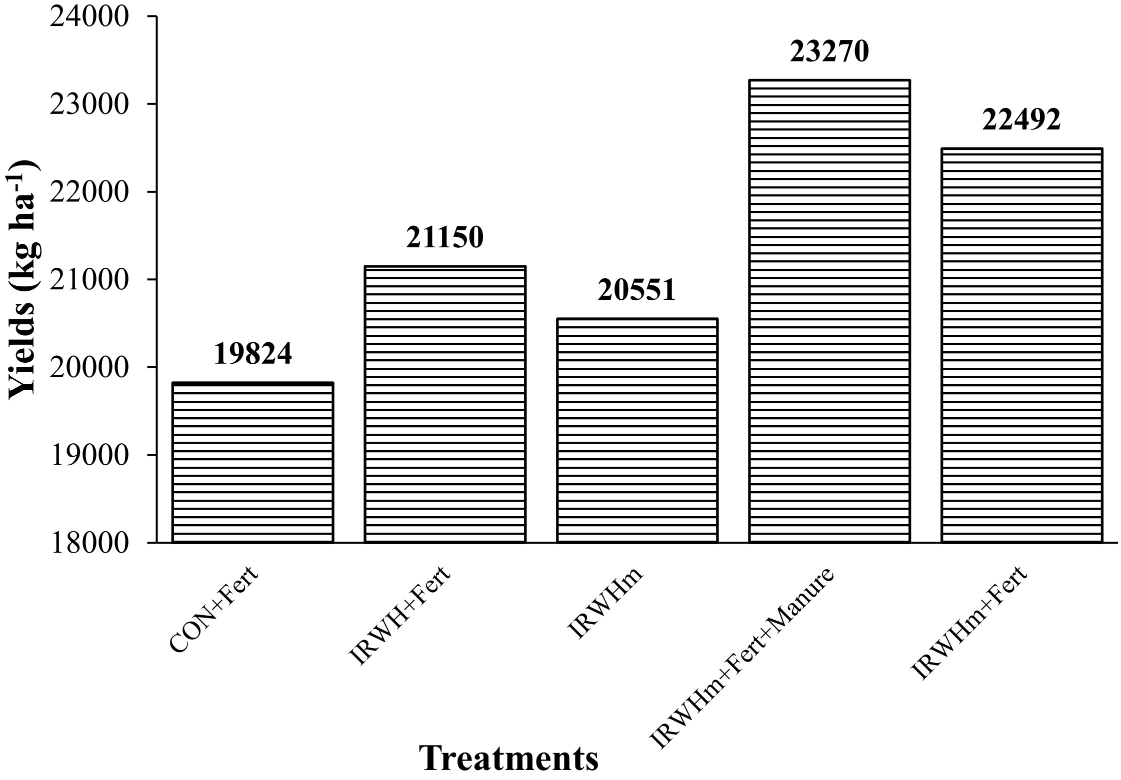


Figure 21 Mean yields for the cabbage from different treatments at Site 1 in Swayimane during the 2017 winter season.

The beetroot yields (Figure 22) also followed the trend observed with green pepper and cabbage where the IRWHm+Fert+Manure outperformed all other treatment followed by IRWHm+Fert > IRWH+Fert > IRWH+Manure > CON+Fert. Comparing IRWH (IRWH+Fert) with CON (CON+Fert), IRWH increased beetroot production by 1627 kg ha^{-1} (159%) as compared to CON. This increase in crop yield by IRWH has the potential to increase income by R7321 ha^{-1} as compared to CON. By changing from CON+Fert to the best treatment (IRWHm+Fert+Manure) beetroot yields increased with 4897 kg ha^{-1} (487%) while income increased with R22036 ha^{-1}. Beetroot prices (R4.50 kg^{-1}) from Mkhondeni Fresh Produce for 30 January 2020 were used.

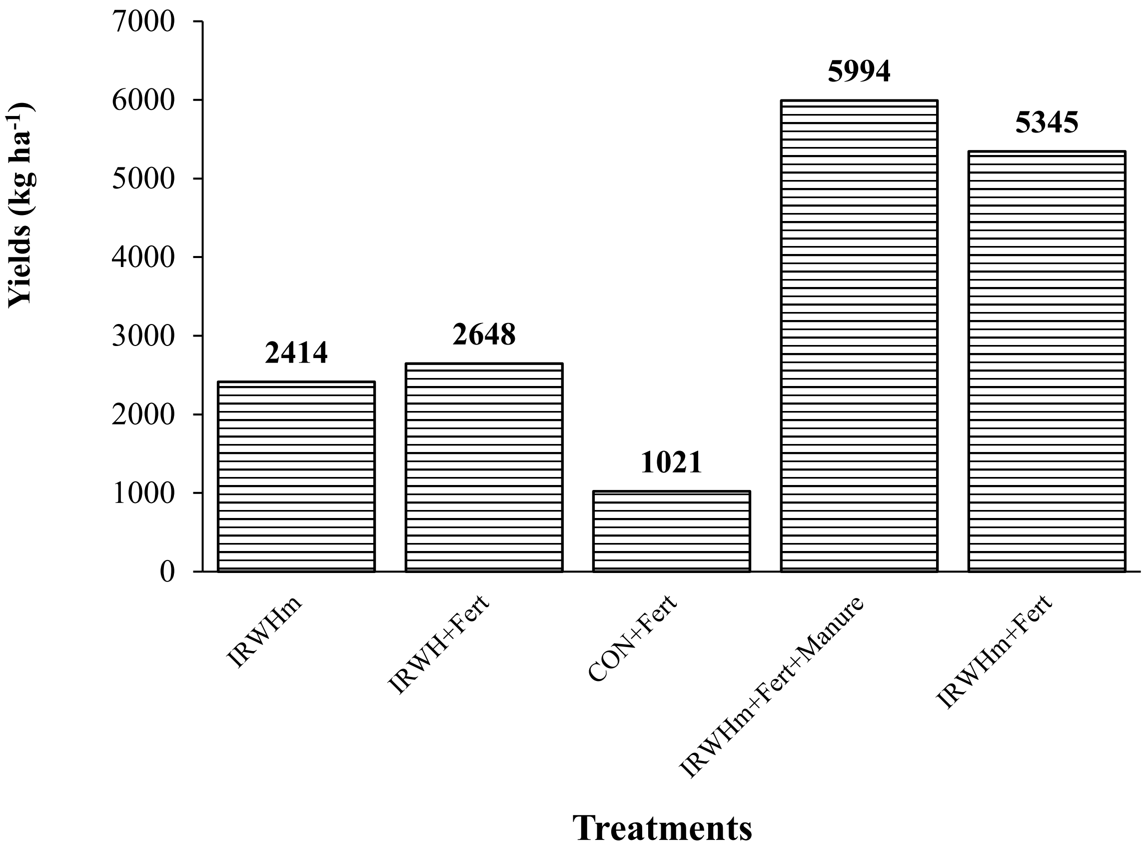


Figure 22 Mean yields beetroot from different treatments at Site 1 in Swayimane during the 2017 winter season.

6.3.1.2.2 Site 2

Figure 23 presents the cabbage yield results at Site 2 in Swayimane. The treatments in this demonstration were slightly different from the ones at Site 1. IRWHm without any fertilizer or manure application was added as an additional treatment. A strong trend IRWHm+Fert+Manure > IRWHm+Fert > IRWH+Fert > IRWHm > IRWH+manure > CON+Fert was observed from the cabbage yields which followed the same trend as compared to vegetable yields produced on demonstration plots at Site 1. Comparing IRWH (IRWH + Fert) with CON (CON + Fert) indicate that the IRWH increased cabbage yields by 1370 kg ha-1 (62%) which will result in R3425 ha^{-1} more as compared to CON. By changing from CON to the best treatment (IRWHm+Fert+Manure) cabbage yields increased with R3512 kg ha^{-1} (159%) which will result in R8780 ha^{-1} more as compared to CON. These incomes compare very well with results obtained at the demonstration plot at Site 1. Prices from Bloemfontein Fresh Produce market for 30 January 2020 were used. Cabbage prices (R2.50 kg^{-1}) from Bloemfontein Fresh Produce market for 30 January 2020 were used.

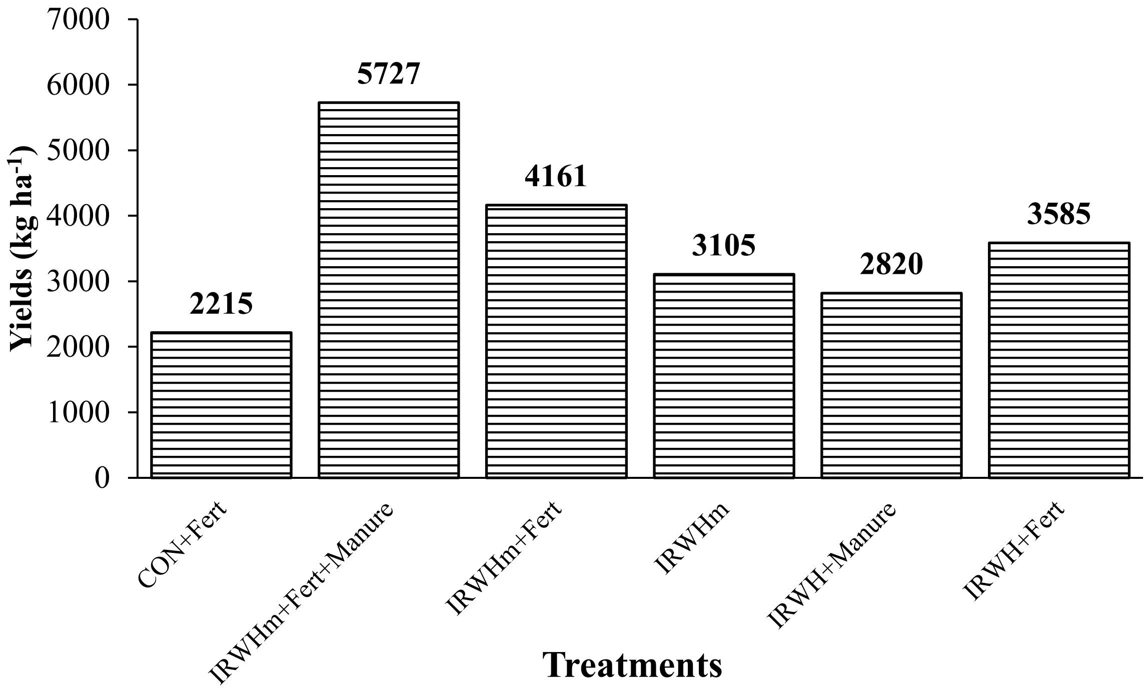


Figure 23 Mean yields for the cabbage from different treatments at Site 2 in Swayimane during the 2017 winter season.

6.3.2 Gladstone

6.3.2.1 Homestead gardens

Table 30 presents the bean dry matter yields at Site 3 and Site 4 in Gladstone. The treatments were highly significantly different ($p<0.001$) from one another for both sites. The treatments followed the order of IRWHm+Fert > IRWH+Fert > IRWH+Manure > CON. When comparing the two tillage treatments (CON+Fert and IRWH+Fert), it can be seen that IRWH has produced 298% and 72% higher than CON at Site 3 and Site 4, respectively. When looking at the impact of mulching (when comparing IRWH+Fert and IRWHm+Fert) it is clear that yields were increased further by 71% and 37% at Site 3 and Site 4, respectively. This clearly demonstrates the beneficial influence of mulching. However, in a rural community, it is not always possible to use organic material as mulch, as it is often used as fodder for animals, but stones can also be considered for use as mulch if it is available.

Table 30 Bean dry matter yield (kg ha^{-1}) at Site 3 and Site 4 in Gladstone during the 2017/2018 summer growing season

Treatment	Site 3	Site 4
CON+Fert	322	417
IRWH+Manure	442	1067
IRWH+Fert	1281	1461
IRWHm+Fert	2192	2319
Average	1059	1316

All the IRWH treatments outperformed the CON treatment. This can be attributed to the fact that the IRWH treatments were able to stop runoff completely. Runoff water on the IRWH treatments could infiltrate into the soil and improved the soil water contents of the soil. This in turn increased the plant available water. Since more water was available, plants were able to grow vigorously, resulting in a large photosynthesis factory, which help to improve the crop yield. The management practices also clearly had an influence on crop performance. The IRWH treatment with the mulch and inorganic fertilizer totally outperformed the other treatments. The mulch blanket suppressed evaporation losses from the soil surface and inorganic fertilizer was readily available. Where organic fertilizer was applied the crop was unable to benefit completely from the organic mulch, due to the fact that it takes some time to decompose and become readily available to the plant and the crop's relatively short growing cycle. Because the beans are legumes, it was also able to bind nitrogen through N-fixation. In a rural setting where community members struggle to afford expensive inorganic fertilizer, it is beneficial to incorporate a legume crop in the production system to save on fertilizer cost.

Table 31 shows the beetroot biomass obtained at Site 3 and Site 4 in Gladstone. There were significant differences between the treatments and at these two sites. As was experienced with beans, beetroot also performed better under IRWH than CON. This is to be expected, since the basins on the IRWH treatment were able to collect the runoff water and conserve it for its productive use. With IRWH (comparing IRWH+Fert with CON+Fert) it was possible to increase yields by 48% and 114% compared to CON at Site 3 and Site 4, respectively. The IRWHm+Fert treatment produced the highest yield at both sites. For the homestead production at Site 3, it was calculated that the equivalent production would have been 16747 kg ha^{-1} (Table 31). On 30 January 2020 the Bloemfontein fresh produce market paid R5 kg^{-1} for beetroot. That means homestead owner at Site 3 could potentially have earned an income of R83735 if she produced beetroot on one hectare using IRWH and applying fertilizer, at the recommended application rate and a mulch blanket equivalent to about 10 t ha^{-1}.

It is interesting to note the huge difference in yields between the two sites. At Site 3 the yields were almost five times that of the yields measured at Site 4, although the soils in the gardens are similar and they have received the same rainfall. This difference can be attributed to the poor management by the homestead owner at Site 4. The owner became sick and had other personal problems and could not manage to control the weeds properly. The weeds had overgrown the main crop and competed with the crop for the available water and nutrients. This clearly demonstrates the importance of sound management practices. Community members can be supplied with the best CSTs to improve their yields and household income, but if they fail to maintain their gardens properly, they will not enjoy the full benefit of the implemented technologies. It was still rather surprising that both owners of Sites 3 and Site 4 have managed to get such good yields, since crops that are producing the edible parts underground are normally not planted in such clayey soils. It is difficult to harvest tuberous crops on a clayey soil and the clay soils easily get water logged, resulting in rotting of the tubers.

Table 31 Beetroot biomass yields (kg ha^{-1}) for Gladstone's homestead gardens during the 2017/2018 summer growing period

Treatment	Site 3	Site 4
CON+Fert	9975	1411
IRWH+Fert	14722	3002
IRWHm+Fert	16747	4742
IRWH+Manure	15008	2822
Average	14113	2822

Table 32 shows the biomass yield for spinach harvested at Site 3 and Site 4 in Gladstone. The spinach biomass yield varied significantly across treatments in these two sites. The treatments followed the order of IRWHm+Fert > IRWH+Fert > IRWH+Manure > CON. A very large volume of spinach was harvested from a small production area. This means that there was more than enough for household consumption and homestead gardeners had surpluses to sell to improve their household income. However, a crop such as spinach is very popular to produce -in homestead gardens in rural communities, and so there is not always an immediate market available for the crop within the production area. This means that community members have to travel long distances to the formal markets to sell their products. However, formal markets are often flooded with crops such as spinach, resulting in homestead gardeners getting low prices for their products, which often does not make it a worthwhile investment. It is thus important that community members be educated in the crop choices they make. This will enable them to make more informed decisions on which crops to plant. It is thus important not only to look at potential yield that can be obtained with the superior CSTs, but also to look at what is needed by the market. If a fast-growing, high-yielding crop with a high nutrient value is required, then the production of spinach using suitable CSTs can be considered.

Table 32 Spinach yields (kg ha^{-1}) for Gladstone homestead gardens during the 2017/2018 summer growing period

Treatment	Site 3	Site 4
CON+Fert	8246	3338
IRWH+Fert	13207	6556
IRWHm+Fert	18513	16836
IRWH+Manure	9992	5704
Average	12490	8109

6.3.2.2 School

Table 33 shows the maize biomass and grain yield results for Site 5 in Gladstone at harvesting. Both biomass and grain yields varied significantly ($p<0.05$) across the treatments. Both parameters followed an order of IRHWm+Fert > IRWH+Org > CON+Fert > IRWH+Fert+NWC. It is naturally expected that the IRWH treatments would have outperformed the CON treatment due to the total stoppage of runoff. However, it is interesting to note that the CON+Fert treatment performed better than the IRWH+Fert+NWC treatment. This again emphasizes the importance of proper weed control. In this case the IRWH treatment did manage to collect the runoff water to be used more productively, but the weeds have competed with the maize crop for the available water and nutrients, resulting in the poor yield obtained with the IRWH+Fert+NWC treatment.

Where mulching and fertilizer application was combined with IRWH it was possible to more than double the yield compared to CON. In a rural community where maize is the staple food of many households, it will most definitely be worthwhile to apply IRWH for maize production. The maize grain is ground or broken to produce maize meal or samp, which is consumed on a daily basis by many households. Soft maize cobs can also be sold as green mealies to hawkers and street vendors at high prices that can make a considerable contribution to the household income.

Table 33 Maize biomass and grain yields (kg ha^{-1}) for different treatments at Site 5 in Gladstone during the 2017/2018 summer growing season

Treatment	Biomass	Grain
IRWH+Fert+NWC	3075	922
CON+Fert	3190	1021
IRWHm+Fert	5627	2251
IRWH+Manure	4964	1986
Average	4214	6180

*NWC = no weed control treatment

Table 34 shows the biomass yields for the beetroot and spinach at Site 5 in Gladstone. For both crops there were significant ($p<0.001$) differences across treatments. Beetroot biomass yield followed an order of IRWHm+Fert > IRWH+Manure > CON+Fert > IRWH+Fert+NWC. For spinach the trend was IRWHm+Fert > IRWH+Manure > IRWH+Fert+NWC > CON+Fert. The yields for both beetroot and spinach were considerably lower than that harvested at Site 3, but more than that harvested at Site 4. The soil at the school is exactly the same as the soil found in the two homestead gardens, however there are marked differences in the yields observed at the different sites. The owner at Site 3 has obtained the highest yields, since she took full ownership of the project and took good care of the crops in her homestead garden. However, working with school and community gardens is more problematic, since there is no single individual that takes full responsibility for taking care of the garden and crops. At the school garden it was expected that the scholars and gardener would have maintained the garden, but they neglected it, especially during the school holidays. It will be possible to produce a variety of crops in school and community gardens by applying appropriate CSTs, but without the full cooperation of the school governing bodies and scholars the success of such projects in school gardens is questionable. The full potential of the CSTs to contribute to school feeding schemes has not yet been realized and should receive more attention.

Table 34 Beetroot and spinach biomass yields (kg ha^{-1}) for different treatments at Site 5 in Gladstone during the 2017/2018 summer growing season

Treatment	Beetroot	Spinach
IRWH+Fert+NWC	4785	3499
CON+Fert	7043	2130
IRWHm+Fert	13226	9269
IRWH+Manure	12097	8747
Average	9288	5911

6.3.2.3 Rainwater productivity

RWP results for the three sites in Gladstone are presented in Table 35. The RWP is an indication of the crop's ability to convert rainwater into food. It is interesting to note that the vegetable crops have much higher RWP values than that of maize. The reason being that the vegetable crops has a short growing period and the marketable product is consumed as the fresh produce. However, the maize crop has a much longer growing period and the end product is supplied as dry grain with a moisture content of about 6.5%. From the results, it is clear that the IRWH treatments were much more efficient in converting rainwater into food. For example, when looking at comparable treatments like CON+Fert and IRWH+Fert at Site 3, it is clear that the IRWH treatment was 48% and 60% more efficient than CON for beetroot and spinach, respectively. The phenomenon that IRWH totally outperformed CON was observed across all sites for all crops. This clearly demonstrates the beneficial effect of applying CSTs, like IRWH, to produce more food with limited water resource.

Table 35 Rainwater productivity (kg ha^{-1} mm^{-1}) results for various crops at three localities in Gladstone during the 2017/2018 growing season

Locality	Crop	Treatment	Yield (kg ha^{-1})	Rainfall (mm)	Water productivity (kg ha^{-1} mm^{-1})
Site 3 (Mrs. Moswaka)	Beetroot	CON+Fert	9975	145	68.8
		IRWH+Fert	14722	145	101.5
		IRWHm+Fert	16747	145	115.5
		IRWH+Manure	15008	145	103.5
		Average	14113	145	97.3
	Spinach	CON+Fert	8246	145	56.9
		IRWH+Fert	13207	145	91.1
		IRWHm+Fert	18513	145	127.6
		IRWH+Manure	9992	145	68.9
		Average	12490	145	86.1
Site 4 (Mrs. Setoute)	Beetroot	CON+Fert	1411	150	9.4
		IRWH+Fert	3002	150	20.0
		IRWHm+Fert	4742	150	31.6
		IRWH+Manure	2822	150	18.8
		Average	2822	150	18.8
	Spinach	CON+Fert	3338	150	22.3
		IRWH+Fert	6556	150	43.7
		IRWHm+Fert	16836	150	112.3
		IRWH+Org	5704	150	38.1
		Average	8109	150	54.1
Site 5 (Maserona Intermediate School)	Maize	IRWH+Fert+NWC	922	265	3.5
		CON+Fert	1021	265	3.8
		IRWHm+Fert	2251	265	8.5
		IRWH+Org	1986	265	7.5
		Average	6180	265	23.3
	Beetroot	IRWH+Fert+NWC	4785	245	19.5
		CON+Fert	7043	245	28.7
		IRWHm+Fert	13226	245	53.8
		IRWH+Manure	12097	245	49.3
		Average	9288	245	37.8
	Spinach	IRWH+Fert+NWC	3499	84	41.9
		CON+Fert	2130	84	25.5
		IRWHm+Fert	9269	84	110.9
		IRWH+Manure	8747	84	104.7
		Average	5911	84	70.7

6.4 SUMMARY AND CONCLUSION

Results from on-farm demonstration plots have indicated that it is possible to increase yields from homestead garden production and smallholder farming plots considerably by applying appropriate CSTs.

At the two demonstration sites in Swayimane, the smallholder farmers were able to increase their yields between 45% and 55% compared to their normal farming practices, by applying rainwater harvesting technologies on their croplands. Similar improvements were also observed in the homestead gardens, where a variety of vegetable crops were produced by making use of IRWH in combination with sound management practices.

Simply by changing from traditional farming practices (CON) to the IRWH production technique it was possible to increase beetroot yield with 48% and 112% at the homestead gardens Site 3 and Site in Gladstone, respectively. The yield increases for spinach at the same sites were 60% and 96%, respectively. This clearly indicates the beneficial effect of IRWH. The yield increases could be attributed to the fact that IRWH was able to stop ex-field runoff completely. Runoff water was collected in basins and percolated into the soil, deeper than the layer from which evapotranspiration occurred. This helped to increase the water available for plant growth and increased yields.

The beneficial effect of combining IRWH with sound management practices, like mulching and fertilizer application, was also demonstrated. For example, by applying both organic mulch and inorganic fertilizer within the IRWH crop production system, it was possible to increase beetroot yields with 68% and 236% compared to CON at Site 3 and Site 4, respectively. The corresponding increases obtained with spinach were 125% and 404%, respectively.

Many resource-poor rural communities in arid and semi-arid areas of SA are experiencing a decline in crop production due to unfavourable climatic conditions and poor soils. However, CSTs have the potential to improve production in a sustainable manner. It is therefore recommended that community members are informed and encouraged to adopt and implement appropriate CSTs, especially in areas where insufficient rainfall is the most limiting factor for crop production, to improve their food production and household food security status.

7 IMPACT OF CSTS AND VARIOUS AGRONOMIC TREATMENTS ON THE NUTRIENT CONTENT (WITH PARTICULAR FOCUS ON PROVITAMIN-A) OF DIFFERENT VEGETABLE TYPES

7.1 INTRODUCTION

CSTs implemented in the study that included either CON or IRWH technology, which were applied in combination with sound management practices (agronomic treatments), like mulching and fertilizer application were used to produce different types of vegetables. The vegetables produced were harvested, and their nutrient determined to assess whether or not agronomic treatments, water use technology, and season affected the nutrient content of the vegetable types.

7.2 MATERIALS AND METHODS

7.2.1 Sample harvesting and freeze-drying

7.2.1.1 Sample harvesting

Vegetables are highly perishable during and after harvesting if subjected to unfavourable conditions (including unsuitable storage conditions). To eliminate these during harvesting, Ziploc bags, cooler boxes, and ice cubes were used to preserve the vegetables from the field to the laboratory. The vegetables were harvested randomly from each plot of CST. Within each plot, they were three replicates. One beetroot and one cabbage per replicate was randomly selected and harvested. Similarly, one yellow-flesh sweet potato was randomly selected from each replicate, and harvested from all CST plots. A bunch of spinach from each replicate was also harvested. Immediately after harvesting, the vegetables were placed in Ziploc bags labelled according to the treatment plot they were harvested from and the Ziploc bags of each vegetable type then placed in a cooler box with ice cubes. The vegetables were immediately transported from the field to the laboratory.

7.2.1.2 Sample Preparation and Freeze drying

Upon delivery at the laboratory, the vegetable samples were washed with deionised water to remove dirt on their surfaces and were then left to dry at room temperature (approx. 25°C. Thereafter, each vegetable sample was cut into slices of approximately 100 g and stored in a freezer at -20°C. The samples were then freeze-dried using a Virtis freeze dryer (# 6 KBTES-55, SP Industries, USA) at 0.015 kPa, -75°C for ± 5 days until they were completely dry. Finally, the dried samples were milled.

7.2.2 Nutritional analysis

Following standard and referenced methods, the raw samples were analysed in duplicate for their proximate composition, individual mineral elements, and provitamin A content. Nutritional analysis was done at Cedara research station of KwaZulu-Natal Provincial Department of Agriculture and Rural Development, except for provitamin A analysis, which was done at the International Maize and Wheat Improvement Centre (CYMMT) in Mexico.

7.2.2.1 Proximate composition

The proximate composition of the vegetable samples was determined according to the methods of the Association of Analytical Chemists (AOAC, 2002). The total mineral content (ash) was determined by the combustion method following the Association of Analytical Chemists (AOAC) Official Method Number 942.05. Fat was analysed by the Soxhlet procedure as described in the AOAC Official Method Number 920.39. Fibre was measured as neutral detergent fibre (NDF) according to the AOAC Official Method Number 2002.0). Protein was determined using the Dumas combustion method described in the AOAC Official Method Number 990.03.

7.2.2.2 Individual mineral elements

The individual mineral elements were determined according to the AOAC Official Method Number 6.1.2 (2002), the Inductively Coupled Plasma (ICP) Spectroscopy.

7.2.2.3 Provitamin-A analysis

The Provitamin-A content of the samples was determined by high-performance liquid chromatography (HPLC) using the procedures described by Lacker *et al*., 1999.

7.3 RESULTS AND DISCUSSION

7.3.1 Effect of agronomic treatments and water use technologies on the nutrient content of different vegetables

The mean nutrient content of each vegetable type cultivated under different treatments and water use technologies in two seasons is presented in Table 36. The treatment combination, CON and fertilizer addition was the control.

7.3.1.1 Beetroot

In the first season, IRWH combined with mulching resulted in higher concentrations of ash and fibre relative to the use of either CON or IRWH in combination with the different agronomic treatments ($p<0.05$). Beetroot produced under the IRWH technology combined with mulching and inorganic fertiliser had the second higher fibre content. Beetroot produced under the CON technology combined with organic and inorganic fertiliser had a significantly high protein content compared to the other treatments ($p<0.05$). In the second season, IRWH in combination with inorganic fertiliser resulted in a significantly higher concentration of ash, fibre, protein, zinc and iron relative to the other treatments. In addition, CON combined with the different agronomic treatments resulted in a significantly higher fat, calcium and phosphorus in beetroot compared to IRWH combined with the different agronomic treatments.

7.3.1.2 Cabbage

Cabbage produced by the CON combined with organic and inorganic fertiliser had significantly high protein and iron content. A significantly higher concentration of fat, ash, phosphorus and calcium was observed in cabbage cultivated under IRWH combined with mulching relative to either of the two water use technologies each combined with the different agronomic treatments.

7.3.1.3 Spinach

The IRWH technology combined with mulching or inorganic fertiliser significantly improved the ash content of spinach. The treatment that combined IRWH with mulching significantly improved the ash and fibre content of the spinach. The protein content of the spinach was significantly improved when the spinach was cultivated under IRWH combined with organic and inorganic fertiliser. Cultivation of the spinach under the IRWH technology in combination with inorganic fertiliser resulted in higher contents of calcium, phosphorus and zinc.

7.3.1.4 Sweet potato

The IRWH combined with inorganic fertiliser resulted in a significantly higher fat, protein, fibre, zinc and iron. The total mineral content (ash) was not significantly affected by the water use technology and agronomic treatments. The concentration of calcium and zinc was significantly higher in sweet potatoes produced by the IRWH that combined and inorganic fertiliser.

Generally, the results imply that the nutrient content of vegetables can be enhanced using different agronomic treatments. The overall nutritional content of different vegetable types was better when planted under the IRWH during the summertime. In winter, due to less rain, this was not the case. However, since the first trial was performed during the March/April 2017/2018 period of the year, it might not be ideal to practise the IRWH technology to address the problem of rain and water shortage.

Table 36 Effect of agronomic treatment and water use technology, either CON or IRWH on the proximate composition and mineral content of different vegetables (on a dry matter basis, mean ± SD)

SEASON 1: Beetroot	Ash (%)	Fat (%)	Fibre (%)	Protein (%)	Ca (%)	P (%)	Zn (ppm)	Fe (ppm)
Con + inorganic (inorg) +organic (org) fertilizer	7.74 ± 0.67a	0.85 ± 0.33a	12.8 ± 0.60a	11.52 ± 0.34a	0.44 ± 0.50a	0.20 ± 0.17a	36.00 ± 0.01a	454.36 ± 0.52a
IRWH + inorg	7.89 ± 0.07a	0.59 ± 0.17b	13.73 ± 0.32a	9.82 ± 0.11b	0.56 ± 0.68a	0.37 ± 0.47a	38.21 ± 0.30a	156.08 ± 0.12b
IRWH + Inorg+Org	6.84 ± 0.40a	0.51 ± 0.23b	13.45 ± 0.01a	6.08 ± 0.53b	0.53 ± 0.60a	0.38 ± 0.47a	27.05 ± 0.07a	136.08 ± 0.11b
IRWH + Mu	9.64 ± 0.35b	1.07 ± 0.00a	17.51 ± 0.16b	8.75 ± 0.59b	0.15 ± 0.44a	-0.45 ± 0.68a	37.97 ± 0.03a	232.79 ± 0.28c
IRWH + Mu + Org + Inorg	8.52 ± 0.12a	0.79 ± 0.22b	14.12 ± 0.40c	9.02 ± 0.29b	0.43 ± 0.47a	0.36 ± 0.44a	31.12 ± 0.18a	106.34 ± 0.48b
Cabbage								
Con + Inorg + Org fertilizer	8.96 ± 0.13a	1.33 ± 0.39a	14.59 ± 0.56a	16.02 ± 0.34a	0.27 ± 0.09a	0.71 ± 0.68a	32.31 ± 0.44a	92.30 ± 0.42a
IRWH + inorg fertilizer	8.81 ± 0.62a	1.08 ± 0.18b	15.73 ± 0.23b	10.72 ± 0.71b	0.38 ± 0.20a	0.42 ± 0.39b	31.48 ± 0.69a	57.48 ± 0.68b
IRWH + Inorg + Org	8.63 ± 0.08a	1.17 ± 0.38b	15.53 ± 0.47a	13.10 ± 0.03c	0.25 ± 0.11a	0.48 ± 0.43b	19.11 ± 0.15b	49.00 ± 0.00b
IRWH + Mu	10.01 ± 0.48b	1.42 ± 0.39a	16.36 ± 0.50b	13.84 ± 0.66c	0.97 ± 1.05b	0.65 ± 0.68a	19.32 ± 0.46b	52.31 ± 0.43b
IRWH + Mulch (Mu) + Org + Inorg fertilizer	8.84 ± 0.64a	1.14 ± 0.04b	14.57 ± 0.11a	13.14 ± 0.55c	0.12 ± 0.41a	0.13 ± 0.10c	17.79 ± 0.28b	63.74 ± 0.36b
Spinach								
Con + Inorg + Org fertilizer	12.29 ± 0.53a	3.18 ± 0.16a	26.96 ± 0.55a	21.18 ± 0.53a	0.76 ± 0.12a	0.43 ± 0.48a	90.44 ± 0.63a	1094.30 ± 0.43a
IRWH + inorg fertilizer	15.64 ± 1.31b	3.07 ± 0.79a	25.77 ± 0.91a	21.42 ± 0.97a	1.75 ± 0.95b	0.96 ± 1.28b	115.54 ± 0.77b	944.50 ± 0.71a
IRWH + Inorg + Org	13.71 ± 0.65a	2.99 ± 0.45a	24.49 ± 0.54a	25.50 ± 0.08b	0.81 ± 0.46a	0.50 ± 0.51a	61.25 ± 0.35c	1600.28 ± 0.40a
IRWH + Mu	16.73 ± 0.30b	3.24 ± 0.67a	28.41 ± 0.01b	21.00 ± 0.14a	0.91 ± 0.19a	0.40 ± 0.46a	111.06 ± 0.12a	1730.08 ± 0.12a
IRWH + Mu + Org + Inorg fertilizer	12.14 ± 0.30a	2.34 ± 0.02a	25.29 ± 0.37a	16.38 ± 0.14c	0.54 ± 0.29a	0.28 ± 0.48c	71.94 ± 0.08c	1064.95 ± 0.06a
SEASON 2: Beetroot								
Con + Inorg + Org fertilizer	8.74 ± 0.54a	0.89 ± 0.11b	17.33 ± 0.20b	11.82 ± 0.23b	0.40 ± 0.41a	0.33 ± 0.31a	28.20 ± 0.28a	267.37 ± 0.52a
IRWH + Inorg fertilizer	10.11 ± 0.43b	0.75 ± 0.67a	20.05 ± 0.51b	13.72 ± 0.24a	0.28 ± 0.20b	0.17 ± 0.04b	32.11 ± 0.16b	600.25 ± 0.35b
IRWH + Inorg + Org fertilizer	7.27 ± 0.16a	0.75 ± 0.39a	17.73 ± 0.33a	11.33 ± 0.28b	0.34 ± 0.29c	0.18 ± 0.10	23.12 ± 0.17c	357.21 ± 0.30c
Spinach								
Con + Inorg + Org fertilizer	23.62 ± 0.01a	2.22 ± 0.01a	28.62 ± 0.68a	22.98 ± 0.22a	0.87 ± 0.11a	0.53 ± 0.31a	27.42 ± 0.59a	557.18 ± 0.25a
IRWH + /Inorg fertilizer	26.17 ± 0.35b	3.06 ± 0.51b	31.41 ± 0.13b	24.11 ± 0.52b	1.07 ± 0.54b	0.63 ± 0.55a	26.25 ± 0.35b	1462.10 ± 0.14b
IRWH + Inorg + Org	23.36 ± 0.26a	2.60 ± 0.54a	24.84 ± 0.38c	20.33 ± 0.11c	1.14 ± 0.55b	0.74 ± 0.68b	29.31 ± 0.43c	659.25 ± 0.35c
Sweet potato								
IRWH + Inorg fertilizer	3.62 ± 0.01a	2.16 ± 0.39a	7.47 ± 0.69a	5.82 ± 0.04a	0.24 ± 0.20a	0.18 ± 0.24a	6.32 ± 0.45a	74.30 ± 0.43a
IRWH + Inorg + Org fertilizer	4.18 ± 0.37a	1.09 ± 0.19b	6.53 ± 0.09b	7.41 ± 0.54b	0.16 ± 0.17b	0.02 ± 0.08b	3.42 ± 0.59b	7.16 ± 0.22b
IRWH + Mu + Inorg fertilizer	4.00 ± 0.69a	0.86 ± 0.04b	6.48 ± 0.04b	6.29 ± 0.03b	0.24 ± 0.27a	0.02 ± 0.07b	3.06 ± 0.09b	19.00 ± 0.07c
IRWH + Mu + Org + Inorg fertilizer	4.14 ± 0.65a	1.29 ± 0.38b	6.91 ± 0.45b	6.89 ± 0.66b	0.31 ± 0.24c	0.24 ± 0.36c	3.47 ± 0.67b	12.48 ± 0.67d

7.3.2 Effect of season, agronomic treatments and water use technology on the proximate composition and mineral content of different vegetables

Data in Table 37 and Table 38 further indicate that agronomic treatment and water use technology are not the only factors that affected the nutrient content of the vegetables, season had an effect as well. The effect of season on the nutrient content of vegetables was investigated in beetroot and spinach. Generally, beetroot and spinach produced in the second season had higher nutrient content than the vegetables produced in the first season (wet season).

Table 37 Effect of season, and agronomic treatments and water use on technology on the proximate composition of different vegetables (g/100 g, dry matter basis)

Treatment		Mean ± SD							
		Ash		FAT		NDF		Protein	
		First	Second	First	Second	First	Second	First	Second
Beetroot (Con +Inorg + Org)		7.74 ± 0.67	7.56 ± 0.18	0.84 ± 0.33	0.61 ± 0.52	12.82 ± 0.6	15.83 ± 0.48	11.53 ± 0.35	13.44 ± 0.69
Beetroot (IRWH + Fert)		7.81 ± 0.07	10.11 ± 0.43	0.59 ± 0.18	0.76 ± 0.67	13.73 ± 0.32	20.06 ± 0.52	9.82 ± 0.12	13.72 ± 0.24
Beetroot (IRWH +Inorg + Org)		6.84 ± 0.4	7.27 ± 0.16	0.51 ± 0.23	0.76 ± 0.39	13.45 ± 0.01	17.73 ± 0.34	6.09 ± 0.53	11.33 ± 0.28
P value	Treatment	0.000		0.000		0.000		0.000	
	Season	0.000		0.000		0.000		0.000	
	T*S	0.000		0.000		0.000		0.000	
Spinach (Con +Inorg + Org)		12.29 ± 0.53	23.62 ± 0.01	3.19 ± 0.16	2.23 ± 0.01	26.96 ± 0.55	28.63 ± 0.69	21.19 ± 0.54	22.98 ± 0.23
Spinach (IRWH + Fert)		15.64 ± 1.31	26.18 ± 0.35	4.07 ± 0.79	3.06 ± 0.51	25.78 ± 0.91	31.42 ± 0.13	21.43 ± 0.97	24.11 ± 0.52
Spinach (IRWH +Inorg + Org)		13.71 ± 0.65	23.37 ± 0.26	3 ± 0.45	2.61 ± 0.54	24.49 ± 0.54	24.84 ± 0.38	25.51 ± 0.08	20.33 ± 0.11
P value	Treatment	0.045		0.010		0.001		0.021	
	Season	0.000		0.045		0.000		0.000	
	T*S	0.087		0.411		0.132		0.001	

Table 38 Effect of season, and agronomic treatments and water use technology on the mineral content of different vegetables (dry matter basis)

Treatment		Mean ± SD							
		Ca (%)		P (%)		Zn (ppm)		Fe (ppm)	
		First	Second	First	Second	First	Second	First	Second
Beetroot									
Con +Inorg + Org		0.45 ± 0.50	0.41 ± 0.42	0.20 ± 0.18	0.33 ± 0.31	36.01 ± 0.01	28.20 ± 0.28	454.37 ± 0.52	267.37 ± 0.52
IRWH + Fert		0.56 ± 0.68	0.29 ± 0.21	0.38 ± 0.48	0.18 ± 0.05	38.22 ± 0.31	32.12 ± 0.16	156.09 ± 0.12	600.25 ± 0.35
IRWH +Inorg + Org		0.54 ± 0.61	0.35 ± 0.29	0.38 ± 0.47	0.18 ± 0.10	27.05 ± 0.08	23.12 ± 0.17	136.08 ± 0.12	357.22 ± 0.30
P value	Treatment	0.000		0.000		0.000		0.000	
	Season	0.000		0.000		0.000		0.000	
	T*S	0.000		0.000		0.000		0.000	
Spinach									
Con +Inorg + Org		0.77 ± 0.13	0.66 ± 0.06	0.43 ± 0.49	0.32 ± 0.18	90.45 ± 0.63	27.42 ± 0.59	1094.30 ± 0.43	557.18 ± 0.25
IRWH + Fert)		1.75 ± 0.95	1.08 ± 0.54	0.97 ± 1.28	0.63 ± 0.55	115.55 ± 0.77	26.25 ± 0.35	944.51 ± 0.71	1462.10 ± 0.14
IRWH +Inorg + Org		0.82 ± 0.46	1.14 ± 0.55	0.51 ± 0.52	0.75 ± 0.69	61.25 ± 0.36	29.31 ± 0.44	1600.29 ± 0.41	659.25 ± 0.35
P value	Treatment	0.000		0.124		0.000		0.000	
	Season	0.000		0.000		0.000		0.000	
	T*S	0.000		0.258		0.000		0.000	

7.3.3 Effect of season, agronomic treatment and water use technology on the Provitamin-A content of different vegetable types

Table 39 and Table 40 show the effect of agronomic treatment, water use technology and season on the Provitamin-A content of various vegetables. Generally, Provitamin-A content varied among the vegetables assessed. In the first season, the Provitamin-A content of both cabbage and beetroot did not significantly change because of agronomic treatment and water use technology.

However, in the second season, a significant variation in Provitamin-A content was observed among the treatments for all the vegetable types tested. In the second season, when spinach and beetroot were cultivated under the CON in combination with organic and inorganic fertilisers, there was a significant increase in Provitamin-A content. This implies that the Provitamin-A content of spinach and beetroot increases when the two types of vegetables are cultivated under drought stress conditions. The opposite was true for sweet potato, as the Provitamin-A content was highest when the vegetable was produced under the IRWH technology in combination with inorganic fertiliser.

Among the different types of vegetables investigated in the study, beetroot only was planted in the two seasons. Therefore, the effect of season on the Provitamin-A content of vegetables was determined for beetroot only. Planting season significantly affected carotenoid content, including Provitamin-A, of beetroot. Overall, higher levels of lutein, zeaxanthin and Provitamin-A were obtained from beetroot cultivated in the second season. Lutein and zeaxanthin are types of carotenoid pigments that do not possess Provitamin-A activity.

Table 39 Effect of agronomic treatment and water use technology on the carotenoid content of different vegetables (µg/g, dry basis)

Vegetable	Treatment	Mean ± SD						
		Lutein	Zeaxanthin	β-Cryptoxanthin	13-cis-BC	BC	9-cis-BC	Provitamin A
Season one								
Cabbage	IRWH + Mu	0.072 ± 0.003	0.309 ± 0.001	0	0.218 ± 0.001	0.232 ± 0.002	0.218 ± 0.001	0.668 ± 0.005
	IRWH +Mu + Org + Inorg	0.061 ± 0.002	0.268 ± 0.005	0	0.215 ± 0.005	0.225 ± 0.006	0.215 ± 0.005	0.655 ± 0.015
	IRWH + inorg	0.090 ± 0.001	0.381 ± 0.004	0	0.223 ± 0.001	0.234 ± 0.000	0.220 ± 0.001	0.676 ± 0.001
	Con+Inorg + Org	0.040 ± 0.002	0.178 ± 0.005	0	0.233 ± 0.011	0.239 ± 0.011	0.233 ± 0.011	0.704 ± 0.034
	IRWH + Inorg + Org	0.084 ± 0.002	0.394 ± 0.028	0	0.240 ± 0.023	0.248 ± 0.024	0.240 ± 0.023	0.727 ± 0.070
	P value	**0.000**	**0.000**	**-**	**0.422**	**0.111**	**0.617**	**0.083**
Beetroot	Con + Inorg + Org	0.064 ± 0.001	0.289 ± 0.010	0	0.205 ± 0.001	0.237 ± 0.000	0.204 ± 0.000	0.646 ± 0.001
	IRWH + Mu	0.050 ± 0.005	0.214 ± 0.021	0	0.237 ± 0.026	0.267 ± 0.031	0.237 ± 0.028	0.741 ± 0.085
	IRWH + Mu + Org + Inorg	0.035 ± 0.001	0.158 ± 0.002	0	0.216 ± 0.005	0.226 ± 0.005	0.217 ± 0.005	0.659 ± 0.014
	IRWH + inorg	0.042 ± 0.001	0.192 ± 0.005	0	0.201 ± 0.004	0.211 ± 0.003	0.199 ± 0.004	0.610 ± 0.011
	IRWH + Inorg + Org	0.053 ± 0.006	0.214 ± 0.025	0	0.221 ± 0.014	0.248 ± 0.016	0.222 ± 0.015	0.691 ± 0.045
	P-value	**0.000**	**0.000**	**-**	**0.129**	**0.106**	**0.141**	**0.160**
Season two								
Beetroot	IRWH + Inorg + Org	0.098 ± 0.004	0.443 ± 0.029	0.111 ± 0.005	0.231 ± 0.004	0.325 ± 0.005	0.226 ± 0.006	0.838 ± 0.018
	IRWH +Inorg	0.160 ± 0.008	0.868 ± 0.072	0.127 ± 0.005	0.280 ± 0.004	0.556 ± 0.014	0.303 ± 0.002	1.203 ± 0.014
	Con + Inorg + Org	0.140 ± 0.012	0.637 ± 0.050	0.132 ± 0.001	0.304 ± 0.000	0.581 ± 0.003	0.307 ± 0.008	1.258 ± 0.004
	P value	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**
Sweet Potato	IRWH + Inorg	0.122 ± 0.013	0.626 ± 0.067	0.163 ± 0.005	6.321 ± 0.229	30.789 ± 0.889	0.977 ± 0.080	38.169 ± 0.738
	IRWH + Mu+Inorg	0.000 ± 0.000	0.143 ± 0.005	0.135 ± 0.010	0.664 ± 0.040	3.568 ± 0.228	0.272 ± 0.006	4.571 ± 0.279
	IRWH + Inorg+Org	0.041 ± 0.002	0.281 ± 0.008	0.403 ± 0.052	2.127 ± 0.009	14.041 ± 0.516	0.490 ± 0.014	16.860 ± 0.537
	IRWH + Mu + Org + Inorg	0.040 ± 0.001	0.252 ± 0.008	0.136 ± 0.002	1.823 ± 0.064	12.393 ± 0.013	0.450 ± 0.012	14.734 ± 0.064
	P value	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**
Spinach	Con + Inorg + Org	23.290 ± 0.170	182.941 ± 17.581	0.000 ± 0.000	8.411 ± 0.877	53.157 ± 2.061	10.547 ± 0.359	72.115 ± 3.298
	IRWH + Mu	21.725 ± 0.140	144.776 ± 4.689	0.000 ± 0.000	6.393 ± 0.046	38.879 ± 1.258	7.093 ± 0.951	52.364 ± 2.163
	IRWH + Mu + Org + Inorg	33.958 ± 0.117	207.975 ± 0.416	0.000 ± 0.000	8.455 ± 0.166	49.022 ± 1.249	9.666 ± 0.845	67.143 ± 2.260

Vegetable	Treatment	Mean ± SD						
		Lutein	Zeaxanthin	β-Cryptoxanthin	13-cis-BC	BC	9-cis-BC	Provitamin A
	IRWH + Inorg	24.242 ± 0.403	152.804 ± 3.085	0.000 ± 0.000	5.187 ± 0.181	29.440 ± 1.900	6.840 ± 0.405	41.466 ± 2.485
	IRWH + Inorg + Org	31.653 ± 4.315	259.489 ± 2.022	0.000 ± 0.000	9.342 ± 0.727	73.799 ± 0.870	13.783 ± 0.002	96.924 ± 0.141
	IRWH+Inorg+Org	25.842 ± 0.473	191.179 ± 1.618	0.000 ± 0.000	13.383 ± 0.090	100.787 ± 0.954	21.007 ± 0.040	135.178 ± 0.903
	IRWH+Fert/Inorg	14.698 ± 1.620	95.521 ± 2.747	0.000 ± 0.000	7.017 ± 0.018	44.007 ± 2.588	10.163 ± 0.749	61.186 ± 3.319
	Con+Inorg+Org	35.968 ± 0.540	249.131 ± 16.660	0.000 ± 0.000	17.883 ± 1.880	140.796 ± 3.265	28.823 ± 1.705	187.501 ± 6.849
P-value		**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**

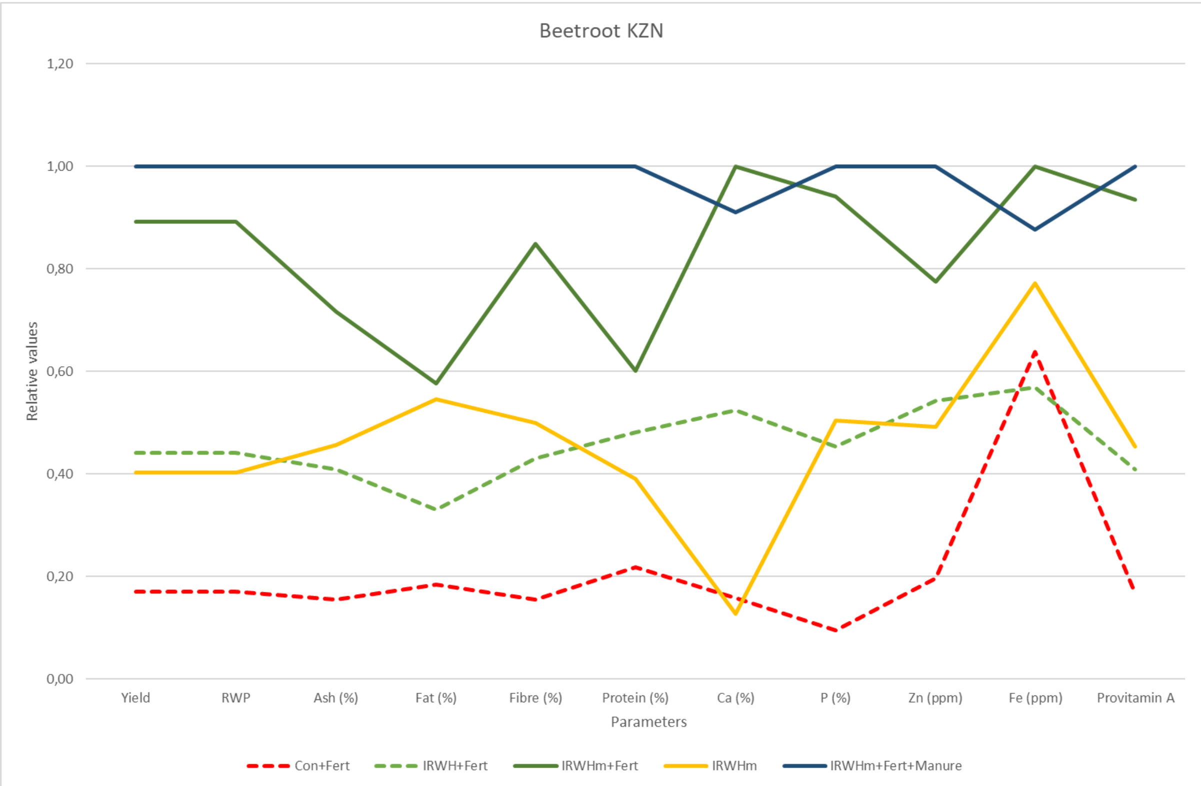
BC= β carotene; Provitamin A= (0.5β-Cryptoxanthin µg/g+13-cis-BC+ BC+9-cis-BC)

Table 40 The effect of season and agronomic treatment and water use technology on the carotenoid content of beetroot (µg/g, dry basis)

	Mean ± SD					
	Lutein		Zeaxanthin		Provitamin-A	
	First	Second	First	Second	First	Second
IRWH + Inorg + Org	0.053 ± 0.006	0.214 ± 0.025	0.098 ± 0.004	0.443 ± 0.029	0.838 ± 0.018	0.691 ± 0.045
IRWH + Fert/Inorg	0.160 ± 0.008	0.868 ± 0.072	0.160 ± 0.008	0.868 ± 0.072	1.203 ± 0.014	0.610 ± 0.011
Con + Inorg + Org	0.064 ± 0.001	0.289 ± 0.010	0.140 ± 0.012	0.637 ± 0.050	1.258 ± 0.004	0.646 ± 0.001
P value Treatment	**0.000**		**0.000**		**0.045**	
Season	**0.000**		**0.000**		**0.000**	
T*S	**0.231**		**0.0590**		**0.030**	

7.3.4 Relative values of yield and nutrient content of different vegetable types grown under different agronomic treatments and water use technologies

Figure *24* to Figure 27 show relative values of yield and nutrient content of different vegetable types grown in Swayimane (KZN) and Gladstone (FS) under different agronomic treatments and water use technologies. As stated earlier, the treatment combination, CON and fertilizer addition was the control. Results show that, relative to the control, for all the types of vegetables investigated in the two provinces, KZN and FS, IRWH technology combined with different agronomic treatment resulted in higher yield, nutrient content, including the micro-nutrient Provitamin-A and minerals.



Con+Fert	=	Conventional Rainfed technology with fertilizer addition
IRWH+Fert	=	In-field rainwater harvesting with fertilizer addition
IRWHHm	=	In-field rainwater harvesting with mulch
IRWHm+Fert	=	In-field rainwater harvesting with mulch and fertilizer addition
IRWHHm+Fert+manure	=	In-field rainwater harvesting with mulch and fertilizer and manure addition

Figure 24 Relative values of yield and nutrient content for beetroot grown at Swayimane under different agronomic treatments and water use technologies.

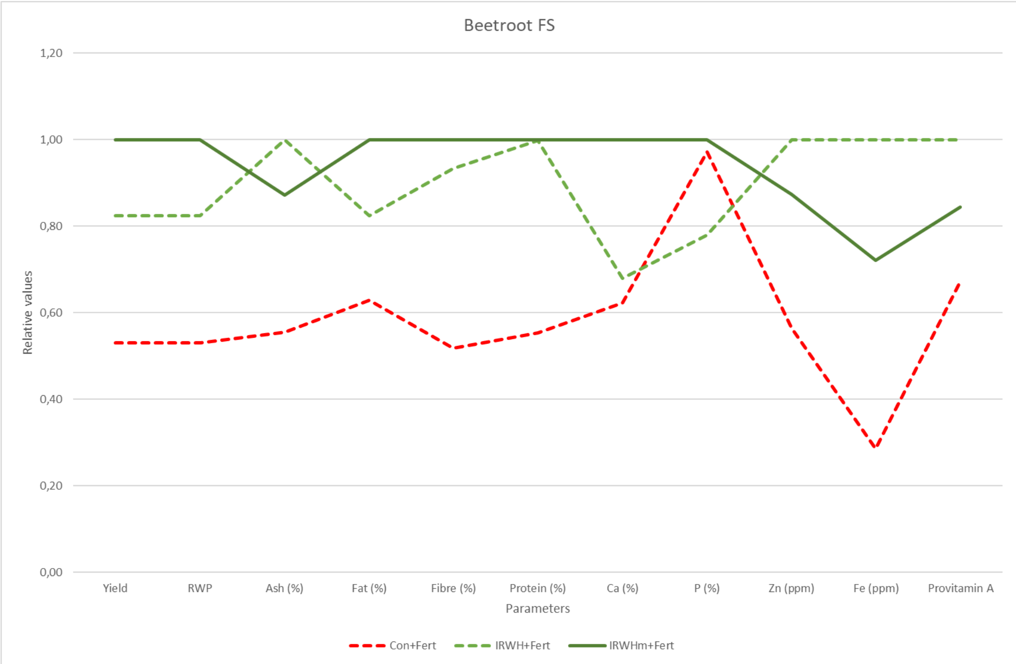


Figure 25 Relative values of yield and nutrient content for beetroot grown in Gladstone under different agronomic treatments and water use technologies.

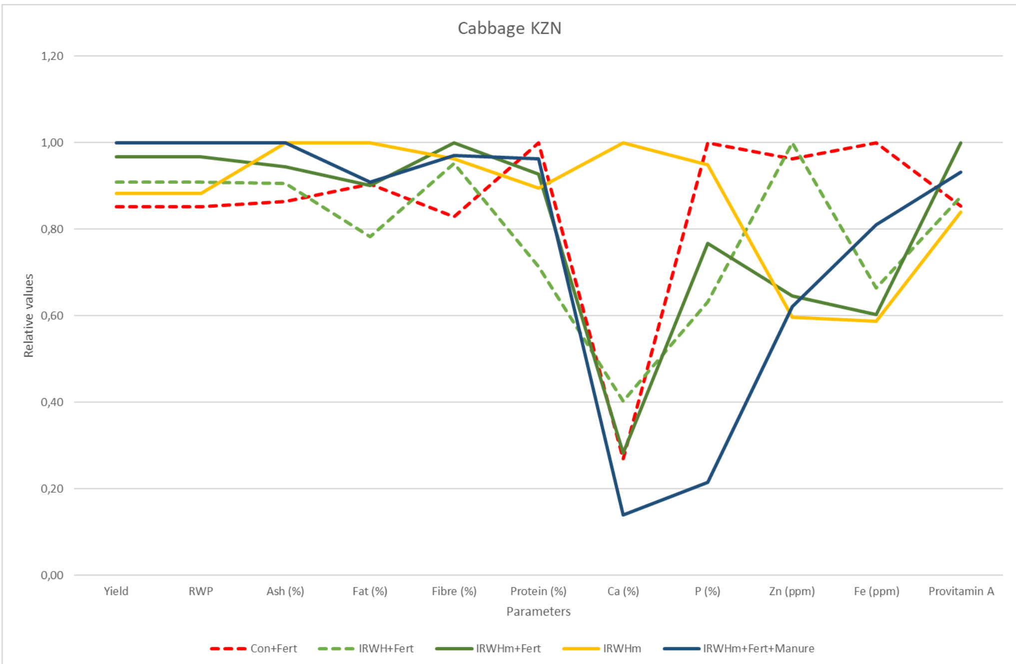


Figure 26 Relative values of yield and nutrient content for cabbage grown in Swayimane under different agronomic treatments and water use technologies.

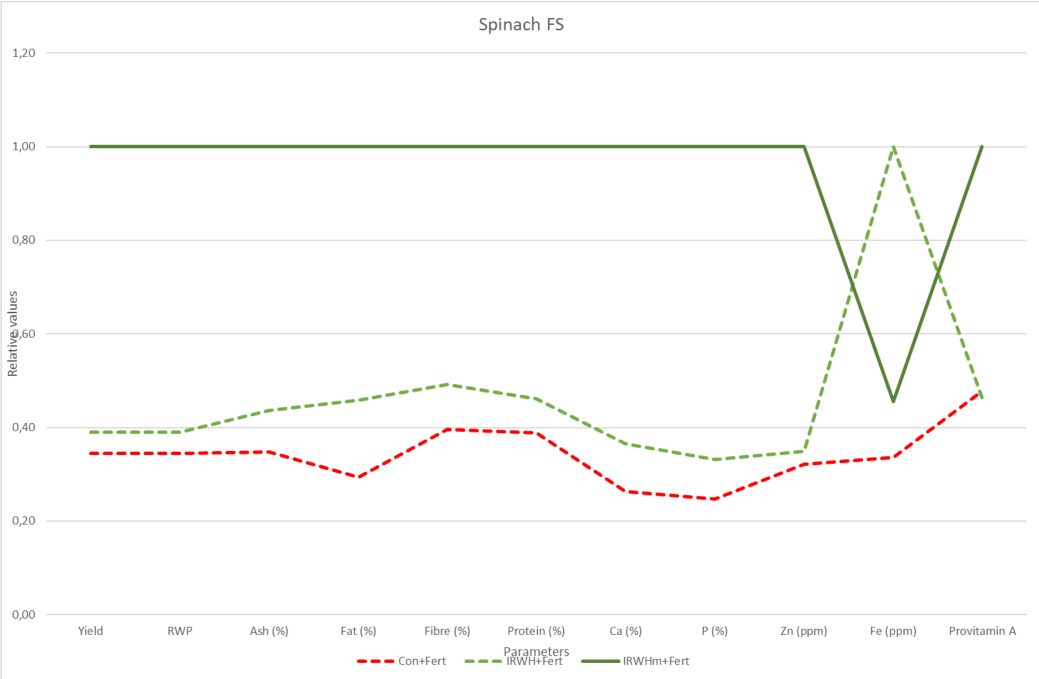


Figure 27 Relative values of yield and nutrient content for spinach grown in Gladstone under different agronomic treatments and water use technologies.

7.4 DISCUSSION

The study demonstrates that agronomic treatments, season and water use technology have different effects on the nutrient of different types of vegetables.

Beetroot: IRWH combined with mulching resulted in higher concentrations of ash and fibre. CON in combination with in organic and inorganic fertiliser resulted in a significantly higher iron content.

Cabbage: The CON combined with the organic and inorganic fertiliser significantly enhanced zinc and iron content of the cabbage. In contrast, significantly higher concentration of ash and fibre was observed in cabbage cultivated under IRWH combined with mulching relative to either of the two water use technology each combined with the different agronomic treatments.

Spinach: The IRWH combined with mulching or inorganic fertiliser significantly improved the ash content of spinach. Furthermore, cultivation of the spinach under the IRWH in combination with inorganic fertiliser resulted in higher contents of zinc.

Sweet potato: The IRWH combined with inorganic fertiliser resulted in sweet potato with a significantly higher fibre, zinc and iron content.

Generally, the study results indicate that, for all the types of vegetables investigated, IRWH technology combined with different agronomic treatment enhanced nutrient content, including total mineral content (ash) and individual minerals, such as zinc and iron) of the vegetables.

Generally, vegetables produced in in the second season (dry) had higher nutrient concentration than the vegetables produced in the first season (wet season). However, this finding is attributed to nutrient dilution by a larger biomass (yield) obtained in the first season relative to the biomass obtained in the second season.

The results indicated that, general, during the second season (dry season), spinach, and beetroot cultivated under the CON in combination with organic and inorganic fertilisers had a significantly highest Provitamin-A content.

7.5 CONCLUSION AND RECOMMENDATION

The main finding of the study with regard to the food and nutrition contribution of CSTs is that the proximate composition, individual mineral content, and Provitamin-A content of different vegetables can be enhanced by adopting IRWH combined with different agronomic treatments, especially including mulching as one of the treatment combinations. Further, investigations with more vegetable types and treatment combinations should be conducted to establish the most recommendable best farming practice for the target farmers.

8 MARKET AND FOOD VALUE CHAINS

8.1 INTRODUCTION

Marketing is one of the key aspects of any business. It is important in building customer relationships as well as creating product awareness. It can also be termed as a necessary activity that encompasses the entire business and is vitally important to sound business health. Without an effective marketing strategy, you stand to lose customers which equates to revenue loss and no growth, therefore the heart of every business success lies in its marketing (Botha, Van Staden, Koatla, Anderson and Joseph, 2014). It can be further mentioned that marketing has been a challenging task for smallholder farmers that come from the rural areas since the new dispensation. A major reason why smallholder farmers (SHFs) with surplus production remain trapped in poverty is the lack of access to markets (Magingxa, Alemu and Van Schalkwyk, 2009). Almond and Hainsworth (2005) argue that field extension agents are ill-informed about local markets and often do not provide the necessary training and assistance so that SHFs can gain access to information about them (Von Loeper, Musango, Brent and Drimie, 2016). Ortmann and King (2007) effectively sum up the challenges facing SHFs in SA as being: (i) low levels of education and literacy; (ii) no access to technology; (iii) insecure land tenure; (iv) high transaction costs (i.e. no access to information and communication, as well as poor roads and long travel distances); (v) no access to credit and insurance; (vi) no access to inputs and services; (vii) no access to markets; and (viii) missing support systems, such as socially organised co-ops and extension services.

The contribution of smallholder agriculture to economic development can be realised if smallholder farmers are linked to high-value markets in the agricultural supply chain so that they can benefit from these lucrative markets. In recent times, there has been high demand for high-value agricultural products, along with more stringent food safety and quality requirements and the emergence of supply-chain integration. All these changes forebode the potential exclusion of small-scale producers from the growing markets. The inability of smallholder farmers to engage in lucrative markets is great cause for concern. Agriculture is becoming increasingly integrated and smallholder farmers are often disadvantaged, and actions must be taken to help them draw profit from their integration into markets (Bienabe, Coronel, Le Coq and Liagre, 2004).

8.2 OBSERVED SITUATION IN THE STUDY AREAS

Both areas studied find it difficult to access these lucrative markets, despite being relatively close to urban areas that have large retailers and wholesalers for fresh produce. The farmers plant vegetables that are needed by these markets, such as cabbage, spinach, sweet potato, maize and madumbi, but they still cannot access the markets. A few successful smallholder farmers sell their produce to formal supermarket retailers and wholesalers such as Spar, Shoprite, New Port and Save across SA, while the majority of farmers simply produce for consumption and sell any surpluses to nearby community members if need be. In Swayimane, there are weak market networks and links, which results in a high proportion of co-operatives not selling their vegetable produce to large formal markets (Khumalo, 2014). As for Gladstone, there are no existing markets apart from informal markets where the buyer sometimes sets the seller prices instead. Many Swayimane smallholder farmers sell their produce informally to middlemen, neighbours, pension markets, and street vendors on the roadside in Pietermaritzburg, Dalton and Wartburg. Other available markets for smallholder vegetable farmers in and around the area are government schools that have feeding schemes, Schools with Boarders in the Wartburg area, fresh produce markets, and churches. Gladstone farmers mainly their sell their produce to informal markets (street vendors) or locally to those who are interested.

According to Sikwela (2013), it is easier for smallholder farmers to enter the informal markets (spot mechanisms) rather than formal markets (Contract signed) such as supermarkets. Informal markets are mainly characterized by the fact that the sellers can directly access the buyers (who are mainly the street vendors). Transaction costs are one of the major barriers to entry that smallholder farmers in Swayimane encounter (Khumalo, 2014). The transaction costs include transportation costs and costs of gathering market information, searching for trade partners, contract enforcement and the distance to formal markets (Ortmann & King, 2007). As a result, many of the farmers prefer to sell their produce at the farm gate, minimize the costs of transaction. In addition, clean safe water for performing daily activities at the start-up level of the value chains is scarce, making it difficult to enter formal markets because of constraints faced to practice value addition practices.

Despite all these challenges, not much research has been done in these areas because of a lack of resources. Table 41 covers some research that has been done by scientists in one of the areas that the study focused on (Swayimane).

Table 41 Smallholder Market Access Index indicators for Swayimane Markets (Adapted: National Agricultural Marketing Council, 2016)

Sub-groups	Indicators	Informal market	Formal market
Input and output market channels	Distance to nearest input market (km)	13 km	22 km
	Distance to nearest output market (km)	< 5 km	13 km
	Proximity to town (km)	13 km	13 km
Value addition	Value addition (add value/does not add value)	Does not add value	Value addition is practised.
Physical infrastructure	State of road to nearest market	Poor	Satisfactory
	Storage facility (have/not have on-farm facility)	No storage facility	Must have a storage facility on the farm
	Cell phone (have/not have cell phone)	Many do have cell phones, but some do not have.	Do have cell phone. (Cell phone is needed for communication)
Market information	Market information (have/not have access)	No access to market information	Access to market information
Training and advisory services	Extension service (have/not have access)	Access to training and advisory services	Access to training and advisory services

Since there was no reports that focused mainly on Gladstone, similar to the research done by NAMC at Swayimane, the team decided to follow the very trend and the results are shown in Table 42.

Table 42 Smallholder Market Access Index indicators for Gladstone

Sub-groups	Indicators	Informal market	Formal market
Input and output market channels	Distance to nearest input market (km)	22.3 km	79.4 km
	Distance to nearest output market (km)	Sell within the village	76.4 km
	Proximity to town (km)	22.3 km	76 km
Value addition	Value addition (add value/does not add value)	Does not add value	Value addition is practised.
Physical infrastructure	State of road to nearest market	Poor (gravel)	Satisfactory (gravel first then tar)
	Storage facility (have/not have on-farm facility)	No storage facility	Must have a storage facility on the farm (but realistically is difficult for farmers to have storage)
	Cell phone (have/not have cell phone)	Many do have cell phones, but some do not have.	Do have cell phone. (Cell phone is needed for communication)
Market information	Market information (have/not have access)	No access to market information	Access to market information
Training and advisory services	Extension service (have/not have access)	Access to training and advisory services	Access to training and advisory services

Distances that have to be covered by farmers from both areas differs a lot. In Swayimane, farmers can access both informal and formal markets within a distance of between less than five and twenty-two kilometres, but as for farmers of Gladstone, they have cover between zero (not guaranteed market) and eighty kilometres. Furthermore, distance from farmers gates and the main road (which is tar road) is closer to their farms as compared to seven kilometres that have to be travelled by Gladstone farmers to reach the main road that links them with the town. Based on the information, it is clear that Gladstone farmers incurred more transportation costs as compare to Swayimane farmers.

8.3 MARKET-RELATED INSTITUTIONAL ARRANGEMENTS

According to Eaton *et al.* (2008), institutional arrangements can be defined as a set of rules or agreements governing the activities of a specific group of people pursuing a certain objective.

Moreover, Eaton *et al* (2008) state that the institutional arrangements involve agreements to exchange or coordinate goods or services. Table 43 shows a description of market-related institutional arrangements that were suggested and adopted for the smallholder farmers in the selected study areas.

Table 43 Description of market-related institutional arrangements for smallholder farmers in the selected study areas

Institutional arrangements	Formal/ Informal	Relationship or duration	Co-ordination of activities	Transaction costs	How do you resolve conflict?	Functional/ dysfunctional	If dysfunctional, how was market access suppressed?	Evaluation: Remain, Remove/ Improve
Spot markets	Informal	Anonymous and once off/ repetitive	Individual	Very low	Negotiations between buyer and seller	Functional/ dysfunctional	Dysfunctional if there is no common agreement between farmer and traders and there will be no market transaction.	Improve
Contract farming	Formal	Personal and repetitive/ once off	Multilateral	Low	Conflict is resolved by discussions between farmer and processor or marketing firm and mutual agreement is made. If there	Functional	N/A	Remain

Institutional arrangements	Formal/ Informal	Relationship or duration	Co-ordination of activities	Transaction costs	How do you resolve conflict?	Functional/ dysfunctional	If dysfunctional, how was market access suppressed?	Evaluation: Remain, Remove/ Improve
					is no agreement, conflict is handled in court.			
Producer Organizations	Formal	Personal and repetitive	Multilateral	Low/ high	Negotiations between the different producers	Functional/ dysfunctional	If there are large quality differences, the higher quality farmers will have less interest in allowing a producer organization to negotiate contracts, or in selling collectively with lower quality farmers.	Remain

Institutional arrangements	Formal/ Informal	Relationship or duration	Co-ordination of activities	Transaction costs	How do you resolve conflict?	Functional/ dysfunctional	If dysfunctional, how was market access suppressed?	Evaluation: Remain, Remove/ Improve
Contract farming with Producer organizations	Formal	Personal and repetitive	Bilateral	Low	Negotiations between processors/ marketing firms and producer organizations	Functional	N/A	Remain

According to Eaton, Meijerink, Bijman and Belt (2007), two alternative institutional arrangements for production and marketing of fresh vegetables can now be observed, next to the 'default' option for most farmers of spot markets: (i) producers' organisations (POs) and (ii) contract farming (or combinations of the two), which is important for high-value, high-quality crops (marketed to supermarkets and export markets).

8.4 ROLE OF THE SMALLHOLDER HORTICULTURE EMPOWERMENT AND PROMOTION (SHEP) ON MARKET ACCESS AND FOOD VALUE CHAINS

The Smallholder Horticulture Empowerment and Promotion (SHEP) approach is an intervention that develops both technical and managerial capacity of smallholder horticultural farmers to practise market-oriented farming. SHEP achieves this by the farmers conducting market surveys themselves, promoting gender equality and establishing business links between farmers and business service providers. The uniqueness of SHEP is that it uses psychological empowerment to develop and keep farmers motivated to acquire production and value addition knowledge, along with management skills that are essential to succeed in the competitive market. SHEP provides necessary training to the farmers, which directly leads to them being empowered, resulting in social capital improvements and market access (Figure 28).

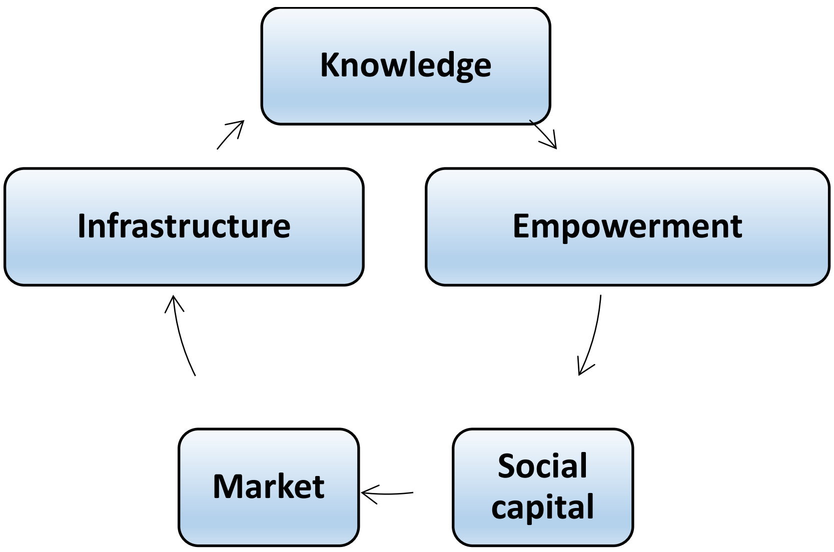


Figure 28 Building assets for market access (*Source*: Cornel SMART Project Presentation, 2014).

8.4.1 Smallholder horticulture empowerment and promotion (SHEP) approach

SHEP is a result of joint efforts between the Japanese and Kenyan governments to shift the mind set of smallholder farmers from "grow and sell" to "grow to sell" (JICA, 2014). JICA (2014) further states that the SHEP approach is an intervention that develops both technical and managerial capacity of smallholder horticultural farmers to practise market-oriented farming.

8.4.2 SHEP's four essential steps

In order to successfully implement SHEP, there are four essential steps that must be carried out by the SHEP implementers. The following section provides a brief description of what each step entails.

8.4.2.1 Step 1. Share goals with farmers

The SHEP implementers organize a sensitization workshop to share the goal of SHEP with the beneficiary farmers. The farmers are made aware that the intervention does not provide material or financial assistance to the farmers. The time frame of the training is also shared along with the details of the SHEP training course.

8.4.2.2 Step 2. Farmers' awareness is raised

In this step, the farmers are made aware of their current situations as well as other opportunities that horticultural farming can offer to them. The SHEP implementers, using exercises such as baseline surveys and market surveys, open the farmer's horizon for horticultural farming as a business. The baseline survey gives the farmers opportunities to look at their current situations in terms of production, income and agricultural techniques. The farmers also conduct market surveys with the guidance of the SHEP implementers. The purpose of the SHEP's farmer-initiated market survey is to make farmers understand how markets operate and what the demands of the markets are from producers. Furthermore, by conducting the market survey themselves, the farmers network with various market players to broaden their interpersonal networks.

8.4.2.3 Step 3. Farmers make decisions

After the farmers are made aware of the business opportunities available to them, they must make important decisions about their horticultural farming business. Those decisions include for whom they must produce, what to produce, when to produce and the quality of the produce. In this step, a target crop selection exercise is conducted so that the farmers are aware of which specific types of crops are demanded by the market, and they collectively agree to produce and sell those crops. The SHEP implementers must help the farmers to make the right decisions although they are not to make the decisions for the farmers. A crop calendar is also made to allow the farmers to plan as a group on production and marketing of targeted crops.

8.4.2.4 Step 4. Farmers acquire skills

This is the final step of the SHEP intervention and in this step, farmers are imbued with knowledge and skills that are essential for producing the target crops demanded by the market. The SHEP implementers along with the extension officer provide the contents of the technical training and in-field trainings are conducted to provide the farmers with skills and knowledge necessary for the practical production of the selected target crops that are demanded by the markets. After this step a process of monitoring and evaluation is conducted using participatory end-line surveys.

8.5 SUMMARY AND RECOMMENDATIONS

The success of every business can be attributed to efforts that were put in place by the owner of the business. Despite the efforts, there are challenges that make it very difficult for business to prosper; one such a challenge is access to markets. Farmers are producing quality products that can easily enter market, but challenges they are facing is that they are not producing at a large scale especially Gladstone farmers.

It is easier for smallholder farmers to enter the informal markets rather than formal markets such as supermarkets. Transaction costs are one of the major barriers to entry that smallholder farmers encounter. These costs include costs of accessing market information, contract enforcement, transportation costs and the distance to formal markets. Therefore, many of the smallholder farmers sell at farmgate to reduce transaction costs. Informal markets are mainly characterized by the fact that the sellers can directly access the buyers who are mainly the street vendors. To enter the formal markets, farmers are forced to work directly with middlemen whom farmers see them as people who are making profit despite them not doing much work. The Project managed to put farmers in touch with informal traders within the nearby towns who normally buy from them at a good price as compared to what was given to them by the middlemen in the formal markets.

This study recommends an approach called the Smallholder Empowerment and Promotion (SHEP) to improve market access and food value chains in the selected study areas. SHEP is a result of joint efforts between the Japanese and Kenyan governments to shift the mind set of smallholder farmers from "grow and sell" to "grow to sell". The intervention develops both technical and managerial capacity of smallholder horticultural farmers to practise market-oriented farming. Farmers are trained on how to conduct markets assessments and how to produce the crops demanded by the market and the required time. For successful implementation of SHEP, there are four essential steps to be conducted, the steps are (1) Share goals with farmers, (2) Farmers' awareness is raised, (3) Farmers make decisions and (4) Farmers acquire skills.

9 CONCLUSIONS AND RECOMMENDATIONS

9.1 SUMMARY

This 4-year project (K5 NUMBER: K5/2555/4) was awarded to address water use for food and nutrition security at the start-up stage of food production in KwaZulu-Natal and Free State. The rationale for the project was the food and nutrition deficit of the very poor, where poverty and food insecurity are expressed by an endless cycle of malnutrition and poor societal and economic development. The study's objectives were:

1 Conduct a detailed literature review of techniques and practices (homestead-, community- and school gardens) to improve water use for food and nutrition security at the start-up stage of food value chains for household food security and livelihoods enhancement in rural environments.
2 Describe and analyse the current natural resources.
3 Identify and select climate smart technologies (CSTs) and practices to improve water use for improved crop production to match dietary and nutrient needs.
4 Demonstrate and implement selected technologies for improved production at homestead-, community- and school gardens in the selected areas for improved households and livelihoods enhancement.
5 Evaluate, monitor and analyse water use for food and nutrition security at the start-up stage of food value chains at homestead-, community- and school gardens improved households and livelihoods enhancement.
6 Explore the role of homesteads, community- and school gardens in producing sufficient food and in entering the food value chain for producers in the selected areas for improved households and livelihoods enhancement.
7 Monitor and evaluate the influence of workable institutional arrangements (water, land use security and market players) and organisational structures on incentives and/or disincentives for homestead-, community- and school gardens with the intention of improved households and livelihoods enhancement.
8 Develop guidelines on best management practices to improve water use. Develop guidelines for security at the start-up stage of food value chains for improved households and livelihoods enhancement.

A mixed-methods research approach was used for this project to attain a comprehensive understanding and observation of performance of the technologies. Monitoring of field trials and the learning of the farmers and extension officers was done. Interventions to improve Provitamin-A access as proxy for food and nutrition security analysis was done by planting vegetables rich in Provitamin-A and assessing the concentration of this substance along each CST treatment applied during planting.

Descriptive analysis; Thematic analysis; Lab based Nutrient as analysis to determine concentrations of minerals and Provitamin-A in planted vegetables was conducted. The major conclusions and recommendations of the study can be organized into three main groups:

❖ **Climate smart technologies (CSTs)**

In Swayimane, results from on-farm demonstration plots showed a considerable increase in yields from homestead garden production and smallholder farming plot through the use of appropriate CSTs. In Swayimane, yields increased by 45% and 55% on the two respective demonstration sites compared to their normal farming practices.

In Gladstone, where only gardens were applicable, the yield increase for spinach at the same sites were 60% and 96%, respectively, indicating the beneficial effect of IRWH which further stopped ex-field runoff completely. The research demonstrated that resource-poor farmers can improve yields and thus incomes through the use of IRWH and sound management practice. It is thus recommended that the technologies be promoted particularly in low-rainfall areas. However, in Gladstone insufficient rainfall is the most limiting factor for crop production to improve their food production and household food security status compared with more naturally higher potential because of the higher rainfall of Swayiname. It is recommended that IRWH should be promoted among farmers due to its proven role in yield improvement thus allowing potential sales due to the surplus and better food and nutrition availability for

- **Institutional arrangements**

Farming, particularly smallholder farming requires resilience in skills for survival and endurance. Human resources are important in this regard. In both areas of study, older people dominated the groups (older than 40). Frequency of ill-heath was expressed by participants. In both areas of study, the Household food insecurity access scale (HHFIAS) indicated that households experience food insecurity, and that in Gladstone, Free State, the households were more food insecure.

It was also found that farming systems differed in the two sites to water availability, but largely due to land usage. In KwaZulu-Natal, there were smallholdings for farming and food gardens, while in the Free State only food gardens were available to the study. In Swayimane, all community members have very big gardens that can be classified as cropland, based on their size (1-8 ha and more). The large sized land was being used effectively in Swayimane. In Gladstone, only 0.5-1 ha land were utilized. Cropland in the Gladstone has not been utilised for over 30 years due to land resources.

Similarly, both study sites are still governed by traditional leadership. The TA in Swayimane facilitates and manages access to, and the use of communal land, which is ultimately held in trust on behalf of the community. Similarly, in Gladstone the land was in trust by Barolong-Boo-Seleka Traditional Council. In both areas the TAs are consulted on access and use of land. Therefore, implications on interventions in the food gardens and field must be considered. As many other rural and semi-rural areas, loose and non-identifiable arrangements were found for water use in both study areas, indicating a need for intervention. The institutional arrangements were also weak for enterprise development and great intervention will have to be embarked on, based on the findings.

For marketing, there were poor to non-existent institutional arrangements, markets was experience as an "after event". Although farmers in Swayimane were part of co-operatives, these were for primary production and not used for marketing collaboration. This was not surprising, but a confirmation of the poor commercial mindset and lack of empowerment in this regard. No secondary co-operatives existed for there were no marketing committees and crop scheduling was not a concept that was understood. Marketing of crops was uncoordinated and largely at farm gate, through external merchants and traders known as "bakkie/van" traders due to them arriving in loading vans.

- ❖ **Food and Nutrition Security**

Generally, the study results indicate that, for all the types of vegetables investigated, IRWH combined with different agronomic treatment enhanced nutrient content, including total mineral content (ash) and individual minerals, such as zinc and iron) of the vegetables.

Vegetables produced in the second season (dry) had higher nutrient concentration than the vegetables produced in the first season (wet season). However, this finding is attributed to nutrient dilution by a larger biomass (yield) obtained in the first season relative to the biomass obtained in the second season. The results indicated that, generally, during the second season (dry season), spinach, and beetroot cultivated under CON in combination with organic and inorganic fertilisers had a significantly highest Provitamin-A content. The findings demonstrated the effect of agronomic treatments, season and water use technology on the nutrient composition of different types of vegetables:

Beetroot: IRWH combined with mulching resulted in higher concentrations of ash and fibre. The CON in combination with in organic and inorganic fertiliser resulted in a significantly higher iron content.

Cabbage: CON combined with the organic and inorganic fertiliser significantly enhanced zinc and iron content of the cabbage. In contrast, significantly higher concentration of ash and fibre was observed in cabbage cultivated under IRWH combined with mulching relative to either of the two water use technology each combined with the different agronomic treatments.

Spinach: IRWH combined with mulching or inorganic fertiliser significantly improved the ash content of spinach. Furthermore, cultivation of the spinach under the IRWH in combination with inorganic fertiliser resulted in higher contents of zinc.

Sweet potato: IRWH combined with inorganic fertiliser resulted in sweet potato with a significantly higher fibre, zinc and iron content.

9.2 CONCLUSION AND RECOMMENDATION

The main finding of the study is that the proximate composition, individual minerals profile, and Provitamin-A content of different vegetables can be enhanced by adopting IRWH technology combined with different agronomic treatment, especially including mulching as one of the treatment combinations. Further investigations with more vegetable types and treatment combinations should be conducted to establish the most recommendable best farming practice for the target farmers:

- ❖ **Value chains and marketing**

Marketing of crops was uncoordinated, was largely at farm gate, through external merchants and traders known as "bakkie/van" traders due to them arriving in loading vans. Unsurprisingly, both areas studied find it difficult to access these lucrative markets, despite being close to urban areas that have large retailers and wholesalers for fresh produce. This is the outcome of smallholder farming and not occupying a niche market. The crops planted by farmers in both study areas are common, therefore they struggle to attract demand from larger markets. However, a few successes were found where farmers know an external merchant that buys directly from them; a limited few supply to formal supermarket retailers and wholesalers such as Spar. In Swayimane, there are weak market networks and links, which results in a high proportion of co-operatives not selling their vegetable produce to large formal markets. In Gladstone, there are no existing markets apart from informal markets where prices are sometimes set by the buyer instead the seller. Many Swayimane smallholder farmers sell their produce informally to middlemen, neighbours, pension markets and street vendors on the roadside in Pietermaritzburg, Dalton and Wartburg. Other available markets for smallholder vegetable farmers in and around the area are government schools through their feeding schemes. Potential exists in producing niche crops such as Madumbe. An application-based platform has already started buying niche crops from Swayimane. Facilitating market access and improving value chains can be improved. A process adopted from Japan, Smallholder Horticulture Empowerment Promotion (SHEP), has been revitalised and by this project. Extension officers have been trained and refreshed on the process and getting farmers ready. Farmers have been engaged and training has been scheduled in the participating farmer groups. Farmers already benefiting from the SHEP model are being identified for farmer-farmer learning in Swayimane. In the Free State, a SHEP co-ordinator has been identified but was difficult to locate and engage.

The main conclusion of the study shows that IRWH combined with agronomic management practices including mulching increased yields, improved mineral and Provitamin-A in various vegetables. Planting vegetables with the use of IRWH in the first season improve Provitamin-A in sweet potato and various minerals in the other vegetable. It is recommended that water harvest technologies, particularly the IRWH, be up-scaled and supported by extension services and other lead farmers. Increased water availed by the IRWH technology availed more nutrients, hence the improved nutrient profile in the vegetable. Upscaling the use of IRWH is encouraged to be implemented by farmers with the support of extension officers. Increased yields mean farmers can sell more produce for improved income and improve food security and livelihoods. However, institutional arrangements related to water and water should be strengthened to improve access to these resources in order to afford farmers an opportunity to improve their opportunities for income. Market access needs to be improved through improving current value chains and accessing establishing others. The SHEP process is one model that should be strengthened for farmers and extension officers to co-identify opportunities and niche markets for farmers.

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APPENDICES

Appendix 1 Situation analysis of Swayimane village for the implementation of CSTs, practices, crops and farming systems

Long-term climate Knowledge of the climate in the study areas will enable decision makers to: i. make more informed decisions; ii. have a better base to plan from; iii. be able to identify the risks and opportunities that the climate holds for the intended water harvesting practices	Rainfall (total, monthly and seasonal distribution, intensity)	It rains throughout the year in Swayimane and the lowest mean rainfall is received between May and August. **Nagle dam (Ta5)** ✓ The annual rainfall in the 5 BRUs ranged from 694-994 mm. ✓ January is the month with the highest mean rainfall (108 mm). ✓ Rainfall values range from 108 mm in January to 11 mm in June. **Valley of a Thousand hills (VWb5)** ✓ Mean annual precipitation is 836 mm. ✓ January has the highest amount of rainfall 141 mm. ✓ Rainfall values range between 141 mm to 10 mm in June. **KwaGqugquma (Xb7)** ✓ The mean annual precipitation is 889 mm. ✓ The highest mean rainfall is recorded in January (150 mm) and the lowest in June (11 mm). **Mkabele (Yb12)** ✓ Mean annual precipitation is 994 mm. ✓ January is the month with the highest mean rainfall, 152 mm. ✓ Rainfall values range from 152 mm to 18 mm in July. **Bruyn's Hills (Yc21)** ✓ The mean annual precipitation is 926 mm. ✓ The highest mean rainfall is recorded in January (149 mm), while the lowest is recorded in June (15 mm).
	Temperature (min, max, frost days, monthly distribution)	**Nagle dam area (Ta5)** ✓ The annual average temperature in the 5BRUs ranges from 16.9°C-19.1°C. ✓ January is the warmest month with average temperature of 27.5°C. ✓ June and July are the coldest months with an average temperature of 7.3°C. **Valley of a Thousand hills (VWb5)** ✓ Average temperature is 18.4°C. ✓ February is the warmest month with average temperature of 27°C. ✓ July is the coldest month with average temperature of 7°C. **KwaGqugquma (Xb7)** ✓ Average temperature is 17.6°C. ✓ February is the warmest month with average temperature of 26.1°C. ✓ July is the coldest months with an average temperature of 6.8°C. **Mkabele (Yb12)** ✓ Average temperature is 17.4°C.

		✓ February is the warmest month with average temperature of 26.1°C. ✓ July is the coldest months with an average temperature of 6.4°C. **Bruyn's Hills (Yc21)** ✓ Average temperature is 16.9°C. ✓ February is the warmest month with average temperature of 25.3°C. ✓ June and July are the coldest months with an average temperature of 6.4°C.
	Solar radiation	**Nagle dam area (Ta5)** ✓ Minimum in June, with 14.7 MJ m^{-2} day^{-1}. ✓ A maximum of 26.5 MJ m^{-2} day^{-1} is reached in December. **Valley of a Thousand hills (VWb5)** ✓ Minimum in June, with 14.5 MJ m^{-2} day^{-1}. ✓ A maximum of 26.7 MJ m^{-2} day^{-1} is reached in December. **KwaGqugquma (Xb7)** ✓ Minimum in June, with 14.2 MJ m^{-2} day^{-1}. ✓ A maximum of 26.9 MJ m^{-2} day^{-1} is reached in December. **Mkabele (Yb12)** ✓ Minimum in June, with 14.3 MJ m^{-2} day^{-1}. ✓ A maximum of 27.5 MJ m^{-2} day^{-1} is reached in December. **Bruyn's Hills (Yc21)** ✓ Minimum in June, with 14.1 MJ m^{-2} day^{-1}. ✓ A maximum of 27.3 MJ m^{-2} day^{-1} is reached in December.
	Relative humidity	**Nagle dam area (Ta5)** ✓ The average relative humidity is 69%. ✓ The minimum relative humidity is 61% during June and July. ✓ The maximum relative humidity is 74% in January and February. **Valley of a Thousand hills (VWb5)** ✓ The average relative humidity is 69%. ✓ The minimum relative humidity is 62% in July. ✓ The maximum relative humidity is 74% in January and February. **KwaGqugquma (Xb7)** ✓ The average relative humidity is 69%. ✓ The minimum relative humidity is 64% during June and July. ✓ The maximum relative humidity is 74% in January. **Mkabele (Yb12)** ✓ The average relative humidity is 68% ✓ The minimum relative humidity is 63% in July. ✓ The maximum relative humidity is 73% in January. **Bruyn's Hills (Yc21)**

		✓ The average relative humidity is 69%. ✓ The minimum relative humidity is 65% during June and July. ✓ The maximum relative humidity is 73% in January and February.
	Evaporation (total & daily)	**Nagle dam area (Ta5)** ✓ The annual A-Pan evaporation is 1670 mm. ✓ The highest A-Pan evaporation is recorded in Dec (182 mm), while the lowest is recorded in June (92 mm) **Valley of a Thousand hills (VWb5)** ✓ The annual A-Pan evaporation is 1664 mm. ✓ The highest A-Pan evaporation is recorded in Dec (178 mm), while the lowest is recorded in June (93 mm) **KwaGqugquma (Xb7)** ✓ The A-Pan annual evaporation is 1652 mm. ✓ The highest A-Pan evaporation is recorded in Dec (175 mm), while the lowest is recorded in June (93 mm) **Mkabele (Yb12)** ✓ The annual A-Pan evaporation is 1647 mm. ✓ The highest A-Pan evaporation is recorded in Dec (173 mm), while the lowest is recorded in June (93 mm) **Bruyn's Hills (Yc21)** ✓ The annual A-Pan evaporation is 1638 mm. ✓ The highest A-Pan evaporation is recorded in Dec (172 mm), while the lowest is recorded in June (94 mm)
	Conclusion	**Nagle dam area (Ta5)** ✓ The climate capability rating is C6: Moderately restricted growing season due to low temperatures, frost and/or moisture stress. Limited suitable crops which frequently experience yield loss **Valley of a Thousand hills (VWb5)** ✓ The climate capability rating is C2: Local climate is favourable for a wide range of adapted crops and a year round growing season. Moisture stress and lower temperatures increase risk and decrease yields relative to C1. **KwaGqugquma (Xb7)** ✓ The climate capability rating is C2: Local climate is favourable for a wide range of adapted crops and a year round growing season. Moisture stress and lower temperatures increase risk and decrease yields relative to C1. **Mkabele (Yb12)**

		✓ The climate capability rating is C3: Slightly restricted growing season due to the occurrence of low temperatures and frost. Good yield potential for a moderate range of adapted crops. **Bruyn's Hills (Yc21)** ✓ The climate capability rating is C3: Slightly restricted growing season due to the occurrence of low temperatures and frost. Good yield potential for a moderate range of adapted crops.
Soil	Land type Parent material Soil form Slope (runoff potential)	**Nagle dam area (Ta5)** ✓ Type: Humic Soils (> 450 mm deep). ✓ Depth: Well drained soils (Hu, Cv, Gf, Sd, Ct, Sp, Bv, Oa, Vf, Kk ,Ag). ✓ Origin: Unconsolidated sediments of alluvial and/or aeolian origin (Du, Fw, Nb). ✓ Slope: 0-35%. ✓ 48.3% of the soils are shallow, 6.8% of the soils are duplex and 35.3% of the soils are of moderate to poor drainage. ✓ In addition, 13.1% of even the more gently sloping areas of the BRU is too rocky to cultivate. ✓ 7.7% of the BRU is too steep for annual cultivation. **Valley of a Thousand hills (VWb5)** ✓ Shallow soils and soils of moderate to poor drainage present an erosion hazard if not managed correctly. ✓ 59.3% of the soils are shallow and 49.0% of the soils are of moderate to poor drainage. ✓ In addition, 16.6% of even the more gently sloping areas of the BRU is too rocky to cultivate. ✓ 13.1% of the BRU is too steep for annual cultivation. ✓ Type: Ab128, Ab130, Ac217, Fa436, Fa461). ✓ Depth: Well drained soils (Hu, Cv, Gf, Sd, Ct, Sp, Bv, Oa, Vf, Kk ,Ag). ✓ Origin: B type (49%), H-Young soils (42%). ✓ Slope: more than 12%. **KwaGqugquma (Xb7)** ✓ Shallow soils and soils of moderate to poor drainage present an erosion hazard if not managed correctly. ✓ 58.5% of the soils are shallow and 51.9% of the soils are of moderate to poor drainage. ✓ In addition, 11.5% of even the more gently sloping areas of the BRU is too rocky to cultivate. 14.6% of the BRU is too steep for annual cultivation. ✓ Type and Origin : H – young soils 46.6; Depth: B – well drained 44.7

		✓ Slope: more than 12%. **Mkabele (Yb12)** ✓ Shallow soils and soils of moderate to poor drainage present an erosion hazard if not managed correctly. ✓ 21.6% of the soils are shallow and 29.7% of the soils are of moderate to poor drainage. ✓ In addition, 4.2% of even the more gently sloping areas of the BRU is too rocky to cultivate. ✓ Type and Origin 22.4% Young and 47.2 Well Drained. ✓ Slope: 5.3%; Risk of Erosion. **Bruyn's Hills (Yc21)** ✓ Shallow soils and soils of moderate to poor drainage present an erosion hazard if not managed correctly. ✓ 23.5% of the soils are shallow and 30.0% of the soils are of moderate to poor drainage. ✓ In addition, 4.6% of even the more gently sloping areas of the BRU is too rocky to cultivate. ✓ Type and Origin: A – humic 30.4%; B – well drained 39.2: H – young soils 22.6. ✓ Slope: FB = 5.4; Low risk for erosion.
Human resource & Socio-economic profile Will help to access: i. Possibility to see what areas are most likely to be influenced ii. To form a basis for assessing changes in the community during the course of the project Relevant information can be obtained through: i. Secondary data sources including previous studies ii. Key informants iii. Formal and informal interaction with the farmers	Number of abled bodies	✓ Average age of the respondents was 55.47 years. ✓ Had attended school for an average of 6.79 years. ✓ Average of 5.95 household members. ✓ 36.8% of the Swayimane sample had visited the clinic in the last month. ✓ 52.6% of the sample had good physical health, while 89.5% had good mental health. Other household members were also reported to healthy by the respondents although there was some incidence of poor physical and mental health. ✓ The family was an important source of labour in family plots.
	Involvement of women	✓ Most farmers were women. ✓ Although men held most land rights, women were actively engaged in agriculture in Swayimane and can be assumed to have some decision-making powers in the work they do.
	Current nutrient status of households	✓ Those who utilize their homestead gardens normally plant crops such as potatoes, cabbage, beans, maize, butternut, beetroot, onions, spinach, pumpkin and maize.
	Employment status of all household members	✓ 52.6% of the respondents identified farming as their primary occupation.

iv. Participatory Rural Appraisal (PRA) and Participatory Action Research (PAR) v. Interviews using structured and semi-structured questionnaires vi. Individual and group discussions vii. Institutional analysis		✓ The majority of respondents earned some income from their primary occupation, and 63.2% estimated their income to be in the R1001-R5000 range.
	Household demographics (sex, age, education, health status, etc.)	✓ Most farmers are women. ✓ The average age of the respondents was 55.47 years. ✓ The sampled farmers had attended school for an average of 6.79 years, and had no formal tertiary qualification in agricultural production and training, but had years of farming experience, had attended some training programmes and had learnt from extension.
	Sources of income	✓ Farming to the very few that are selling. ✓ Government social grants are the main source of income. ✓ Non-agricultural employment.
	Household income and expenditure	✓ About one in two respondents identified farming as their primary occupation. ✓ Many respondents earned some income from their primary occupation, and about two in three estimated their income to be between R1001-R5000.
	Conclusion	✓ The respondents in these communities have the capacity to produce both for household consumption and for sale. ✓ The farmers need appropriate training to improve produce quality and value chain readiness.
Infrastructure	Access to implements	✓ The farmers use basic tools and equipment; however, they have access to tractors for hire. ✓ Local shops do not stock inputs and equipment, farmers must purchase these from Wartburg and other major towns. ✓ Most communities have access to public transport, which travels along the tarred major roads in the community.
	Access to land	✓ Land rights were largely held by men in Swayimane, but all the respondents in this sample said that women could also hold land rights. ✓ Women could go directly to the chief (31.6%), their male relatives or buy land (21.1%).
	Access to water resources (tanks, irrigation)	✓ There are communities with community taps and others with taps in each homestead. ✓ Some households store water in tanks and drums, etc.
	Animal component	✓ The respondents in this community keep mostly poultry.
	Conclusion	✓ Farmers can produce with the infrastructure currently available to them, however, implementing water technologies which increase efficient water use could improve farmer output.

Farming systems	Current practices and crops	✓ Cultivating most of their land for household consumption and selling several commodity crops when possible. ✓ Farmers estimated that their gardens ranged from 0.025 ha to 1 hectare, while when combined, their fields could be as large as 6.ha. ✓ Most farmers had two areas of land under cultivation; a small garden next to the home, and larger fields adjacent to the homestead's living and storage buildings. ✓ Farmers to have a small garden they used to grow a variety of vegetables such as onions, carrots, beetroot, and spinach for household consumption. ✓ Few farmers were commercially producing cabbage and several other vegetable crops. ✓ The home gardens cultivated by most farmers were more characteristic of diverse polyculture systems.
	Constraints	✓ Access to pesticides and fertiliser was limited because the village shops did not stock, travel to Wartburg or Durban to purchase some inputs, due to the distance of these places, the farmers had resolved to pool their purchasing. ✓ Some pests no longer responded to pesticide application, and pest outbreaks occur even after treatment. ✓ Water shortage affects vegetable production.
	Scale of production	✓ The farmers identify themselves as smallholder farmers and practise gardening on pieces of land, which are less than a hectare.
	Institutional arrangements	✓ Gardens should not be watered with water from springs/rivers/taps, however, these rules are not enforced. ✓ Umgeni water is the only enforcer as they regulate tap water, however, they are largely perceived as absent. ✓ Community members are encouraged to share water with those who do not have water.
	Conclusion	✓ This is a mixed farming system characterised by resource scarcity. ✓ Farmers practise either subsistence or semi-commercial small-scale production
Water sources	Available and capacity	✓ Farmers had access to the following water sources: in house tap water, communal tap water, river or stream, borehole, well, spring, rainfall, water truck and other sources. ✓ 95% of the sample had access to tap water and it was their main source of water, while another 79% used rainfall as well. ✓ Tap water is not always available, thus farmers had to use alternative water sources ✓ .

	Water use (currently)	✓ Many farmers use a combination of water sources, e.g. municipal, river and or stream water, wells, etc. ✓ Negative perceptions of river and spring water quality reduce willingness to use water. ✓ Every farmer who harvested rain water used it. ✓ The municipality delivered water to specific areas in Swayimane, however only those households situated near the roads along the water truck's route had access.
	Conclusion	✓ Water availability is a challenge in these communities. ✓ Focus on municipal water as being of a high quality may result in farmers overlooking the advantages of using water from sources. ✓ If water from other sources is considered polluted, how can farmers process it for use on food, which will be consumed with little, or light cooking?
Food and nutrient security status	Access to various food groups	✓ The average HFIA Score for the Swayimane respondents was 3.72, indicating that most households were food secure as their score was very close to 0. ✓ 42.1% of the households were food secure
	Food diversity	✓ Their dietary diversity score based on a 24-hr recall was 6.95 food groups out of 12.
	Eating patterns	✓ 31.6% had smaller meals ✓ 26.3% had fewer meals ✓ 21.1% had no food at all ✓ 21.1% went to sleep hungry ✓ 10.5% did not eat the whole day and night.
	Conclusion	✓ Most households experience different levels of food insecurity as shown by the common occurrence of consuming smaller or fewer meals, etc. ✓ It is important to determine the food environment of communities in Swayimane and to determine patterns of food availability and scarcity throughout the year.
Access to inputs & marketing	Seeds/seedlings, fertilizers, etc.	✓ Bought in Wartburg or Durban, however the high transport costs make it difficult for farmers to buy in bulk or to buy timeously.
	Are they selling or not	✓ Very few households produced for household consumption only, while the majority produced enough to sell.
	Who are their clients (if they are selling)	✓ Local community residents. ✓ In-formal traders from outside the communities. ✓ Some supermarkets.

	Conclusion	✓ Farmers have access to markets but in both input and produce markets they are price-takers. ✓ Farmers are making a profit through sale and production of green mielies and potatoes, therefore a market for other produce could be developed ✓ .
Challenges experienced by community	Major household needs	✓ Irrigation water ✓ Cost of transport
	Conclusion	✓ Introduce production technologies that are less dependent on irrigation water and can be applied successfully under dryland conditions.
Access to extension services	Extension services	✓ The farmers had access to an extension officer, although he was responsible for several communities.
	Conclusion	✓ It is difficult for farmers to meet extension on an individual basis and develop a one-on-one relationship, which allows for individualised extension.

Appendix 2 Situation analysis of Gladstone village for the implementation of CSTs, practices, crops and farming systems

Long-term climate	Rainfall (total, monthly and seasonal distribution, intensity)	✓ Area marginal for crop production due to low & erratic rainfall (< 450 mm from Nov-Apr). ✓ Mean annual precipitation for area is 599 mm. ✓ Minimum of 342 mm rainfall received in 1984. ✓ Maximum of 1055 mm rainfall received in 1988. ✓ Receives approximately 85% of annual rainfall between October and April. ✓ February is the month with the highest average rainfall (97 mm). ✓ July is the month with the lowest average rainfall (10 mm). ✓ Maximum monthly rainfall values range between 367 mm (February) and 61 mm (June). ✓ Minimum monthly rainfall values range between 18 mm in March and 0 mm from May to October.
	Temperature (min, max, frost days, monthly distribution)	✓ January is the warmest month with average temperature of 20.9°C. ✓ July is the coldest month with average temperature of 6.9°C.
	Solar radiation	✓ Minimum in winter months during June, with 3410 W m^{-2} day^{-1}. ✓ A maximum of 7319 W m^{-2} day^{-1} is reached in December
	Relative humidity	✓ Both minimum and maximum relative humidity is at its lowest during September with values of 22.8% and 81.8%, respectively. ✓ Relative humidity peaks during April with a maximum of 95.7% and a minimum of 38.1%.
	Evaporation (total & daily)	✓ Water losses due to high evapotranspiration during summer. ✓ A minimum evapotranspiration of 2.0 mm day^{-1} occurs in June and a maximum of 6.7 mm day^{-1} in December.
	Conclusion	✓ Need to increase effective rainfall by employing CSTs such as rainwater harvesting and conservation (RWH&C). ✓ The use of correct fertilizer is very important for the farmers and villagers because it will help in producing good crop yields. ✓ Select optimum planting date to avoid mid-summer drought & early frost damage.

		✓ In making sure that soils hold more water community members should apply organic or stone mulches to minimize the water losses through evaporation. Mulches also keep soil cool in summer. ✓ Crop production can commence if good rain is received in November. From December until the end of April the areas are characterized by good rainfall and mean maximum temperatures of less than 30ºC.
Soil	Type (sand, clay, etc.)	✓ The clay content of some soil forms ranged from 34 to 54% in the topsoil and from 60 to 73% in the subsoil.
	Depth (effective rooting zone)	✓ The effective rooting depth is between 700 and 900 mm.
	Water holding capacity (if available)	✓ The clayey soils have a higher water holding capacity than the sandy soils, so it should be used for crop production especially where rainfall is a limiting factor for crop production.
	Land type	✓ Gladstone community completely falls within Land Dc17. ✓ Land type Dc17, which makes up 53% of the total area of Thaba Nchu.
	Parent material	✓ Mainly derived from the sandstone, shale and mudstone of the Beaufort Group with dolerite intrusions.
	Soil form	✓ Dominant soil forms in this community suitable for RWH&C are Sepane, Swartland, Arcardia and Bonheim. ✓ Soils found to be unsuitable for RWH&C are of Mispah, Glenrosa, Mayo, Klapmuts and Escourt forms, and shallow members of Swartland soil form.
	Slope (runoff potential)	✓ Slope in Gladstone varies between 0 and 12%. ✓ The slope for most of the lands is less than 3% with small areas having slopes between 3% and 4%. ✓ The community of Gladstone occurs in the upper four lower three position of the landscape.
	Conclusion	✓ Boundaries of Gladstone should be properly fenced. ✓ Soil maps should be used to select most suitable area for CST/P or WST techniques and used for total village planning

		✓ According to Hensley *et al*. (2006) soils with an effective rooting depth > 900 mm met the criteria for the application of IRWH.
Human resource & Socio-economic profile	Number of abled bodies	✓ The households consist on average of six people – two adults and four children (including grandchildren). ✓ More women (54%) than men (46%). ✓ The older generation is majority since most of the youth have move to urban areas with the aim of seeking employment and some going to tertiary institutions.
	Involvement of women	✓ In many cases, the men either have passed away or are employed somewhere else, so the women that stayed behind are mainly responsible for producing food for household consumption. ✓ Elderly women working in their homestead gardens produce mainly maize, as staple food, and a variety of vegetable crops mainly during the summer growing period.
	Current nutrient status of households	✓ Those who utilize their homestead gardens normally plant crops such as potatoes, cabbage, beans, maize, butternut, beetroot, onions, spinach, pumpkin and maize.
	Employment status of all household members	✓ More than 75% of the adult population is unemployed. ✓ Almost 50% consider themselves a farmer due to the fact that the own some livestock and have a backyard garden (but they are actually unemployed). ✓ Some of the women work as domestic workers and some young men work do general work in Bloemfontein ✓ Number of the men are working in the mines in Welkom, Virginia, Carletonville and Rustenburg. ✓ Men that are working elsewhere usually send money home on a monthly basis.
	Involvement of children	✓ The youth are the future farmers and producers in agriculture so their present lack of participation in the agricultural sector is a serious concern.
	Household demographics (sex, age, education, health status, etc.)	✓ Majority of community members are between the ages of 41 and 65 years. ✓ Most community members have grade 10. ✓ Most adults were married at some point in time, but some are now widow/widower or divorced.

		✓ Health status deteriorates on daily basis due to unemployment and lack of access to basic services. ✓ Despite having a clinic in the village, in most of the time it does not have the necessary or needed medication for chronic patients.
	Sources of income	✓ Farming to the very few that are selling. ✓ Government social grants are the main source of income. ✓ Non-agricultural employment.
	Household income and expenditure	✓ Livestock owners sell some of their cattle and sheep to those who need them for funerals, traditional ceremonies and weddings. ✓ Apart from those who are earning salaries, the main sources of income are old age pensions, disability grants and child support grants. ✓ The majority of the households (70%) have a total monthly income of less than R1500. ✓ Almost all incomes are used to buy groceries.
	Conclusion	✓ Raise awareness amongst the youth about agriculture in general and its importance in their lives. ✓ Despite men being the main decision makers in the households, women are the main role players in a taking care of the garden. ✓ When women, especially those who are married, want to plant anything in those gardens they have to consult men before buying any seeds or seedlings.
Infrastructure	Access to implements	✓ Community members do not have access tractors and other farming implements. ✓ Most households own basic gardens tools (rake, spade, fork) to work in their homestead gardens.
	Access to land	✓ Each household has a homestead garden of 50 X 50 m, but only a few utilize it. ✓ Based on the policies of the previous government of Bophuthatswana, whenever a community member was given a homestead (plot) by the Traditional Council or government, they were also given a piece of land to be used as cropland irrespective of whether the village member had applied for it or not.

	Access to water resources (tanks, irrigation)	✓ There is a tap in the backyard of each household, but it is often running dry for long periods. ✓ There are three big tanks were provided by the previous government of Bophuthatswana situated about 200 m from the residential area. ✓ Some households have JoJo tanks where water can be collected from the rooftops.
	Animal component	✓ Some own livestock such as cattle, goats, pigs, sheep, poultry, horses and others including turkey and ducks. ✓ Cattle and sheep used for lobola and traditional ceremonies. ✓ Sheep and cattle are the dominant livestock in the village. ✓ Rangelands are in poor conditions due to overgrazing and poor veld management practices.
	Conclusion	✓ Homestead gardens need to be used more productively for food production. ✓ Where households have access to tanks, roof water harvesting can be merged with CST/P or WST such as the IRWH technique to enable community members to produce crops throughout the year.
Farming systems	Current practices and crops	✓ Types of farmers: Livestock, Crop & Mixed (both crops and livestock are kept on the same backyards, and each part of the system contributes to the other.) ✓ Crop production has for years being the main survival of villagers and are essential for their daily needs as part of a nutritious plate for daily consumption. ✓ Production in backyard gardens has been taking place at the village for a very long time. ✓ Due to the low and erratic rainfall most of the community members find it extremely difficult to produce crops successfully. Therefore, more community members invested in livestock production than in dryland crop production.
	Constraints	✓ Insufficient water supply. ✓ Lack of access to market. ✓ No or poor fencing. ✓ Poor soils. ✓ Backyards are often not planted due to draughts. ✓ Lack of basic agricultural knowledge.

	Scale of production	✓ The size of the backyards in the village are more than twice the size of those in the urban areas. ✓ All villagers have access to a backyard garden and the sizes differ from where your homestead is situated.
	Access to production equipment	✓ Access to tractors and implements to cultivate larger homestead-, school and community gardens is a serious problem. ✓ Most households own basic garden tools to prepare basins for IRWH in their homestead gardens.
	Access to water	✓ Experience frequent draughts. ✓ Not able to irrigate crops due to shortage of water in the village ✓ Municipal taps run dry for most of the time.
	Major agricultural needs	✓ Water (including infrastructure), tractors, fencing, storage, labour, equipment & inputs.
	Institutional arrangements	✓ Since the collapsed of the then government of Bophuthatswana after 1994, lawlessness has become a serious problem in the village. ✓ Most of the institutional arrangements that use to be practised and adhered to have vanished and only a few is practiced (e.g. if livestock damage crops the matter is referred to the headman who impose a penalty fine for the damages payable to the crop owner). ✓ Very few community members are aware of any institutional arrangements in the village. ✓ Crime in the area has increased due to unemployment and the current situation in the country. ✓ Fences have been stolen in most of the borders of the village including the rangelands; as for the croplands, there is nothing.
	Conclusion	✓ Proper measures should be put in place to control livestock numbers in rangelands. ✓ Farmers should be assisted with the necessary inputs. ✓ Homestead gardens should be fully utilized. ✓ School- and community gardens should be utilized as well. ✓ Disseminate information to increase farmers' knowledge with regards to legislations and governing agriculture.

		✓ The use of inorganic fertilizer or animal manure should be promoted because it will help in producing good crop yields. ✓ Implement and enforce institutional arrangements that will be to the benefit of agricultural production within the village. ✓ Extension officers should play their role.
Water sources	Available and capacity	✓ Water is available in each homestead garden, but the use thereof is controlled. ✓ Each household has access to 6000 ℓ of free water per month, but none pay anything if they use more. ✓ Tapped water not allowed to be used for irrigation purposes. ✓ If households do not adhere to the water regulations a penalty can be imposed by the village headman. ✓ Has two windmills but water capacity coming from those windmills is extremely poor.
	Water use (currently)	✓ Crop production mainly under rainfed conditions. ✓ Tapped water can only be used for household consumption (drinking and cooking). ✓ Water collected in tanks and drums can be used for supplemental irrigation of crops in backyard gardens or as drinking water for animals. ✓ Water in the river is mainly used by livestock for drinking purposes.
	Conclusion	✓ Since the area is marginal for crop production due to low and erratic rainfall community members should increase the effective rainfall by employing appropriate CST/P or WST practices, as some already did in their homestead gardens. ✓ In making sure that their soils hold more water community members should apply organic or stone mulches to minimize the water losses through evaporation.
Food and nutrient security status	Access to various food groups	✓ 54.5% of villagers do not always have sufficient food. ✓ Food shortages most common around January to March since this is the time after Christmas whereby everyone goes beyond his/her means to entertain him or herself.

	Food diversity	✓ Due to the low and erratic rainfall most of the community members find it extremely difficult to produce crops successfully. Therefore, more community members invested in livestock production than in dryland crop production. ✓ The majority of community members produce a variety of vegetables and fruits in their homestead gardens. They grow crops such as maize, carrots, pumpkins, spinach, potatoes, tomatoes, onions, cabbage, beans, peaches and apples. During winter a few of them plant spinach.
	Eating patterns	✓ 41% have fewer meals and 45% have smaller meals in order to cope with food insecurity situation. ✓ 32% of community members do not have any food but are helped by neighbours and friends. ✓ 24% of community members sometimes goes to bed hungry.
	Nutrient status of children of various age groups	✓ None of the households in the village meets neither the required nutrient status nor the daily intake of a nutritious plate.
	Conclusion	✓ Community members should be encouraged to produce a variety of crops by making use of CST/P OR WST practices in order to have access to a more balanced nutrient diet.
Access to inputs & marketing	Seeds/seedlings, fertilizers, etc.	✓ Due to financial constraints, not all villagers are able to buy seed as most of them are unemployed. ✓ Over 80% of villagers do not apply expensive inorganic fertilizers; most of them use kraal manure instead. ✓ Even though community members struggle financially they do not buy seeds and fertilizer jointly in order to save money. ✓ Due to conflict amongst the villagers the majority of them prefer to work individually. ✓ Small packets of vegetable seeds are bought at Shoprite in Thaba Nchu.
	Are they selling or not	✓ Production in homestead gardens is mainly for household consumption. ✓ Even if community members do produce crops on a large scale they have nowhere to sell their produce since they have no access to markets.
	Who are their clients (if they are selling)	✓ Crops are mainly for own consumption purposes, but those who have more than enough (surplus) they either sell or exchange with fellow villagers.

		✓ The price is determined and agreed between the seller and the buyer.
	Conclusion	✓ Since the majority of community members are unemployed and do not have money, government departments should assist with the necessary infrastructure (tools, fencing, tractors and implements) and inputs (seeds, fertilizer) to utilize backyard gardens and croplands more productively. ✓ Accessible markets should be established and inputs need to be made available at affordable prices. ✓ Educate farmers of what is expected to them by the markets. ✓ Create opportunities for farmers to have access to financial institutions and markets. ✓ A market orientated culture should be encouraged to ensure that the community members become economically viable and their standard of living is uplifted.
Challenges experiencing by community	Major household needs	✓ Water. ✓ Income. ✓ Electricity. ✓ Garden tools. ✓ Fencing.
	Conclusion	✓ The TA should be recognized at local, provincial and municipal level and be given the power to enforce institutional arrangements that can improve the agricultural productivity and livelihoods in rural communities. ✓ Land use rights must be abolished and farmers/villagers need to be given full title deeds. With "guaranteed ownership" farmers will invest in their croplands without the fear that land might be taken from them. ✓ The land allocated to individuals for crop production needs to be matched with the soil maps so that only the areas with high potential soils are utilized for crop production. ✓ Suitable weed, insect and disease control practices should be put in place and form part of proper management practices on the croplands. ✓ Relevant departments should provide the basic needs of community members (water, sanitation, electricity, communication, health, education, safety and security).

		✓ Accessible markets should be established and inputs need to be made at affordable prices.
Access to extension services	Extension services	✓ The extension officer who is responsible for Gladstone is also responsible for many other villages in and around Thaba Nchu so he hardly ever finds time to visit Gladstone. ✓ The extension officer is not visible in the community and most community members do not know him.
	Conclusion	✓ Employ more extension officers with knowledge and expertise within the field of work they will be doing in order to speed up the process of empowering and/or developing small-scale farmers, especially in rural areas. ✓ Experts in the field of crop and rangeland production, from either the national and provincial Departments of Agriculture or the private sector, need to provide farmers/villagers with formal and informal training in all aspects of agricultural production.

Appendix 3 KwaZulu-Natal Stakeholder workshop agenda.

AGENDA: Stakeholder Workshop 21 November 2017

1)	Tea, Welcome and Introduction:	(Dr Chitja & All)
2)	Background to the Project	(Dr Chitja)
3)	Brief Presentation by each stakeholder on own Water Smart Programmes	(Dr Chitja)
4)	Presentation of Proposed Water Smart Technologies	(Dr Botha)
5)	Discussion on Possible Partnerships	(Dr Chitja & All)
6)	Closure & Lunch	(Dr Chitja & All)

Appendix 4 Future research needs

- ✓ Technology adoption processes for communities to explore human capacity and capabilities of both farmers and extension staff that supports them.

- ✓ Appropriate policies for the implementation of CSTs with special focus on the involvement of youth and market access should be further studied.

- ✓ Further research on best models for appropriate commercialisation for homestead farmers should be explored where niche markets can be occupied sustainable by the farmers.

- ✓ Further research should also include more physiological studies related to nutrient improvement of crops and specific wellbeing outcomes and attempt to attain direct cause and effect of agricultural interventions and crop interventions.

Appendix 5 Knowledge dissemination and capacity building

A) YEAR 2017/2018

- **Stakeholder workshop**

Using the Institutional data from the first two Deliverable reports, a list of all stakeholders and their contact details were finalised. An invitation letter explaining the background of the project, aims and the roles of each stakeholder, with special focus on mutual benefit was prepared by the team for distribution to the various stakeholders. The team selected venues for the stakeholder workshops in the two provinces. The team aimed to implement the agreed technologies during the 2017/2018 planting season.

Stakeholder workshop attendees and signing of MOUs at UKZN for Swayimane (KwaZulu-Natal)

- **Knowledge dissemination**

The team began working on the project in 2016. During the first year, the team was concerned with reviewing literature and selection of sites. In 2017/2018 some results were ready to be shared and disseminated at conferences, nationwide and abroad. These included food security measurement, CSTs and value chains, all key facets of the project.

✓ ***Global Food Security Conference (December 2017)***

As a panellist in one of the plenary sessions on The role Gender in Food Security: Lessons from WRC projects in KwaZulu-Natal and Limpopo, Dr Chitja shared lessons on gender and its role in water-use access and water use security was shared on emerging lessons from the current and previous WRC project. The role of gender and the participation along of women and men along the value chain was also articulated. At this conference a poster paper on "*Identification of factors leading to human, social and individual agency of smallholder farmers for market access and participation*" by B. Zinkhali and J. Chitja was presented.

✓ ***Food and Nutrition Security Measurement, Belgium (15-17 November 2017)***

A presentation on "*Identifying the essential components of a proposed food and nutrition security tool: lessons learnt from existing metrics*" was made by V.G. Murugani and J.M. Thamaga-Chitja. The abstract of the paper read as follows:

Food and nutrition security is a human right; however, it is not enjoyed by at least 795 million who have no access to adequate and nutritious food and a further 2 billion individuals who suffer from hidden hunger. Accurately determining the incidence and severity of food and nutrition insecurity remains a challenge, since it is an outcome of several transdisciplinary processes, and its attainment is dependent on other aspects of the human condition (e.g. health, poverty and the environment). Single indicators, which allow for the accurate measurement of different aspects of the four food and nutrition security pillars and a single outcome need to be developed. The objective of this review is to document the existing food and nutrition security indicators, highlight their gaps and propose a way forward. Peer reviewed papers and grey literature with the key words 'food and nutrition security measurement'; 'food security measurement' and 'nutrition security measurement' will be reviewed. The data will be analysed to show the different dimensions and the aspects under consideration. The results will show the absence of a universal measurement, instead different indicators developed various stakeholders for specific contexts, which measure food access (e.g. quality, quantity) and utilization (food consumption, anthropometric measures), mostly at the household and individual level will be identified. In addition, the different units of analysis and the application of the indicators either individually or in combination will be discussed. The successes of the different indicators, for example allowing researchers and policymakers to quantity and characterize the incidence of hunger and malnutrition worldwide, will be highlighted. As will the shortcomings of individual indicators, challenges associated with the use of multiple but different indicators, for example, limited capacity to perform accurate assessment and spatial and temporal comparisons. This will be linked with the challenges associated with developing accurate, well-targeted intervention and sustainable strategies.

The results will then be used to identify components, which could be included in a universal food and nutrition security indicator. These components would reflect the evolution of the sector, particularly in a period where food and nutrition security are considered prerequisites for sustainable development, in an environment where livelihoods are threatened by climate change and human displacement, etc. Acknowledgements: We acknowledge the support of the University of KwaZulu-Natal and the South African Water Research Commission project K5/2278.

✓ ***Joint DAFF, AFAAS, SASAE 2017 Conference (29 October - 03 November 2017)***
An oral presentation on "*Rainwater Harvesting: Climate Smart Techniques for increased Smallholder Productivity*" was presented by J.J. Botha, J.J. Anderson & T.A.B. Koatla.

At the conference, an exhibition displaying CSTs was also made. Many of the Department of Agriculture and Rural Development's officials, including the Director of Rural Development in KZN and the national minister of Agriculture, showed keen interest in RWH&C work and expressed their desire that the project team assist the Department to implement applicable CST nationwide.

✓ ***4th Global Science Conference on Climate-Smart Agriculture (28-30 November 2017)*** An oral presentation on "*Up scaling rainwater harvesting techniques in homesteads and croplands for sustainable food production in rural areas*" was made by J.J. Botha, J.J. Anderson and T.A.B. Koatla.

B) YEAR 2018/2019

- **Farmers' days**

✓ ***Gladstone***

On Thursday 31 May 2018 the Free State Department of Agriculture and Rural Development (DARD), University of KwaZulu-Natal and the ARC-SCW& AE conducted a Farmer's day in Gladstone village near the town of Thaba Nchu on CSTs and practices. This activity formed part of a four year (01/04/2016-31/03/2020) project titled: "*Water use for food and nutrition security at the start-up stage of food value chains*", initiated and funded by the WRC. The main aim of the day was to raise awareness regarding food and nutrition security via the use of the CSTs, such as IRWH, and to share preliminary research findings of the 2017/18 summer growing season of demonstration plots of the homestead gardens and school garden production in Gladstone to the beneficiaries, whom are mainly small-scale farmers. The DARD and ARC-SCW&AE have a long history on research work conducted in Gladstone village that focused mainly on household food production where a variety of vegetable crops are planted in the homestead gardens by making use of the IRWH crop production technique and expansion to the cropland by making use of specialized implements to create water harvesting structure for production on a larger scale to eradicate hunger and poverty in the village. With the current project the focus has shifted to food and nutrition security at the start-up stage of food value chains and marketing strategies to enter the in-formal and formal markets like Checkers, Shoprite, Spar, etc. The main speakers of the day, Dr Botha, Dr Anderson and Mr. Koatla, have encouraged and motivated community members from Gladstone, Yorksford and Woodbridge II, scholars from Maserona Primary School and Adult Based Education and Training (ABET) learners to take up the CSA technologies and practices for food production to improve their household and rural livelihoods. At the workshop that followed the formal presentations the roles and responsibilities of the various stakeholders were discussed as well as the techniques and practises to apply during the upcoming winter and summer growing periods and the suitable crops to be planted to ensure a nutritional meal on a daily basis.

The day was ended on a high note were attendees pledge their commitment to actively participate and take ownership of the project.



✓ ***Swayimane***

On 06 and 07 June 2018 the research team (Dr Chitja, Dr Botha, Dr Anderson and Mr. Koatla) together with the technical assistant team (Mr. Khuzwayo and Mr. Mandries) conducted information days in Swayimane near Wartburg, which is about 30 km North East of Pietermaritzburg in KwaZulu-Natal. The aim of these days was to present to the farmers and community the activities conducted during the implementation and monitoring of the CSA technologies and management practices plots prepared during the 2017/18 growing season. Furthermore, preliminary results together with challenges encountered thus far were also presented and discussed. This was done in order to plan for the upcoming winter and summer seasons. Various stakeholders were also invited to these information days of which the KwaZulu-Natal Department of Agriculture and Rural Development (KZNDARD) under the directory of extension service, University of KwaZulu-Natal (UKZN) as well as the KwaZulu-Natal Department of Education (KZNDOE) through school representatives were present. On 06 June 2018, it was held at KwaMaphumulo, eStezi area and on 07 June 2018 it was at Msilili area which both areas are within Swayimane area. Farmers, community members as well as different stakeholders were given a chance to visit the experimental plots in both areas. Both days were very informative and successful to both farmers and research team. As a result, the majority of farmers attended were very interested to test these technologies in their gardens.

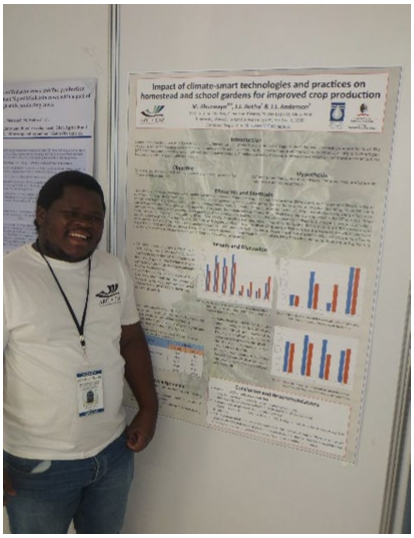
- **Knowledge dissemination**

✓ ***LandCare Conference (September 2018)***

Four project team members form the ARC-ISCW (Dr Botha, Mr. Koatla, Mr. Khuzwayo and Dr Anderson) attended and presented at the LandCare Conference in Bloemfontein that was held from 25-27 September 2018. Mr Khuzwayo is co-supervised by Dr Chitja, the project leader. One oral and one poster presentations were made. The presentations were:

a) Koatla, T.A.B., Botha, J.J, Anderson, J.J., 2018. *Access to markets via the improved AgriFood Value Chain through the Adoption of Rainwater Harvesting Techniques: Case Study of Gladstone, Free State Province*. (Oral presentation)

b) Khuzwayo, M., Botha, J.J. & Anderson, J.J., 2018. *Impact of climate smart technologies and practices on homestead and school gardens for improved water use and crop production.* (Poster presentation)



✓ ***Howard Davis Ukulinga Symposium***

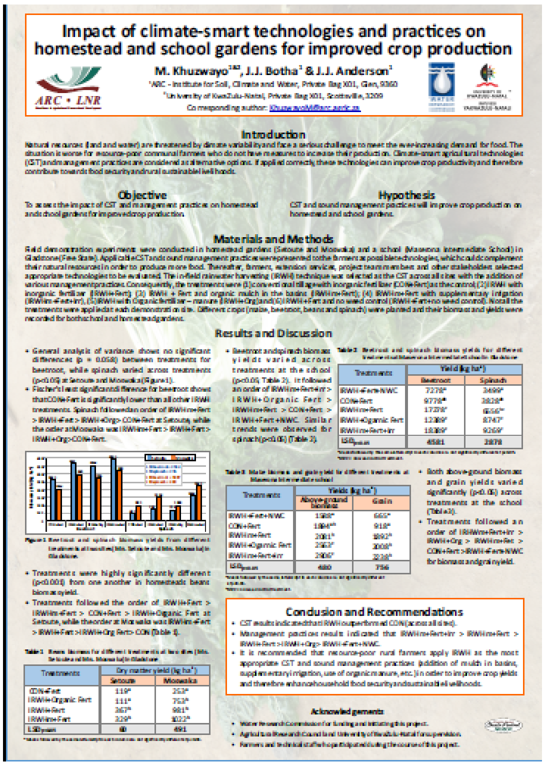
Ms Bongiwe Zikhali, a Masters student's work on "*Exploring water use for food and nutrition security: Preparedness of entering the value chain value chain*" was presented at the symposium. Although not directly related to all aspects of the current WRC project Dr Murugani, a postdoc/researcher in the project also presented on "*Aspects of the value chain and human capital requires for farmers' market access*".

✓ ***Master Dissertation Submission for Examination***

Mr Ntokozo Mazibuko submitted his Masters dissertation titled: Selection and Implementation of Climate Smart Agricultural Technologies, performance and willingness for adoption. His dissertation is in manuscript format and journals are being identified. Dr Chitja supervised Mr Mazibuko's study.

✓ ***Combined Congress (January 2019)***

At the Combined Congress of the Southern African Society for Horticultural Sciences, South African Society of Crop Production, Southern African Weed Science Society and Soil Science Society of South Africa held in Bloemfontein from 21-25 January 2019 a poster paper on "*Impact of climate smart technologies and practices on homestead- and school gardens for improved crop production*" by M. Khuzwayo, J.J. Botha & J.J. Anderson was presented. This poster was very similar to the one that was presented at the LandCare conference, but only focus on the results obtained at Gladstone.



✓ ***Conservation Agriculture workshop (January 2019)***

At the conservation agriculture (CA) workshop held on 23 January 2019, during the Combined Congress at the University of the Free State, Dr Botha made a presentation on CA systems under rainfed crop production. Here special reference was made to climate smart technologies used by community members from Gladstone and Swayimane to produce a variety of crops in their homestead gardens.



- **Exhibitions**

✓ ***LandCare Conference (September 2018)***

At the LandCare Conference held in Bloemfontein from 25-27 September 2018, the researchers from ARC-ISCW, Glen have set up an exhibition that focus on the CSTs.



✓ ***Combined Congress (January 2019)***

At the Combined Congress held in Bloemfontein from 21-25 January 2019, the researchers from ARC-ISCW, Glen have set up an exhibition that focus on the CSTs.


- **Visitors**

On 11 September 2018 three officials from the Department of Agriculture, Forestry and Fisheries (DAFF) visited the Glen office to get more information on CSTs. The purpose of the visit was to see whether the Department could implement similar projects like the one that is conducted in Gladstone and Swayimane in Mpumalanga. Dr Botha from the ARC-SCW&AE has first given a background presentation on rainwater harvesting, before they went to Gladstone village to look at homestead gardens where the IRWH technique is used successfully to produce a variety of vegetable crops in homestead gardens.

- **Capacity building**

Capacity building at community level with individuals and households took place throughout the year during by means of discussions, interviews, workshops, training and farmers' days that the research team and other stakeholders were involved in. Training was regarded as an important component of the project. The training of farmers, extension officers and scholars involved formal and practical or hands-on training. Community members received hands-on training in the construction of rainwater harvesting structures, planting of various crops, weed- and insect control, harvesting and marketing.

C) YEAR 2019/2020

- **Formal training and workshop**

✓ ***Gladstone***

Training and a workshop on CSTs and food value chains was held at the Gladstone Community Centre on 19 March 2019. The following villages were invited, Gladstone as the host, Yoxford, Woodbridge II and Tseki. The Programme director was Mr. Sebolai from the ARC-SCW&AE. Mrs. Setlofane opened the event with a prayer. Mr. Mosala, headman of Gladstone village, did a word of welcome. Mr. Sebolai introduced the guests. Dr Botha presented the purpose of the day, background and introduction of the project, climate smart technologies for food production in homesteads and croplands. Dr Anderson made a presentation on the production of seedlings and soil fertility. Mr. Khuzwayo gave a brief background on what happened during the past season and the challenges that were experienced and identified. Mr. Koatla did a topic on food chains, value adding and marketing, communication and conflict resolution. Dr Anderson then discussed the upscaling and out scaling which included, roles and responsibilities, commitment and strategy. Dr Botha touched on the way forward whereby it was decided that there should be training given to those community members of the villages that attended. The reason being that they said that those who were trained previously are now old and they cannot train others. Ms. Anna Hini raised this issue from Yoxford village. One person was chosen per village that attended who would be the contact person on everything that needs to be done at the respective villages. A decision was taken to have a competition among farmers around February 2020, villages should have functional committees by end of April 2019, and that is when training will start at respective villages. Challenges that were identified during the workshop included insects, moles, water shortage' dysfunctional committees, inputs (seeds and fertilizer), youth training, laziness and weeds and birds

✓ ***Swayimane***

A series of introductory meetings were held with farmers, local leadership and the local Department of Agriculture during the 2018/19 growing season. These meetings were intended to explain the overall purpose of the project and the project objectives. Furthermore, the purpose of these meetings were also aimed at selecting in collaboration with relevant stakeholders appropriate CST coupled with sound management practices for food and nutritional security at the start up stage of food value chains. After the introductory meetings were conducted, selected appropriate CST were implemented. Since the demonstrations could not be employed in all the farmers homesteads in the entire selected villages, neighbouring farmers were invited to participate during the implementation at selected homestead to receive informal trainings during the process.

After the technologies were implemented, several farm visit were conducted in order to capacitate farmers for the following critical CSTs:

- **Weed control**

During interviews with farmers during the establishment stage of the project, farmers raised weed control as the major issue they were facing as far as the good quality yields are concern. The research team, consisting of researchers and technical staff intervened and develop the best management practices as far as the weeds are concern. Farmers in the demonstration plots and those interested from neighbouring homestead received the trainings on how best the weeds can be control during the continuous visits and the technical staff and the students involved in the project clearly demonstrate to farmers on how best they can control their weeds under the application of climate and water smart agricultural technologies and management practices. It was very contenting to hear the farmers mentioned that they were no longer experiencing weed problems after the research was established and the best weed management practices were taught to them.

- **Supplementary Irrigation**

As part of the outcomes from the interviews conducted during the establishment of the project, farmers raised short and spatial distribution of rainfall resulting to extended dry period for irrigating their homestead gardens. The team consisting of technical staff and students introduced the use of JoJo tanks to capture the water from roof-tops during rainy seasons and use the collected water for their household requirements but most of it for irrigating their homestead gardens as supplementary irrigation. Crops that were planted in farmer's homestead gardens during winter could reach the maturity stage because the water which was an issue before was address through introduction of the use of JoJo tanks to capture water and collect it for the use as supplementary irrigation.

- **Mulching**

As scientifically predicted, it was also captured from engagements with farmers about challenges they are facing as far as their production is concern. It transpired during those engagement with farmers that their crops are experiencing excessive amounts of sunlight which increases the evaporation demands resulting to a complete crop failure. The team consisting of students and technical staff requested the farmers and further trained them about the importance of mulch application in their gardens to avoid the rapid loss of soil moisture required by the plant through evaporation. The effect of mulch application was tested by adding a treatment with mulch application and treatments without mulch. The treatment with mulch applied on it performed better than other treatments and farmers could recognised the difference between treatments themselves.

- **Use of inorganic and organic fertilizers**

Most of the farmers where the project is conducted are old women relying mostly on government grants for survival. In that regard, it was captured from the conducted interviews that most of these farmers are struggling to source expensive inorganic fertilizers to supplement limiting nutrients which are essential for plant growth. The team further train farmers on how best they can use their kraal manure as fertilizer for crops since most have livestock in their homestead. They were asked to reserve a treatment for organic fertilizer in their homestead gardens when climate and water smart agricultural technology was demonstrated. Since the use of manure is a bit critical exercise as its effectiveness relies on many factors such as the quality of manure, the age of manure, etc. Farmers were still indecisive about its effectiveness.

- **Principles of selected technologies**

Farmers were allowed to choose the technology that they would like to test from their homestead gardens and croplands. In the croplands, the farmers selected the IRWH, MB and NT as CSTs while in their homestead garden, they only selected the IRWH but coupled with sound management practices. During the fourth night visits, farmers were always taken through the principles of each technology demonstrated and during the formal training conducted in March, farmers were provided with guidelines on how best they can manage their selected technologies.

Further from the informal trainings that were constantly conducted during the growth cycle of the crops planted, the information day was conducted in villages where demonstrations were applied. These trainings were held with local Agricultural extension officers and attended by attended by extension officers and managers. They focused on the principles of climate and water smart agricultural technologies and management practices for food and nutritional security at a start-up food value chains. Furthermore, they were intended to share the results obtained during the post season as they were conducted just after harvesting and to allow farmers to see the performance of different technologies for possible up-scale and out-scaling. These training workshops were divided into in-house trainings as well as field trainings.

The in-door training / workshop was conducted in order to cover the following critical items:

- Give background of the project, its aims and objectives, share the different applicable climate and water smart agricultural technologies on food and nutrition security at a start-up stage of food value chains.
- Share the results of the previous season.
- Provide farmers with food value chains, value-adding strategies and how to access market and remain competitive.
- Production of seedlings and fertilizer application.
- Significance of growing food that will address their nutritional and dietary requirements.

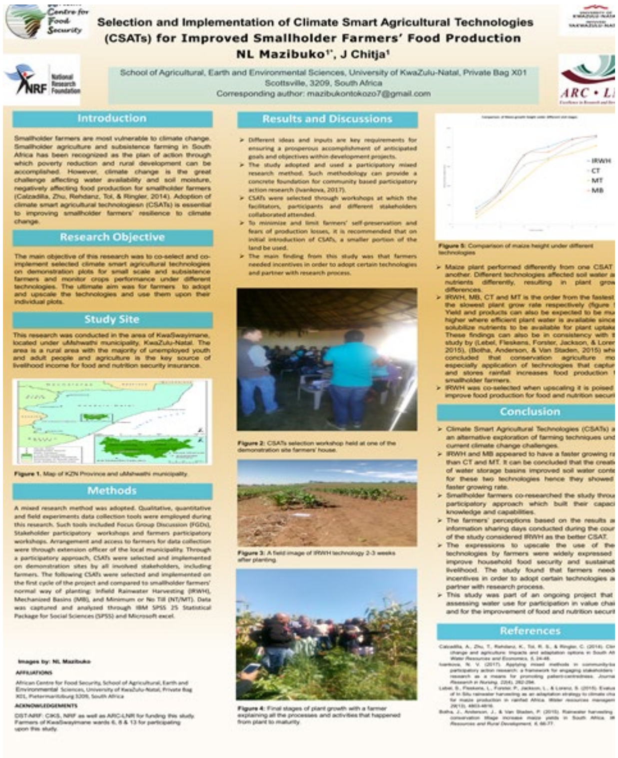
- **Knowledge dissemination**

✓ ***4th Industrial Revolution Summit (March 2019*)**

At the 4th Industrial revolution summit held at the ICC in Durban on 25 and 26 March 2019 and oral presentation on "*The contribution of climate- and water-smart agricultural technologies as an alternative solution for emancipation of rural economies*" was presented by M. Khuzwayo, J. Chitja, J.J. Botha, J.J. Anderson & N. Nongqwenga.

✓ ***eThekwini Mile Conference (June 2019)***

A poster paper on "*Selection and implementation of climate smart agricultural technologies for improved smallholder farmers' food production*" by N.L. Mazibuko and J. Chitja was presented at the eThekwini Mile conference.



✓ ***Combined Congress (January 2020)***

At the Combined Congress held in Bloemfontein from 20-24 January 2020 a poster on "*Suitability of selected ecotopes for the application of climate and water smart technologies*", by M. Khuzwayo, J.J. Botha, J.J. Anderson & N. Nongqwenga was presented.

✓ ***Agro-Processing Sector Forum (February 2020)***

An oral presentation on "*A paradigm of water management – Integration of climate and water smart agriculture, food and nutritional security with agro-processing technologies for food value chains"* by M. Khuzwayo, was presented at the Agro-Processing Sector Forum, Olive Convention Centre, Durban on 14 February 2020.

- **Exhibitions**

✓ ***Nampo (May 2019)***

At the Nampo harvest day of GrainSA held from 14-17 May 2019 Dr Anderson has set up an exhibition where he showcased the use of CSTs for the production of vegetable and cash crops in homestead gardens and croplands. Visitors to the stall showed keen interest in the techniques and many commercial farmers enquired on how these techniques can be applied on a larger scale as many are struggling with water scarcity to continue producing their crop economically. Dr Anderson has also conducted a live interview on RSG radio on the use of CSTs to address food insecurity.

Appendix 6 Formal Degrees

✓ 3 Masters students	(1 Graduated in 2017, 2 to complete in 2020)
✓ 1 Doctorate	(To complete in 2021)
✓ 1 Post Doctorate	(Completed)
✓ 1 Research Project Assistant	(1-built year capacity)