PARTICIPATORY SCHOOL-BASED VEGETABLE GARDENS TO ENHANCE SCHOOL FEEDING SCHEMES AND WELL-BEING OF CHILDREN IN MAMELODI, GAUTENG PROVINCE

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edited by

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EXECUTIVE SUMMARY

School-based participatory vegetable gardens are a long-term strategy that complements supplementation and food fortification programs to address hidden hunger. Running a school garden requires not only horticultural knowledge but also enthusiasm, organizational capacity and ability to mobilize parents and people in the area. The success of school gardens is dependent on existing political commitment and national policies that support and provide an enabling environment for the development and implementation of garden activities in schools. Addressing constraints such as supplies, technical support, infrastructure, tools and the involvement of parents and other community members is critical for the success of school gardens. School gardens implemented in South Africa often lack the participation of governmental institutions and parents, which are also essential components of a successful school garden programme.

The identification of problems and challenges of school garden programmes in this knowledge review document will assist in the development of a complete school garden model, by creating a more substantial involvement of different community members that reside around schools. The overarching aims of the project were:

- To establish vegetable gardens in two schools namely Bula Dikgoro and Mahlasedi Masana Primary Schools in the Mamelodi area, that provide vegetables to supplement nutrition for children and adults in the community;
- To improve the schools' infrastructure required for crop production in the school gardens;
- To contribute to human capacity development through school engagement and on-site training to transfer skills to the communities;
- To measure and optimise water use of selected vegetable crops in school gardens for improved nutritional water productivity and water use efficiency;
- To implement simple irrigation and nutrient management tools/technologies in school gardens for enhanced irrigation management of selected vegetable crops;
- To improve efficiency in the protection of soil and water resources by rainwater harvesting and reduced nutrient leaching.

Qualitative methodology on exploring the existing literature review was developed to answer the set of objectives of this study. The literature review focused on situational analysis on past, present and ongoing work on school-based vegetable gardens. The literature review highlighted a critical need for multi-stakeholder engagement in school garden establishment through the involvement of parents, guardians, voluntary workers, and the communities residing around the schools. In addition, the experience of the ARC team in the establishment of school gardens from Cofimvaba, Eastern Cape was used to address the objectives.

The literature review showed that malnutrition, either over- or under-nutrition, is becoming a significant problem in South Africa, especially among school-aged children. This more often leads to poor school attendance and high rates of dropout. The school environment provides an excellent opportunity for children and the community to learn about nutrition and health. Nutrition knowledge greatly influences the dietary behaviours of children and adults. School gardens have the advantage that learners can practically learn how to produce healthy food for a balanced diet. In that way, they will feel connected to their responsibility to ensure that a healthy meal is provided every day and can influence food choices in their families. Furthermore, school gardens increase food availability and diversity, can be used to promote micronutrient-rich vegetables and can benefit the mainstream education curriculum.

The activity of the project started through assessments of the two school gardens based on available infrastructure as well as learner and household characterization on food utilization and access. Given the survey results, it was evident, from both socio-economic and household food security status, that there were leaners who come from food-insecure households. Further empirical findings also indicated a correlation between measures of food security and household food security indicators. The results warrant the establishment of a food garden at the schools to supplement learners to reach daily dietary intake requirements.

The project established two vegetable school gardens, namely at Bula Dikgoro and Mahlasedi Masana public primary schools in Mamelodi, Pretoria, Gauteng, as a pilot study. In each school garden, training on necessary crop production, seedbed preparation and irrigation maintenance were provided for selected school gardening members from the schools. Irrigation systems were installed and selected winter and summer vegetable crops were planted. The vegetables were chosen based on their suitability to the area and nutritional value. New biofortified crops (e.g. orange-fleshed sweet potatoes), as well as healthy new crops (e.g. moringa), were also introduced to promote consumption in the schools and the community. Open field vegetable production systems were supplemented with veggie tunnel and bag systems to improve vegetable accessibility, pest and disease management and optimum resource utilisation.

Several production techniques were tested, including in-situ, in-field and rooftop rainwater harvesting, as well as bag and veggie tunnel systems. Rooftop rainwater harvesting showed the highest potential to mitigate the effects of climate change for increased crop productivity, as the amount of rainwater collected can be stored in tanks for supplementary irrigation of crops at critical periods of the crop-growing season, or in the event of prolonged dry spells. The metal roof tested in the study schools had a runoff collection efficiency of approximately 70%, which indicates a potential for the collection of at least 92 400 litres of water during a normal rainfall season, with a total rainfall of 400 mm during the growing season and a roof catchment area of at least 330 m^2. The potential amount of rainfall collected through the rooftop rainwater harvesting technique is, however, dependent on the availability of water storage tanks at the schools.

The adoption of a climate-smart production system is also critical, as this can be implemented in combination with rooftop rainwater harvesting for maximum crop productivity and reduced risk of crop failure. Thus, this study recommends the implementation of a bag system, due to its capability of cultivating a considerably higher number of plants per unit of land/area utilized for crop production. The implementation of a bag system resulted in increased crop yield per m^2 of land utilized, and therefore higher crop water use efficiency. The amount of irrigation water used per m^2 of the produce was also considerably lower with the bag system. However, it is recommended that economic viability studies be conducted to assess the cost-benefit analysis with the implementation of the bag system.

The project identified that food garden programmes should involve a component on the training of educators and garden personnel, provision of gardening equipment and technical advice, as well as support by government and various role players for their increased effectiveness as a nutrition-learning tool. The project provided AgriSETA accredited vegetable production training to capacitate the school garden beneficiaries.

In conclusion, the project has been successfully implemented and shows excellent potential to be rolled-out to other schools. It was identified that school gardens are beneficial through social benefits, improved beneficiary skills, and provided access to highly nutritious vegetables in the school feeding programme. It is essential that the school committee knows enough to teach the community and that the community is prepared to learn from it. It is recommended that schools encourage children to report at home what they are doing at school, invite families to visit the garden, create a model garden and distribute seedlings. Each school garden team can face challenges that are unique to the circumstances of its school community. The trained school garden beneficiaries must remain committed throughout the season, and when the school staff leaves for school holidays, the chair of the garden committee should delegate someone who can manage the garden following the guidance provided.

Future research should focus on the introduction of green technology such as solar-driven irrigation systems to improve sustainability and vertical vegetable production system where availability of open field is limited as well as on-site climate-smart research, the establishment of household gardens, support the schools with infrastructure such as the provision of boreholes and water storage tanks. It is also important to explore the impact of vegetable gardens towards meeting dietary requirements of school children and pre-processing at the school level to introduce nutritious products such as soup and veggie drinks while including high-value crops in the gardens for income generation. This will support the financial requirements for the sustainability of the garden and further inspire community participation. The pilot project has been successfully implemented and had shown excellent potential to be rolled-out to other schools around the country, to combat hidden hunger which is prevalent in school children and women in South Africa.

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LIST OF ACRONYMS AND ABBREVIATIONS

ALVs	African leafy vegetables
ANOVA	Analysis of variance
ARC-SCW	Agricultural Research Council – Soil, Climate and Water
ARC-VOP	Agricultural Research Council – Vegetable and Ornamental Plants
CGF	Conditional Grant Framework
DAFF	Department of Agriculture, Forestry and Fisheries
DEA	Department of Environmental Affairs
DoBE	Department of Basic Education
DOH-SA	Department of Health, Republic of South Africa
DSI	Department of Science and Innovation
FAO	Food and Agriculture Organisation
IFPRI	International Food Policy Research Institute
LAI	Leaf Area Index
LSD	Least significant difference
NSNP	National School Nutrition Programme
RSA	Republic of South Africa
SC	Stomatal Conductance
SPAD	Soil Plant Analysis Development
SPSS	Statistical Package for the Social Sciences
SWC	Soil water content
TUT	Tshwane University of Technology
WRC	Water Research Commission

LIST OF SYMBOLS

A	Catchment area (m^2)
K	Potassium
L	Litre
LAN	Lime Ammonium Nitrate
N	Nitrogen
P	Local precipitation (mm/year)
P	Phosphorus
PUE	precipitation use efficiency (kg produce ha^{-1} mm^{-1} rainfall)
RC	Runoff coefficient (non-dimensional) which depends on roof material
RWHP	The amount of rainwater harvested from the roof (L/year)

REPOSITORY OF DATA

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CHAPTER ONE
INTRODUCTION AND BACKGROUND

1.1 Introduction to participatory school-based gardens

A school garden is an innovative teaching tool and strategy that incorporates hands-on activities into classroom-based lessons by providing a dynamic environment in which learners observe, discover, experiment, nurture and learn. Learners' unhealthy eating habits with no or less consumption of fruits and vegetables is a vital health concern (Watts, 2018). The school food environment currently is not conducive to healthy eating habits, particularly in poorly resourced South African schools. Learners often arrive at school without having breakfast, their lunch box is often filled with bread only, and most of them bring money to the school, which allows them to access unhealthy food sold from tuck shops and vendors (Faber et al., 2013). School-based vegetable gardens have the potential to positively impact on learners' health, education and awareness of the physical environment (Laurie et al., 2017). Knowledge and skills gained by learners can potentially contribute to household food and nutrition security through the implementation of healthy eating and lifestyle habits (Laurie et al., 2013). Thus, school gardens can further be used as a vehicle to spread knowledge of food production and nutrition (Laurie et al., 2017). The extent to which school gardening programs are successfully implemented plays a critical role in the rate at which poverty and widespread malnutrition can be reduced. The National School Nutrition Programme (NSNP) has been introduced in South Africa to improve learner performance by providing nutritional meals through the cultivation of vegetable gardens (Public Service Commission, 2008).

Agricultural interventions such as food gardens should aim to increase the access of highly nutritious food crops, including fruits and vegetables and promote the expansion of under-exploited natural resources such as traditional food crops. Indigenous vegetables require minimum production inputs, and people are accustomed to them, as they know how to cultivate and prepare them. African leafy vegetables grow relatively easily, quickly and can be harvested within a short period (Maseko et al., 2018; Jansen van Rensburg et al., 2012). These crops grow on soils of limited fertility, are relatively drought-tolerant, provide good ground cover, and are usually cultivated without pesticides or fertilizers (Maseko et al., 2018; Nyathi et al., 2016). Besides, African leafy vegetables (ALVs) are rich in micronutrients, such as iron and zinc content (Nyathi et al., 2016). African leafy vegetables such as kale (*Brassica oleracea*) leaves and cowpea (*Vigna unguiculata*) leaves and pods have an abundance of β-carotene (the precursor of vitamin A) and ascorbic acid. As a result, they can considerably contribute to meeting requirements for micronutrient deficiency, which are critical nutrients for developing countries like South Africa, particularly in women and children (Van Jaarsveld et al., 2014; Faber & Wenhold, 2007). Vitamin A deficiency is caused by a habitual diet that provides too little bioavailable vitamin A to meet physiological needs (Underwood, 2000). Since animal food sources such as dairy products, liver and egg yolks are often out of the financial reach of resource-poor households, many households rely on dark-green leafy vegetables to source micronutrients. Estimates suggest that more than 80% of the dietary intakes of micronutrients in Africa are from plant foods (Steyn et al., 2016; Faber & Wenhold, 2007).

Growing a variety of vegetables in school gardens can assist in combating malnutrition among children, by increasing the availability of vegetables in the school catering facilities (Mongwa, 2005). Learners can also obtain hands-on experience in vegetable gardening, which will contribute to increased knowledge of vegetables, willingness to taste vegetables, and intake of vegetables at the household level (Laurie et al., 2007). Thus, a school food garden programme can play an essential role in teaching learners about gardening concepts and skills to increase home production for household food and nutrition security (Laurie et al., 2013). Food garden programme should involve a component of the training of educators and garden personnel, provision of gardening equipment and technical advice, as well as support by government and various role players for their increased effectiveness as a nutrition-learning tool (Laurie et al., 2017). To increase the crop productivity of school-based vegetable gardens, the implementation of adequate water management practices should be encouraged in both irrigated and dryland crop production. These include practices such as deficit irrigation (Maseko et al., 2019) and rainwater harvesting (Biazin et al., 2012; Ibraimo, 2011), which are particularly important in dry countries like South Africa, where the available rainfall is in general not sufficient to meet crop water requirements (Hensley et al., 2011).

This project would not be able to provide solutions for all the nutrition-related problems in schools and households of South Africa. However, it endeavoured to establish sustainable and productive vegetable gardens in selected schools, in order to improve access to vegetables, as these crops can potentially be used in the school meals, or be sold as a source of income. With such intention, a comprehensive literature review on school-based vegetable gardens and a situational analysis of the study sites were necessary. Bula Dikgoro and Mahlasedi Masana public primary schools in

Mamelodi, Gauteng Province, South Africa were selected as study sites. The total number of learners involved in the school feeding programme were 1182 and 1753, respectively.

1.2 Rationale

Insufficient vegetable and fruit consumption causes 2.7 million deaths annually worldwide and belongs to the top ten risk factors contributing to mortality (Ruel et al., 2005). The International Food Policy Research Institute (IFPRI) predicts an 18% rise in the number of malnourished children in sub-Saharan Africa from 2001 to 2020 (IFPRI, 2001). According to the World Health Organization (WHO, 2020), vitamin A and micronutrient deficiency remain a widespread problem and a cause of cardiovascular diseases, cancer, chronic respiratory diseases and diabetes, all of which results in 60% of all deaths globally. In the rural parts of South Africa, vitamin A deficiency is a severe health problem, particularly in women and children. A survey indicated that 63.8% of pre-school children were vitamin A deficient, one in three children under six years of age is afflicted with vitamin A deficiency, and one out of two children (1-9 years old) had less than 50% of the required intake of energy, vitamins A and C, as well as iron (Fe) and zinc (Zn) (Mchiza et al. 2020; Bain et al., 2013; Smuts et al., 2005).

Malnutrition, including undernutrition, vitamin A, iron and zinc deficiency, is globally among the leading causes of disease burden and mortality in children (Ruel et al., 2005). Nutritional deficiencies are similarly a significant health problem in South Africa. Some findings on the severity of micronutrient deficiency in South Africa indicated that about 50% of children between 1 and 9 years old required intake of energy, vitamin A, vitamin C, riboflavin, niacin, vitamin B6, folic acid, iron and zinc (Mchiza et al. 2020; Shisana et al., 2013).

ARC-VOP implemented a food-based approach project in the Eastern Cape Province, which focused on technology transfer and mobilization of local organizations. An Evaluation of the project indicated that participating households in the project showed lower levels of reported illnesses for children aged 1-5 years, better knowledge of nutritional aspects and higher intake of β-carotene-rich vegetables than non-participating households (Laurie et al., 2007). Department of Science and Innovation (DSI) funded the ARC-VOP to establish school gardens in five schools (Arthur Mfebe Senior Secondary, Siyabalala Senior Secondary School, St Marks Junior Secondary School, Gando Junior Secondary School and Bangilizwe Junior Secondary School) in Chris Hani District Eastern Cape Province. The project contributed to better quality and quantity of vegetable production in the school gardens, the introduction of highly nutritious vegetables, the addition of knowledge on cultivation practices of vegetables among the learners and its extension among the rural communities. This project provided more evidence that agricultural interventions can contribute significantly to nutritional outcomes. Crops employed in the projects were orange-fleshed sweet potato (*Ipomoea batatas*), African leafy vegetables, carrot, spinach (swiss chard) and butternut. These crops are all rich in β-carotene, which is converted to vitamin A in by the human body.

The ARC-VOP was commissioned by Water Research Commission (WRC) to establish vegetable school gardens in two schools (Bula Dikgoro and Mahlasedi Masana public primary schools) in the Mamelodi East, Pretoria, Gauteng Province, South Africa as a pilot study. Mamelodi is 1328 m above sea level and has an annual rainfall of about 500 mm with mean daily maximum temperature during the summer season of 29°C and mean daily minimum temperature during the winter season of 4°C. The study site has semi-arid climatic conditions.

1.3 Aims and objectives of the study

The overall objective of the project was to address food security and malnutrition in schoolchildren through the participation of communities that reside around the schools in order to improve vegetable accessibility to the school feeding programme. The overarching aims of the project were:

1. To establish vegetable gardens in two schools namely Bula Dikgoro and Mahlasedi Masana Primary Schools in Mamelodi area, that provide vegetables for nutrition to children and adults in the community;
2. To improve the schools' infrastructure required for crop production in the school gardens;
3. To contribute to human capacity development through school engagement and on-site training to transfer skills to the communities;
4. To measure and optimize water use of selected vegetable crops in school gardens for improved nutritional water productivity and water use efficiency;
5. To implement simple irrigation and nutrient management tools/technologies in school gardens for enhanced irrigation management of selected vegetable crops;

6. To improve efficiency in the protection of soil and water resources by rainwater harvesting and reduced nutrient leaching.

1.4 Research approach and methods

Bula Dikgoro (-25.7044°, 28.3986°) and Mahlasedi Masana (-25.7149°, 28.4184°) are public primary schools located in Mamelodi East, City of Tshwane Metropolitan Municipality, Gauteng Province. They were identified by the Water Research Commission (WRC) as a pilot site to establish school-based vegetable gardens to supplement the school feeding programme in order to address food insecurity and micronutrient deficiency among schoolchildren. School nutrition gardens are a long-term strategy that complements supplementation and food fortification programs. This project promoted the production of green leafy vegetables (commercial exotic and African leafy), sweet potato and legume crops in the schools. These crops are high in micronutrients (Fe, Zn and Beta-carotene) that are often lacking in children's diet.

1.5 Report structure

The approaches used in this project are aligned to answer the specific objectives of the project and they are presented in Chapters in this report. The first chapter provides a general introduction, objectives of the project and of the rationale for the project. The second chapter is a comprehensive literature review to collate existing knowledge and understand the problems/challenges that exist at present in current school-based vegetable gardens. As the human diet usually consists of carbohydrate and mineral nutrients, a range of underutilized crops were explored to be included in the programme. Available literature was collected and critically analysed concerning crop water use, nutritional value, cropping systems and local relevance. Detailed attention was given towards understanding irrigation, fertilisation, crop rotation/intercropping and agronomical cultivation practices of selected summer and winter indigenous and commercial exotic vegetable crops. In order to develop strategies for improving resources inputs (water and nutrient) in school-based vegetable gardens, the problems/challenges and lessons learnt in the establishment of school gardens were highlighted.

The third chapter addresses the assessment of the two schools through a feasibility study. Based on the evaluation, the necessary required infrastructure, gardening tools, inputs and potential crops to be produced in summer and winter months were identified. The assessment further identified critical factors such as primary water source and availability of water, soil and water quality, the existence of irrigation system, size of the garden, training requirement of the school garden beneficiaries, fencing requirements, presence of JoJo tank and rainwater harvesting infrastructures and presence of garden committee. This Chapter addressed objectives 2 and 3 of the project.

Chapter four focusses on the implementation of the project and covers activities such as land preparation and application of manure to improve soil water holding capacity of the soil. The chapter describes the installation of equipment (including soil water measuring sensors and wetting front detectors), vegetable crops planted (based on their seasonal requirements) and preliminary water balance and plant physiological studies at the school gardens. Results on different vegetable production systems, water use, rooftop rainwater harvesting, yield and vegetables supplied to the school kitchen are presented and discussed. This Chapter addressed objectives 1, 4 and 6.

Chapter five presents aspects related to stakeholder engagement and training provided on vegetable production. The training included learning basic gardening practices (planting, fertilization, watering, harvesting, storage, and nutritional values), gardening and irrigation management at their respective schools. The chapter further discusses the basic understanding of the beneficiaries on Vegetables and Health, such as growing sweet potato, potatoes, indigenous crops, cowpea, onions, and carrots, butternut, spinach, tomatoes pumpkin and squash as well as the nutritional value of vegetables. A crop management and garden planning concept to ensure sustainable growth of the crops, both in summer and winter seasons are also presented. This Chapter addressed objective 3.

Chapter six presents the school garden pilot concept demonstration. This Chapter touched on the connection between the school learners, community and nature. The challenges, critical success factors of the project are discussed in this Chapter. Chapter seven provides a general summary, conclusion and recommendation on future research.

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CHAPTER TWO

REVIEW OF LITERATURE ON PAST, PRESENT AND ONGOING WORK ON SCHOOL-BASED VEGETABLE GARDENS

2.1 Introduction and background

A school garden is an innovative teaching tool and strategy that incorporates hands-on activities into classroom-based lessons by providing a dynamic environment in which learners observe, discover, experiment, nurture and learn. Learners' unhealthy eating habits with no or less consumption of fruits and vegetables is a significant health concern in South Africa (Kunene & Taukobong, 2017; Naidoo et al., 2009). The school food environment currently is not conducive to healthy eating habits, particularly in poorly resourced South African schools. Learners often arrive at school without having breakfast, their lunch box is mostly filled with bread only, and most of them bring money to the school, which allows them to access unhealthy food sold from tuck shops and vendors (Faber et al., 2013). School-based vegetable gardens can have a positive impact on learners' health, education and awareness of the physical environment (Food and Agriculture Organization, 2004). Knowledge and skills gained by learners can potentially contribute to household food and nutrition security through the implementation of healthy eating and lifestyle habits (Laurie et al., 2013). School gardens can further be used as a vehicle to spread knowledge of food production with a linkage to nutrition (Laurie et al., 2017). The extent to which school gardening programs are successfully implemented plays a critical role in the rate at which poverty and widespread malnutrition can be reduced. Several school nutrition programs have been introduced in South Africa to improve learner performance by providing nutritional meals through the cultivation of vegetables in school gardens (Moletsane, 2016).

Growing foods such as commercial vegetables, new biofortified crops (e.g. orange-fleshed sweet potatoes), as well as healthy new crops (e.g. moringa) in school gardens can assist in combating malnutrition among children, by increasing the availability of vegetables and fruits in the school catering facilities (Mongwa, 2005). School gardens can also be used to promote the expansion of under-exploited natural and traditional resources such as the ALVs. These vegetables are rich in micronutrients such as iron and zinc; the leaves have abundant β-carotene levels (the precursor of vitamin A) and ascorbic acid. As a result, they can considerably contribute to meeting requirements for micronutrient deficiency, which are critical nutrients for developing countries like

South Africa, particularly in women and children (Van Jaarsveld et al., 2014; Faber & Van Jaarsveld, 2007). Since animal food sources such as dairy products, liver and egg yolks are often out of the financial reach of resource-poor households, many households rely on dark-green leafy vegetables to source micronutrients. Estimates suggest that more than 80% of dietary intakes of micronutrients in Africa are from plant-based food (Faber & Van Jaarsveld, 2007).

The hands-on experience obtained by learners in school gardening can contribute to increased knowledge of vegetables, willingness to taste vegetables, and intake of vegetables and fruits at the household level (Laurie et al., 2017). Thus, school food garden programmes can play an essential role in teaching learners about gardening concepts and skills to increase home production for household food and nutrition security (Laurie et al., 2013). Food garden programmes should involve a component of the training of educators and garden personnel, provision of gardening equipment and technical advice, as well as support by government and various role players for their increased effectiveness as a nutrition-learning tool (Laurie et al., 2017). To increase the crop productivity of school-based vegetable gardens, the implementation of adequate water management practices should be encouraged in both irrigated and dryland crop production. These include practices such as deficit irrigation (Maseko et al., 2019; Allen et al., 1998) and rainwater harvesting (Biazin et al., 2012; Ibraimo, 2011; Oweis et al., 1999), which are particularly important in dry countries like South Africa, where the available rainfall is in general not sufficient to meet crop water requirements (Hensley et al., 2011).

2.2 Methods used for literature research

The literature review used a systematic qualitative approach to identify relevant research works. The comprehensive search included online sources, peer-reviewed papers published in journals, books and other publications such as popular articles. Literature from universities, national research institutions, student theses, conference proceedings, working papers, and project reports was considered. The search was conducted using various search engines such as Google, Google Scholar, Scopus, etc., using the following terms: “school garden”, “school vegetable garden”, “food security of schoolchildren” or ‘’school nutrition’’ or “school garden and community support”, ‘’ implementation of school garden’’ and ‘’sustainability of school gardens’’ in South Africa and the rest of the world. The review looked at benefits of a school garden, strategies for implementation, situational analysis for intervention planning in schools, stakeholder and policymakers' engagement, challenges and critical successes. This review, however, is not aimed at providing solutions for all the nutrition-related problems in South Africa schools.

2.3 School nutrition and school gardens

Severe poverty and consequent hunger, low learning levels and high school dropout (FAO, 2004) is a worldwide problem. Shisana et al. (2013) reported that 16.5% of girls were overweight compared to 7.1% of boys, and 11.5% of girls were obese compared to 4.7% boys (Table 2.1). Stunting, low body weight and micronutrient malnutrition, which includes deficiencies in iron, iodine and vitamin A, are some of the main challenges faced by school-age children (FAO, 2019). These challenges influence the children's health, development and educational achievements negatively (Faber et al., 2013). Micronutrient malnutrition, also known as "hidden hunger", is another major social problem in South Africa (Faber & Wenhold, 2007). The irony of over- and under-nutrition as well a range of micronutrient deficiencies, requires complementing strategies and an integrated approach to ensure optimal nutrition (Department of Health, 2012).

Although programmes and interventions in various sectors are increasingly aimed at improving nutrition (FAO, 2014), schools are the main social context wherein knowledge, behaviours and attitudes are developed (FAO, 2004). By influencing the attitudes of school children towards food and nutrition security, families can benefit through the transfer of skills and knowledge at the household level.

Table 2-1: Anaemia and iron deficiencies in children under five years in South Africa. A comparison of the SANHANES-1, NHANES, NFCS-2005 and SAVACG-1995. (Source: Shisana et al., 2013).

Age	Anaemia	Iron deficiency anaemia	Iron deficiency
SAVACG (1-5 years)	21.4%	5.0%	4.8%
NFCS-2005 (1-5 years)	28.9%	11.3%	7.8%
NHANES (1-3 years)	5.1%	2.1%	9.2%
SANHANES-1 (<5 years)	10.7%	1.9%	8.1%

For children to become healthy future adults with secure livelihoods, there is a need for an enabling school environment, excellent opportunities for acquiring skills and knowledge relevant to life and environment (FAO, 2004).

2.3.1. The national school nutrition programme

In South Africa, the government introduced the Primary School Nutrition Programme in 1994, which was handed over by the Department of Health to the Department of Basic Education in 2006 (DoBE, 2011). The programme then expanded to secondary schools and changed focus to educational outcomes and school nutrition; thus the name changed to the National School Nutrition Programme (NSNP) (Moletsane, 2016). During these changes, several critical issues that needed to be improved were identified (Public Service Commission, 2008) and these include:

- Costs of the school feeding programme and logistical complications;
- Lack of capacity and inadequate/under-resourced management systems;
- Poor adherence to quality and quantity standards.

The objective was to provide meals to school children in quintile one to three schools (DoBE, 2008). The programme has three sub-programmes, namely (Laurie et al., 2013):

1. The feeding programme – aimed at reducing short-term hunger through the provision of nutritious meals to learners and therefore improve their learning capacity;

2. The sustainable food production in school programmes – aimed at providing knowledge and transfer skills to schools and surrounding communities, by promoting the implementation of sustainable food production initiatives for household food security;
3. The nutrition education programme – aimed at promoting healthy eating and lifestyle among school communities through the strengthening of nutrition education and knowledge.

Therefore, the NSNP concept was focused more on educational intervention than a health intervention and was based on a few legislative provisions (Public Service Commission, 2008). The Conditional Grant Framework (CGF) is a policy document that guides the funding of the NSNP, stipulating the programme as poverty alleviation and educational intervention legislated by the Division of Revenue Act (DORA; Act 5 of 2004; National Treasury, 2008) with the Department of Basic Education as the chief custodian. The important legislative framework that guides the NSNP is the SA constitution and International Children's Charter which emphasize access to quality food and essential nutrition; the National Educational Policy Act 27 of 1996 as well as the SA Schools Act 84 of 1996 which highlights the right to access quality primary education and learner success; and the 2003-2005 Strategic Plan for the Department of Education which covers the care for children affected by HIV/AIDS (Public Service Commission, 2008). The Preferential Procurement Policy Framework (Act no. 2000) guides the procurement of food for the NSNP, with provinces deciding between a centralised or decentralised model (Rendall-Nkosi et al., 2013).

Challenges with compliance to the NSNP guidelines of providing meals to learners for five days a week was reported to be mainly due to unreliable delivery or non-delivery of food, as well as delivery of poor quality food products by service providers (Public Service Commission, 2008). Coupled to that is the lack of facilities such as cold rooms or refrigerators for storage of food.

One of the three pillars of the NSNP places the focus on sustainable food production, which encourages schools to establish school gardens to enhance the meals (Rendall-Nkosi et al., 2013). A National Report (2008) by the Department of Education indicated that 50% of the sampled schools in Free State, Gauteng and KwaZulu-Natal Provinces had active gardens, with the number of schools with active gardens in Mpumalanga and Eastern Cape Provinces increase from 12% in 2004/5 to approximately 45% in 2006/7. A decline in several schools with gardens from 6503 in 2008 to 3994 in 2011 has been reported in other studies (Rendall-Nkosi et al., 2013).

Drought incidence may be one of the reasons for this decline, as mentioned in the Public Service Commission report (2008).

The Public Service Commission (2008) reported that the NSNP increased learner enrolment and attendance at school, improved classroom participation as well as social and physical participation.

2.3.2. The school garden programme and benefits

School gardens have several benefits, which can be categorised into educational and economic/food security benefits (FAO, 2004). The advantage of the style of learning that takes place in a school garden is that it uses direct contact with the natural phenomenon and becoming more experiential and inquiry-based (Blair, 2009). The educational benefits include:

- Relevance and increased quality of education – by introduction into the curricula essential life skills;
- Learning to establish and maintain vegetable gardens and, their benefits and increased awareness of the availability of micro-nutrient rich fruits and green leafy vegetables;
- Improved attitude towards agriculture as a school subject;
- Practical teaching on environmental issues, nutritional education and healthy diets;
- Providing students with a tool for survival during periods of food shortages;
- Cognitive development – by stimulating children's need to understand and make sense of what they are experiencing in the garden;
- Developing and strengthening the children's capacities for experimental observation and analytical examination.

Economic and food security benefits include:

- Sustainable food production methods that are applicable at home for food security;
- Creating income generation opportunities;
- Improved food availability and diversity;
- Improved nutritional quality of food at home and schools – thus reducing the incidence of malnutrition.

For the NSNP, the primary benefit is a sustainable supply of right quality products, thus resolving one of the significant challenges. Vegetables, fruits and others can be harvested fresh from the garden with no need for storage.

Several school food garden projects were implemented across various provinces of South Africa (Mongwa, 2005; Tundzi, 2008; Laurie et al., 2013). The projects were developed as a tool for health promotion among young people, as well as for knowledge generation on food production methods that conserve natural resources and the environment. The school-gardens included the following vegetables: spinach, cabbage, tomatoes, pumpkin, kale, eggplant, and onions (Figure 2.1).

Figure 2-1: Teacher demonstrating to learners the benefits of a school-garden (Source: ARC-DSI, 2018).

Before the implementation of the projects, initial meetings were held between the funding institution and school stakeholders such as principal, teachers, learners, and caretakers. These meetings consisted of identifying priorities such as a garden that is organically grown or not, would prioritize growing food for the school feeding scheme, and the school would be responsible for maintaining the garden, a process in which teachers, learners, caretakers, and other community members were encouraged to participate. Selected staff members of the schools were trained in agriculture and school garden-related practices such as planting seeds, shaping garden beds, weeding and harvesting. Perceptions of learners, teachers and parents on the benefits of school food gardens were evaluated in one study through a cross-sectional survey (Laurie et al., 2013). Such studies may also include socio-demographic information of each learner, as well as analysis of children's dietary intake and dietary diversity (Beery et al., 2013).

The garden programs described above were conceived as a health-promotion intervention, and the initial focus was on nutrition. Although the gardens contributed much-needed fresh vegetables to learners' diets, with their relatively small yields, they could not significantly improve learners' dietary diversity and nutritional status over the long-term, as a high enough year-round yield was not attained. Instead, the gardens appeared to have played a role in changing mindsets about healthy eating and increasing knowledge of various aspects of growing, preparing and eating health-promoting fruits and vegetables (Laurie et al., 2017).

The school food gardens also potentially provided a resource for active, experiential learning opportunities in a formal (linked to specific curriculum topics and integrated with classroom-based learning) or informal (through after-school activities or during playtimes) contexts (Beery et al., 2013). It was, however, demonstrated that different types of knowledge required different types of teaching interventions. For instance, learners ability to identify fruits and vegetables was reported as best shown in the nutrition education combined with gardening intervention, when compared to the gardening only and nutrition only interventions. Learners' nutrient-function associations were best demonstrated in the nutrition education intervention only, followed by the nutrition education combined with gardening. Thus, there was no single intervention that could be used to improve all types of knowledge.

The following vital lessons were taken from the implementation of school-garden programmes (Beery et al., 2013; Laurie et al., 2013; Faber et al., 2013): (1) In order to achieve sustainability; a school garden needs to address not only practical challenges, for example, related to maintenance, but also cultural challenges in order to maintain adequate levels of motivation among the school community; (2) Long-term engagement with the garden is required, as the hard work of a garden lies not in the establishment of the site, but rather in the regular maintenance over the years; (3) Successful school gardens should be able to change attitudes to gardening and change the cultures around them – cultures at school, and cultural attitudes toward gardening and landscaping.

2.3.3 Perceptions and use of school gardens

Nutrition knowledge has a significant influence on dietary behaviours of children and adults, healthiness and willingness to try functional foods (Moletsane, 2016). Knowledge can be gathered from theoretical and practical work through educational platforms, but it can also be gathered through experience by observation of individual behaviours and then passed on from generation to generation (Moletsane, 2016). This is very important, as consumers with less nutrition knowledge are less willing to try functional foods (Moletsane, 2016). Laurie et al. (2013) found that the majority of learners interviewed enjoyed working in the garden, referred to it as their duty and above that, they indicated the primary purpose as learning about healthy eating and food production. Parents also indicated that school food gardens had a positive influence on children's behaviour and that gardening can teach children about a healthy diet (Laurie et al., 2013). The same study found that most teachers had a positive feeling about learners being exposed to garden work. However, awareness campaigns and information sessions are required as some parents see garden activities as unfair or unfit for learners. About 29% of the parents interviewed by Laurie et al. (2013) perceived garden work as a low-status activity, 21% rated it as boring, 29% thought it should be a punitive exercise, while 33% did not agree with primary school children working in the garden. This could be due to the parents' previous experience with gardening as a job where awareness campaigns could play an important role to influence their mindset.

2.3.4 Strategic elements required for the implementation

The main elements of a successful school garden programme (FAO, 2005) includes:

- Clear objectives – well defined, realistic and specific to address a problem. Agreed to by all stakeholders, with a precise balance between learning and production; taking into account learners and community expectations;
- Appropriate institutional arrangements – school gardens address issues like school curricula, training of teachers and trainers, access to land and funding as well as nutrition. All the relevant institutions should be involved in the school garden;
- Training – development of training material and training of teachers and community members in the planning, management and use of school gardens;

- Integration of school gardening and related activities into the curricula – this has to take into account the national priorities and choices related to the curricula. However, learning activities pertaining to crop production, nutrition, environment and life skills could benefit from the school garden;
- Land and water development – fencing, irrigation, land preparation, etc. will need funding. Ownership, maintenance obligations and rights to use should be clear. A transparent process leading to material and financial sustainability, with a good "exit strategy" should be in place;
- Budgetary provision – core costs for the programme and physical inputs for the school garden should be well pronounced;
- Monitoring and evaluation – all parties involved in the planning and implementation should also be included in the monitoring and evaluation process.

Furthermore, hard work is the basis of a successful garden. In this case, the key elements include (Jowell, 2011):

- Dedication – household gardens are driven by the need for food, community gardens by the potential to raise income revenue and both are absent in a school garden. There is evidence that a dedicated school maintenance person ensures a successful school garden rather than a volunteer teacher;
- Land – sufficient fenced area with secure tenure is critical. A garden of 10 m x 10 m can support a family of 6-8, therefore for a school feeding programme, available land must be significantly more to meet the demand.
- Planting material – continuous access to quality seeds, seedlings and virus-free plant material;
- Water – several school gardens are a failure due to lack of irrigation water. Without water, plants will not survive, and without a close-by water source, it will be difficult to ensure enough irrigation at the correct time;
- Technical support – ongoing mentorship is necessary for the success of the garden. This will include advice on planning, pest and disease control, correct fertilizer application, which are areas that need proper understanding;
- Nutrition focus – the focus of the garden should be agriculture and nutrition. Therefore, the garden has to provide a variety of vegetables with the right balance of micronutrients and dense energy foods.

- Care during school holidays – this is an integral part as the plants will need care throughout the year. A dedicated maintenance person may be required for this.

Laurie et al. (2017) correctly mentioned that addressing constraints such as supplies, technical support, infrastructure and tools is critical for the success of school gardens. Successful school-based physical activity and nutrition intervention necessitates the involvement of parents and other community members in school gardens (Bain et al., 2013; Pérez-Rodrigo and Aranceta, 2003).

2.3.4.1 Political commitment and institutionalization

The success of school gardens is dependent on existing political commitment and national policies that support and provides an enabling environment for the development and implementation of garden activities in schools (FAO, 2011; FAO, 2004). School garden programmes should be a national effort to improve education quality and access for children in general (FAO, 2004). Institutionalization of school gardens is vital to the sustainability of the intervention (FAO, 2004). Governments should have a clear vision of how school garden initiatives will fit into their overall educational goals (FAO, 2011; FAO, 2004).

The absence of clear national policies and guidelines for the implementation of garden-based learning has many problems, such as (FAO, 2007):

- Confused aims – problems with reconciliation of learning objectives and garden activities;
- Widespread negative image – where garden activities can be seen as punitive
- Poor garden planning and coordination – with a lack of perception of links between food, nutrition and health;
- Lack of community support and integration into the curriculum – leading to a lack of sustainability;
- Inadequate monitoring and evaluation – leading to a high failure rate of gardens
- Insufficient capacity – to translate policies into context.

Governments can encourage school garden movement by taking the lead in changing attitudes, enabling inter-sectoral collaboration, availing funds, developing national curriculum and promoting teacher development (FAO, 2010).

2.3.4.2 Responding to the local environment and location-specific needs

School garden programmes should take into account local customs and needs, to specific socio-economic, climate and environmental situations (FAO, 2004). Eating habit is a function of environmental cues surrounding food intake (Patrick and Nicklas, 2005). The incidence of climate change, high rates of HIV/Aids and unemployment are critical in the implementation of school gardens. Garden activities should include teaching learners how to respond to the environment, strategies to mitigate climate change and resilience.

2.3.4.3 Key roles played by a school garden programme

School gardens contribute significantly to increasing the relevance and quality of nutrition education in schools, improves society's knowledge of food production techniques and nutritional benefits while motivating the development of home gardens (FAO, 2004).

School gardens can have both educational and community benefits. Such benefits can include (Jowell, 2011):

- Nutrition education – school gardens have a positive impact on nutrition understanding, provides a practical learning environment;
- Community empowerment – through community training, especially for women, who have greater control of food provision in the families;
- Social cohesion – the establishment of social networks and motivation for community development;
- Psychosocial benefits – reduction in social alienation and family disintegration.

Schools gardens can complement school feeding programmes and enhance their long-term impact on nutritional status and learning achievements of learners (FAO, 2004). School gardens can also be used to promote micronutrient-rich vegetables in homes and community gardens (FA0, 2004).

A significant number of children in South Africa go to school either hungry or without having a meal (Faber et al., 2013). The study found that 20% of leaners went to school without eating breakfast, and only 24% carried lunchboxes containing bread/sandwich. The learners who had breakfast had bread or porridge only on their own or with a protein-rich vegetable or fruit (Faber et al., 2013). In terms of nutrition management, 13% of the schools had a policy on foods that learners bring to school with a focus on healthy foods (Faber et al., 2013). Many schools also did not comply with the mandate of serving vegetables and/or fruits every day, maybe due to lack of appropriate storage facilities as vegetables and fruits are bulky and perishable (Faber et al., 2013).

The decisive point is that 99% of teachers agreed that they need to promote good health and nutrition, 46% believed that it could be done through teaching, 15% believed by encouragement and 11% by setting an example (Faber et al., 2013).

2.4 Nutritional knowledge, attitudes and practices of learners

While knowledge is the understanding of a given topic, attitudes are personal, perceptive and cognitive beliefs that influence behaviour or practices of an individual; and practices are observable actions of an individual (FAO, 2014). Improved nutrition knowledge through nutrition education can have a positive influence on healthy food choices (Oldewage-Theron and Egal, 2010).

Successful nutrition education and behaviour change strategies are mostly based on local dietary beliefs and practices (DOH-SA, 2012). Eating habits developed by children are affected by factors such as availability and preferences towards particular foods, parent's beliefs and practices (Patrick and Nicklas, 2005). Oldewage-Theron and Egal (2010) found that although the knowledge of general nutrition facts was fair for primary school learners in QwaQwa, there was inadequate knowledge of food groups and their roles in the diet. The study further found that even though the importance of inclusion of a variety of foods in a diet was valued, it was not reflected in the daily food selection (Oldewage-Theron and Egal, 2010). Studies have shown that eating vegetables and fruits as "good for you" is not a guarantee of their consumption as the intake could remain below the recommended levels (Moletsane, 2016), meaning that nutritional knowledge did not influence daily healthy food choices (Schreinemachers et al., 2018; Abrahams et al., 2011). This brings the question of knowledge and putting the knowledge into action, nutrition knowledge and choosing food for taste, not nutritional quality.

2.5 Learners feeding practices and perceptions

A child's attitudes and beliefs around food is to a more significant part shaped by home and school environment (Wiles et al., 2011). The marketing of food to schoolchildren has been on the spotlight as it influences child obesity (Davis and Carpenter, 2009). Parents have the most significant influence in the early childhood stages, but as the child grows, media, peers and nutrition education at schools become the greatest influencers (Wiles et al., 2011). When children reach the adolescent stage, the family become less critical while friends, peers and social media become vital influencers on their eating habits (Pérez-Rodrigo and Aracenta, 2003). South African children demonstrate unhealthy eating habits with school tuck shop choices mostly limited to fizzy drinks, chips and fried cakes (Naidoo et al., 2009).

Some schools have designated tuck shops for learners to buy food and drinks, either to raise funds or for individuals to make a profit (Wiles et al., 2011). At times, fast-food restaurants are concentrated within a short walking distance from schools, giving learners greater access to low-quality food (Davis and Carpenter, 2009). Due to peer pressure, eating from tuck shops and fast-food restaurants is perceived to be more "cool" than bringing lunchboxes from home. Faber et al. (2013) found that 57% of learners brought money to school. It has been reported that learners are least likely to buy fruits from school tuck shops compared to "unhealthy" items because it is deemed unpopular by peers (Wiles et al., 2011). A variety of foods sold in school tuck shops included "unhealthy" food item like chips, sweets, biscuits (Faber et al., 2013) and again "healthier" food items were found to be more expensive, which made it unlikely for learners to buy them if they were to prioritize value for money (Wiles et al., 2011). For example, canned fruit drinks were more expensive than carbonated drinks (Wiles et al., 2011). Davis and Carpenter (2009) found that in the US, students whose schools were near restaurants were likely to be overweight or obese.

2.6 Challenges and opportunities for implementation

Although food gardens have been emphasised as a tool to maintain a healthy diet, there are some uncertainties, especially at the substance level (Jowell, 2011). This is because cultivation has not led to increased consumption, maybe due to lack of nutrition knowledge; growers often prefer to grow maize than other vitamin-rich crops, perhaps because of the focus on income generation and ease of management; consumption of vegetables is sporadic and at low levels, maybe due to lack of knowledge and eating for taste rather than nutrition. Laurie et al. (2017) mentioned some challenges of establishing and sustaining a school garden as lack or insufficient knowledge and skills to manage the garden, lack of resources, poor soil quality, lack of support from school governing body (SGB) and parents and failure to link school gardens to core- or extra-curriculum activities. School access to fresh vegetables and fruits can be increased through local production at a school garden or in the community (Faber et al., 2013).

Understanding the issues surrounding the nutritional impact of food gardens requires an understanding of what improved nutrition is, the impact of income replacement on nutrition and the need for nutrition education (Jowell, 2011). Nutrition education at school levels has the potential to influence dietary preferences at homes as children can influence food choices in their homes. The combination of nutrition education with vegetable gardens has shown a positive impact on the diet (Jowell, 2011).

There is growing evidence that supports school food gardens and creates opportunities for their development (Jowell, 2011):

- Growing and preparing school gardens increases children’s preferences for healthy fruit and vegetables;
- School gardening with nutrition education results in voluntary changes in diet
- Gardening activities improves children’s understanding and attitudes to their natural environment;
- School gardens offer an opportunity for hands-on learning, which is more advantageous than classroom learning.

However, how will the garden curricula benefit the mainstream curriculum (FAO, 2010)?

- With agriculture in the curriculum, the basics of horticultural practices can be learned in the garden;
- As the garden responds to environmental concerns, environmental lessons can be learned practically;
- The garden activities should be designed to improve learners knowledge on nutrition and health issues as part of life orientation;
- Sales and marketing of garden produce will equip learners with business skills.

2.7 Problems and challenges with existing school gardens

Yu (2012) describes the major challenges to the success of school gardens. In general, the problems are mainly due to a lack of broad-based support and lack of strategic planning.

The first main problem is limited funding, which is related to issues such as the maintenance of the garden. Most successful school gardens have at least one paid employee to maintain them, who can maintain the garden even during school holidays. If schools have to fund garden activities, then there is a challenge of rightfully prioritizing educational needs before the garden needs. Without funding, there will be no dedicated garden coordinator. Where there is poor or no voluntary participation of adults, it further leads to overburdening of teachers, as they now have to continue with the teaching with an added responsibility of the garden. Teachers often have limited time for "extra" activities after teaching, pointing a need for adult participants. Another important problem is the lack of teaching experience or training in gardening. This can limit the teacher's enthusiasm on the school garden, leading to hesitation and unwillingness to participate in or plan lessons around the garden.

From a resource point of view, lack of land can be another challenge for school gardens (Foeken et al., 2010). This has an impact on the capacity of the school garden to produce enough for the learners. Coupled to that, a piece of land allocated to the garden can be changed to use for other projects such as building classes as this may be a higher priority for education. A lack of water poses a serious challenge to the success of the garden. Where the schools have to pay for municipal water, which links to the funding of the garden, a decision may be to cut water supply to the garden to save on costs.

2.8 Identification of nutrition-related problems and solutions

Hunger and malnutrition are outcomes of inadequate food intake (Jowell, 2011). Hunger relates to food insecurity in terms of availability and malnutrition is not only the lack of sufficient micronutrients in the food basket (Jowell, 2011), but it includes undernutrition and over-nutrition. Inadequate dietary intake is an immediate cause of malnutrition, and therefore, agriculture with a behaviour change approach can contribute to improvements in nutrition (DOH-SA, 2012). The solution to malnutrition is availability and access to adequate types and diversity of food (Jowell, 2011) and using local foods rich in micronutrients can be one good strategy (DOH-SA, 2012).

Stunting was found to be more prevalent (14.1%) than overweight (12%) and obesity ((2.8%), at a primary school in QwaQwa (Oldewage-Theron and Egla, 2010). Abrahams et al. (2011) found that 20% of learners in schools in the Western Cape were overweight, and 19% were stunted.

Communication strategies that are aimed at raising awareness about the effects of malnutrition, increased availability of a variety of micronutrient-rich foods are essential parts of the solution (DOH-SA, 2012). School gardens can be used to share knowledge about food production, creating a culture and love for food gardens linked with nutrition (Laurie et al., 2017). Food gardens have the potential to impact on malnutrition by providing nutritional diversity. Since dietary and behavioural patterns acquired in the adolescent stage influences long-term behaviour, good nutrition education programmes should be developed and implemented at this stage (Oldewage-Theron and Egal, 2010).

2.9 Nutrition education in schools

Nutrition education is vital as it provides people with knowledge, skills and motivation to make wise dietary and lifestyle choices, to build a strong basis for a healthy and active life (FAO, 2005). Factors that influence nutritional status is lack of education and nutritional knowledge, inappropriate nutrition education, misconceptions and passing on of harmful diet traditions and poor nutritional practices (Oldewage-Theron and Egal, 2012). Although nutrition education in schools has proven to be effective in improving nutrition knowledge and diet changes (Oosthuizen et al., 2011), nutrition education in South Africa is less prevalent than the total number of hours (50 hours) recommended as a minimum to facilitate behaviour change in children (Oldewage-Theron and Egal, 2012).

The interaction of school-going children with their peers, teachers, parents and siblings help them develop their behaviour (FAO, 2015). Children attain and learn eating habits and practices as they grow and develop (Pérez-Rodrigo and Aranceta, 2003). The school is part of a network that influences their eating habits and patterns (FAO, 2015), as it is where they spend most of their time. School-based nutrition education should not only focus on nutritional information but equally on developing skills and behaviours related to areas such as food preparation, preservation and storage, cultural aspects of food and eating as well as consumer aspects, amongst others (Pérez-Rodrigo and Aranceta, 2003). To put a health promotion approach into productive action, all school-based activities outside the classroom, related to healthy eating can be viewed as part of an extended nutrition education programme (FAO, 2015). Above that, nutrition education should be part of the school curriculum for all school ages, progressing from early age to secondary school (Pérez-Rodrigo and Aranceta, 2003). Although nutrition education is an effective way of fighting malnutrition and poor health, Oldewage-Theron and Egal (2012) found that not much time per week was allocated to the subject. A strong relationship between knowledge and training received by educators and their ability to teach the subject matter was observed (Oldewage-Theron and Egal, 2012).

HealthKick is a school-based nutrition and physical activity intervention in South African primary schools in low-income settings (Draper et al., 2010). It aims at promoting healthy eating habits in children, parents and educators; increasing participation of children, parents and teachers in health-enhancing physical activities; promoting an environment where schools and communities facilitate the adoption of healthy lifestyles (Draper et al., 2010). This programme supports the aim of nutrition education, which is to encourage the application of knowledge to action (Oosthuizen et al., 2011). The Food and Trees for Africa organisation in collaboration with Woolworths Trust and Department of Education started the EduPlant programme, to help promote environmental education and sustainable natural resource management through school gardening (FAO, 2010). This further supports nutrition education in schools.

2.10 Vegetable crops with high nutritional value

Currently, the Sub-Saharan Africa, including South Africa faces three major interrelated catastrophes, which are climate change, the rising cost of crop production and malnutrition threatening sustainable food production, especially for the vulnerable unemployed and poor people, including indigents (FAO, 2016). The Food and Agriculture Organization (FAO), projected that by 2075 there would be 9.5 billion people in the world, which means innovative efforts are required to improve sustainable food production with high nutrient content, especially for pupils from poor and low-income households (Dupont, 2015). This creates a thrust opportunity for the agricultural sector around Southern Africa to develop and utilize drought adaptation mechanisms and strategies to cope with climate change and food insecurities.

Laurie et al. (2017), defined school food gardens as a vehicle for spreading knowledge of food production, creating a culture and love for food gardening and linking with nutrition, which could supplement nutrition among school pupils. Meanwhile, Shisana et al. (2013) stated that in South

Africa, 64% of pre and primary school children are vitamin A deficient. This could be the result of low intake of nutritious food, even though learners and educators are aware of its benefits for human health (Laurie et al. 2017). Thus, as stated by FAO (2004) more efforts are required in ensuring the health well-being of learners, not only for their well-being, but also for that of the future workforce and economic growth of a nation, continent and the world, and this could be achieved through the introduction of school nutrition projects.

Nyathi et al. (2016) who evaluated the nutritional content of three selected African leafy vegetables (amaranth, spider plant and sweet potato) reported a higher nutrition content in these crops as compared to the commercial vegetable Swiss chard (Table 2.2). The nutrient values presented in Table 2.2 suggest that ALVs can be a good alternative for supplementing nutritional elements, especially micro-nutrients (Beta-carotene and iron). Findings from these authors support the promotion and utilization of ALVs as food crops and for human malnutrition alleviation, especially in rural communities, which are the most vulnerable to food insecurities. However, as plant foods generally have low bioavailability of micronutrients, their consumption should be combined with animal foods in order to reduce the prevalence of nutrient deficiencies (Platel and Srinivasan, 2016).

Table 2-2: Mean nutrient content per 100 g edible portion of African leafy vegetables compared to their commercial counterparts (Source: Nyathi et al., 2016).

	Nutrient content (mg 100 g^{-1} fresh mass)		
Crop	**Iron**	**Zinc**	**β-carotene**
	2013/2014		
Amaranth (*Amaranthus cruentus*)	10.2	0.5	4.5
Spider plant (*Cleome gynandra*)	15.7	0.5	2.9
Sweet potato (*Ipomoea batatas*)	10.2	0.6	1.5
Swiss Chard (*Beta vulgaris*)	4.3	0.4	1.7
	2014/2015		
Amaranth (*Amaranthus cruentus*)	24.5	1.4	12.8
Spider plant (*Cleome gynandra*)	19.6	0.9	11.4
Sweet potato (*Ipomoea batatas*)	13	0.5	9.5
Swiss Chard (*Beta vulgaris*)	5.1	0.5	2.1

Some ALVs are rich sources of micronutrients, but their availability is influenced by input factors such as water availability to the plant and fertilizer use (Van Jaarsveld et al., 2014). Despite this constraint, Schönfeldt and Pretorius (2011), Uusiku et al. (2010) noted that micronutrients such as vitamin A, calcium, iron, magnesium and zinc levels of selected leafy vegetables of sub-Saharan Africa are markedly high. Their superior levels of nutrients are likely to compensate for the low bioavailability of iron and zinc micronutrients that these crops might offer when included in the human diets. Hunt (2003) who investigated the effects of vegetarian diets on human health found no higher incidence of iron deficiency anaemia in vegetarians as compared to non-vegetarians, despite the higher intake of phytic acid and other plant-based inhibitors of iron and zinc absorption in the former group. van Jaarsveld et al. (2014) provides data on the nutrient content of a variety of ALVs (Table 2.3), which confirms that indigenous crops are highly nutritious and can be utilized in combination with commercial vegetables to curb malnutrition and poverty (Wenhold et al., 2011; Van Jaarsveld et al., 2014).

Table 2-3: Micronutrient content of African leafy vegetables (per 100 g raw), (Source: Van Jaarsveld et al., 2011).

African leafy vegetable	Calcium	Magnesium	Zinc	Iron	Vitamin C	β-carotene	Moisture
	(mg)	(mg)	(mg)	(mg)	(mg)	(µg)	(g)
Amaranth (*Amaranthus cruentus*)	443	242	0.70	5.1	2	7138	82.0
Spider plant (*Cleome gynandra*)	232	76	0.04	2.1	2	5936	87.5
Jute mallow (*Corchorus olitorius*)	310	87	0.57	3.6	1	4307	79.6
Winter Squash (*Cucurbita maxima*)	177	67	0.75	9.2	2	4247	85.6
cowpea (*Vigna unguiculata*)	398	62	0.42	4.7	9	7031	82.4
Mustard spinach (*Brassica rapa*)	152	42	0.3	1.4	8	3593	92.2
Nightshade (*Solanum retroflexum*)	199	92	0.56	7.2	5	5566	89.5
Watermelon (*Citrillus lanatus*)	212	59	0.74	6.4	10	4956	81.3

Pre and post-harvest management of vegetable crops can ensure a nutritionally secured future, particularly for the vulnerable poor and unemployed. However, storage life and productivity of vegetables explicitly produced for human consumption are at risk due to infestation of weeds, pests and pathogens. FAO (2016), noted that pest and disease management also includes the use of cultivation practices that suppress pests and diseases, the use of resistant cultivars and cultural control is an integral part of pest and disease management, to improve shelf and storage life before preparation for consumption to ensure food and nutrition security.

2.11 Vegetable cultivation practices for enhanced nutritional content

2.11.1 Irrigated crop production

The Republic of South Africa covers an area of 122 081 150 ha in total of which approximately 14 million ha (13%) is cultivated, comprising of highly fertile and marginal land, of which approximately 1.6 million ha are presently under irrigation (FAO, 2016). While the FAO (2005) noted that irrigated crop production for food security is practised on an estimated land area of 1.6 million ha of which approximately 0.26 million ha are affected by waterlogging and/or salinization. Besides, South Africa has been categorized as one of the 30th driest countries in the world with an annual average rainfall of less than 500 mm, which is significantly lower amount than the world annual average of 860 mm (FAO, 2016), which is likely to decrease due to climate change as a result of global warming. South Africa has been declared a water-scarce country with more than 80% of the country classified as hyper-arid to semi-arid, with the majority of the country receiving below 500 mm of rainfall annually (Bennie and Hensley, 2001). One of the contributing factors to water scarcity is the energy system of South Africa which is a significant source of greenhouse gas (GHG) emissions, accounting to approximately 83% of the total emissions in the country (Department of Environmental Affairs, 2011), which is likely to contribute significantly towards climate change in the country. Meanwhile, DAFF (2015) forecasted a significant increase in the frequency and intensity of drought occurrence due to the effects of climate change.

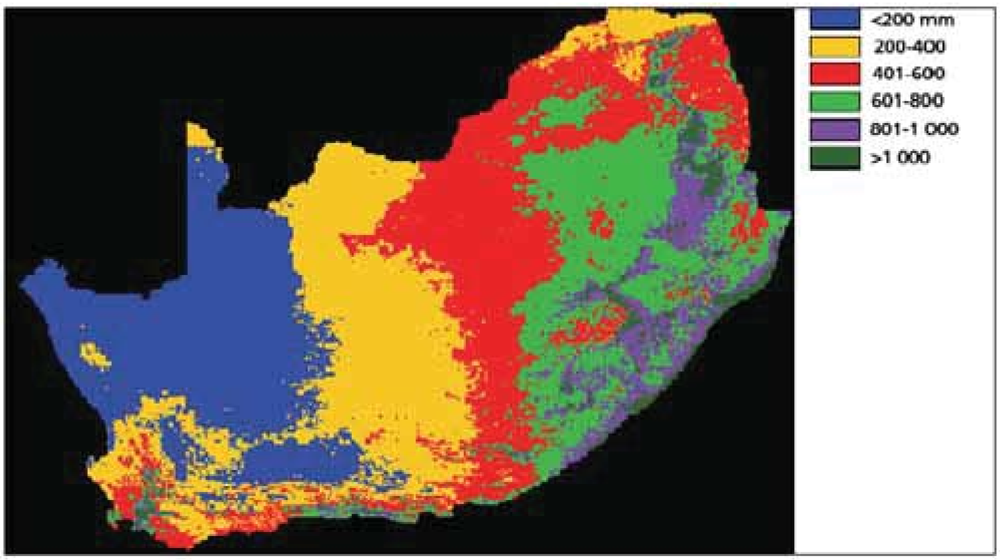

Figure 2-2: Overview of rainfall distribution across South Africa (*Source: DAFF, 2015*).

Given the poor distribution and low amounts of rainfall in South Africa, more innovative efforts are required to help the farmer increase food production with less irrigation water (ARC-SCW, 2005; Bennie and Hensley, 2001). Britz and Sigge (2012) and DoA (2014) reported that irrigated crop production contributes approximately 25-30% of commercial agricultural production for local and export and specifically comprises of maize (10%), wheat 30%, vegetables and fruits up to 60%. Sisulu and Scaramella (2012) indicated that water scarcity in South Africa is a significant concern when observed within the context of its immediate impact on agriculture, and taking into account the vulnerability of rural households regarding food and nutrition security; as a result, possible increase in crop failure.

Only about 12.5% of the arable land in South Africa is irrigated, yet it produces approximately 30% of the national production of food (DoA, 2014). Table 2.4 provides individual components of the irrigated agricultural basket to the entire country's vegetable production with the high value of irrigated crop production to total agriculture produced in South Africa, such as potato, tomato and onions.

Table 2-4: Gross value of major irrigated vegetables produced in South Africa (*Source: DoA, 2014*).

Irrigated vegetable crops	Value in 2009/10 (R1000)
Potatoes (*Solanum tuberosum*)	5 155 176
Pumpkins (*Cucurbita pepo*)	277 911
Beetroot (*Beta vulgaris)*	106 120
Lettuce (*Lactuca sativa*)	125 860
Carrots (*Daucus carota*)	340 719
Green beans (*Phaseolus vulgaris*)	100 788
Cabbage (*Brassica oleracea*)	161 768
Gem squashes (*Cucurbita pepo*)	52 029
Sweet potatoes (*Ipomoea batatas*)	120 396
Tomatoes (*Solanum lycopersicum*)	1 555 089

Irrigation on vegetable production has been utilised to realise optimum yield. Globally, the three main irrigation types are 55-65% for surface irrigation; 75-85% for mechanised and non-mechanized sprinkler systems and 85-95% for localised irrigation, (FAO, 2005). Meanwhile, subsurface deficit irrigation as a management practice in South Africa resumed approximately 10 years ago and presently covers nearly 12 000 ha (Malan, 2008). Furthermore, micro-irrigation amounts to approximately 296 000 ha of the total area under irrigation of 1.4 million ha in South Africa.

Although ALVs might still be lacking behind with regards to the national database of annually produced vegetables, efforts have been made to reintroduce these crops into society through improved cultivation practices to ensure quantification of water use efficiency and nutritional water productivity of African leafy vegetables under different cultivation practices (Jansen van Rensburg, 2012).

2.11.1.1 Deficit irrigation

Shortage of irrigation has forced decision-makers in water-scarce countries to develop new approaches in irrigation water applications. Annandale et al. (1999) defined deficit irrigation as an optimising management strategy under which crops are deliberately allowed to sustain some degree of water deficit and yield reduction, through the application of less water than is required by the crop, particularly in grain crops such as wheat. Wang et al. (2010) observed success with the implementation of deficit irrigation on fruit trees and vineyards. Benefits were also observed on sweet potato, in which contents of β-carotene were increased with reduced irrigation applications below optimal levels (Laurie et al. 2013). However, for successful implementation of deficit irrigation, appropriate knowledge of crop responses to water deficits and crop water use is required, including the identification of critical crop growth stages, and the economic impacts of yield reduction (Allen et al., 1998).

2.11.1.2 Supplemental irrigation

Allen et al. (1998) stated that supplemental irrigation is a management strategy in which a limited amount of water is applied to rain-fed crops that can normally grow without irrigation. While water harvesting is generally utilised in areas that receive between 100-300 mm of rainfall annually, supplemental irrigation is used in areas with a slightly higher annual rainfall of approximately 300-600 mm (Oweis et al., 1999), with the ultimate goal, is to provide sufficient water supply to the crop during critical growth stages in order to maximise crop yield per unit water. Zhang et al. (1998) stated that supplemental irrigation is practised to supplement the expected total seasonal rainfall, which can be an ideal irrigation management strategy under limited water supply.

2.11.2 Dryland crop production

The South African primary agricultural crop production has been implemented under semi-arid and arid climatic conditions where frequent occurrences of drought are shared, where cultivation is heavily reliant on rainfall to ensure economic and food security stability. According to the ARC-ISCW (2005), over 90% of South Africa is classified as dryland, i.e. arid to sub-humid, with 82% being classified as arid to semi-arid. This amounts to approximately 1.5% of South Africa's agricultural land, which includes both cultivated areas and rangeland (DoA, 2014). The most dominant crops produced under such conditions are mainly cereals and oilseeds, as these have a higher tolerance to water stress (Oweis et al., 1999). According to the estimates by FAO (2016), South Africa has approximately 14 million ha arable land under rain-fed with potential for commercial farming, of which 7 million ha is described as having medium potential, while the remaining with low potential.

South Africa has an indicator of 0.6-0.7 for traditional water stress (DoA, 2014), this place the agricultural sector under immense pressure due to less available water for irrigation or to depend solely on rainfall for crop production. Since the demand for food in South Africa is inevitable and is expected to continually increase in the future due to urbanisation (FAO, 2016), there is a need to increase the exploitation of rain-fed agriculture, which will play a significant role in increasing crop production to meet the growing demand for food (Hensley et al., 2011), while maintaining adequate water allocations to municipal and industrial sectors. Moreover, part of the contributing factors to the worldwide increase in attention to promoting sustainable dryland farming systems is the escalation in the cost of establishing new irrigation schemes and the high cost for their maintenance (Rao et al., 2004).

Maize is the most vital grain crop in South Africa, also considered as a primary feed grain and the staple food of the majority of the South African population; an estimated 8-17% of the area planted to white and yellow maize is under irrigation, while 83-92% is dryland (DAFF, 2018). Wheat is another staple food in South Africa, where approximately 80% is cultivated under dryland. Over the past 10 years, very low yields were obtained in both dryland and irrigated wheat productions, despite an increase in consumption, due to climate change and rising input costs (DAFF, 2012). In South Africa, the consumption of potato has been growing in urban areas, meanwhile in rural areas maize is still the preferred staple meal, while dryland potato production accounted for approximately 16% of the hectares under total production (FAO, 2016). As South Africa faces a sharp decline in rainfall and increasing average temperatures, both field crop production and horticulture are incredibly vulnerable, especially under rain-fed conditions.

DoA (2014) classified crops according to their suitability based on their climatic zones in South Africa, as follows:

1. Summer annual crops, which include maize, soybean, groundnuts, cotton and sorghum. Of these, maize and groundnuts are the most widely grown under irrigation in South Africa;
2. Winter annual crops which include wheat, barley and dry pea, while, wheat is the most widely grown under irrigation in South Africa;

3. Perennial sub-tropical fruit, nuts, and sugarcane.
Vegetables can be produced in almost all climatic zones of South Africa, provided that sufficient irrigation water is available. This can be ensured through the implementation of rainwater harvesting and conservation technologies.

Oweis et al. (1999) reported that rainwater harvesting could significantly improve crop water productivity, and minimise problems of water scarcity for crop production. Zhu et al. (1994) emphasised that rainwater harvesting has been utilised for many years in semi-arid areas to solve problems of domestic and irrigation water shortages.

In-field rainwater harvesting techniques, as described by Oweis and Hachum (2006), must have the following three components, as evident in Figure 2.3:

- **The catchment area** is the part of the land that contributes some or all its share of rainwater to another area outside its boundaries. The catchment area can be as small as a few square meters or as large as several square kilometres. It can be agricultural, rocky or marginal land, or even a rooftop or a paved road.
- **The storage facility** is a place where runoff water is held from the time it is collected until it is used. Storage can be in surface reservoirs, subsurface reservoirs such as cisterns, in the soil profile as soil moisture, and groundwater aquifers.
- **The target area** is where the harvested water is used. In agricultural production, the target is the plant or the animal, while in domestic use, it is the human being or the enterprise and its needs.

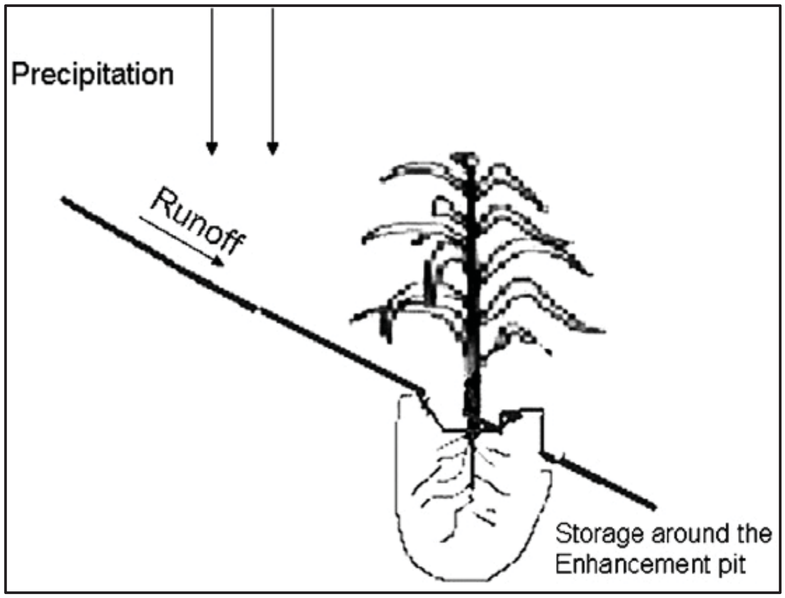

Figure 2-3: Typical designation of the micro-catchment rainwater harvesting systems, (*Source: Biazin et al. 2012*).

Biazin et al. (2012) reported that applied micro-catchment rainwater harvesting techniques in Sub-Saharan Africa include pitting, contouring, terracing and micro-basins. However, micro-catchment rainwater harvesting systems are designed to collect runoff from a relatively small catchment area, mostly 10-500 m^2, within the farm boundary and are also utilized in areas with water storage in the soil for dry spell mitigation (Figure 2.6). Meanwhile, techniques for enhancing infiltration, reduce runoff and evaporation or for improved soil moisture storage in the crop-rooting zone, are known as in-situ rainwater harvesting (Ngigi, 2003).

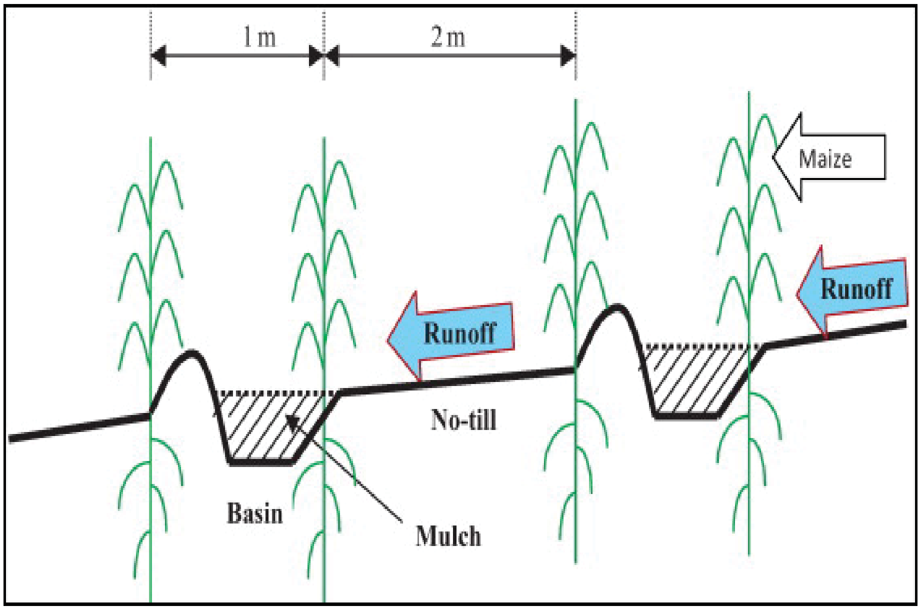

Figure 2-4: No-till in-field runoff water-harvesting technique, with mulch in the basins (*Source: Hensley et al., 2011*).

Hensley et al. (2011) introduced an innovative method of rainwater harvesting and named it in-field rainwater harvesting, which is a strategy to manage rainfall and runoff for subsistence farmers on the marginal semi-arid crop with high runoff potentials. The application of this technique significantly increased the yield of maize and sunflower between 30% and 50% as compared to the conventional tillage method. Noticeable increments in crop yield were also observed for leafy vegetables (cabbage and Chinese cabbage, between 40 and 60%) as compared to the conventional method. While Bennie and Hensley et al. (2011) used concepts such as precipitation use efficiency (PUE, kg produce ha^{-1} mm^{-1} rainfall) proved to be a valuable crop use efficiency parameter for comparing the level of precipitation utilization of different management practices for dryland crop production to ensure optimum yield realization. A field study conducted at the Agricultural Research Council – Vegetable and Ornamental Plant (ARC – VOP) to test different rainwater harvesting practices in leafy vegetables (Figure 2.5), showed significantly higher PUE values under the in-field rainwater harvesting (90 kg ha^{-1} mm^{-1}) as compared to the in-situ rainwater harvesting and conventional flat cultivation practices (60-70 kg ha^{-1} mm^{-1}), particularly during a dry rainfall season (less than 350 mm). Increased crop yield with the implementation of the in-field rainwater harvesting was also observed on sweet potato during two consecutive seasons of measurements in a semi-arid climate environment (Laurie et al., 2017).

Figure 2-5: Rainwater harvesting and conservation trial conducted on leafy vegetables during the 2015/2016 growing season at the Agricultural Research Council – Vegetable and Ornamental Plant (*ARC – VOP*).

Rainwater can also be harvested using the rooftop technique. The main objective of this technique is to make water available for future use. Capturing and storing rainwater for use is particularly crucial in dryland, hilly, urban and coastal areas. Rooftop rainwater harvesting is the technique through which rainwater is captured from the roof catchments and stored in reservoirs (Figure 2.6) (Castelo, 2018). Harvested rainwater can be stored in the sub-surface groundwater reservoir by adopting artificial recharge techniques to meet the household needs through storage in tanks.

Figure 2-6: Rooftop rainwater harvesting technique for the collection of rainwater from roof surfaces, with subsequent storage in tanks connected to gutters adjacent to roofs. Water stored in tanks is used for irrigation of small gardens (Source: Castelo, 2018).

Implementation of rainwater harvesting techniques has several potential benefits (Blignaut and Sibande, 2008; Govaerts et al., 2009; Biazin et al., 2012) including increased agricultural income through improved crop yield and quality, increased soil available water for crop production, reduced risk of crop failure, improved water and nutrient use efficiency and an overall improvement in the environment and socio-economic conditions of the people. A study conducted in South Africa to assess the impact of rainwater harvesting on small-scale farming systems showed considerable improvement on land productivity with the use of the in-field rainwater harvesting (1.88 ha required for cultivation to meet the total caloric requirement of a household) compared to the conventional flat cultivation practice (6.39 ha of land needed to achieve the same needs) (Kahinda et al., 2008). Another study implemented in a semi-arid area of South Africa showed the significant contribution of the in-field rainwater harvesting to climate change adaptation through increased plant available water and buffering during the dry spells (Botha et al., 2014). Noticeable improvement on yield and quality of leafy vegetables was observed in a field study conducted in the semi-arid area of Roodeplaat at ARC – VOP research station (Figure 2.7).

Figure 2-7: Leafy vegetables cultivated under the in-field rainwater harvesting combined with a mulching application on the cropped area, ARC – VOP.

2.12 Intercropping systems

Intercropping involves the cultivation of two or more crop species at the same time in the same field. The spatial arrangements between crops can be as follows (Ouma and Jeruto, 2010):

- Row intercropping – Growing two or more crops together at the same time with at least one crop planted in rows.
- Strip intercropping – Growing two or more crops together in strips wide enough to separate crop production using machines, but close enough to interact.
- Mixed cropping – Growing two or more crops together in no distinct row arrangement.
- Relay intercropping – Plant a second crop into a standing crop at a time when the standing crop is at its reproductive stage but before harvesting.

Intercropping has been implemented on a variety of crops, resulting in several benefits including reduced field management, risk minimization of crop failure, effective use of available resources, efficient use of labour, increased crop productivity, erosion control and food security all year round (Owuor et al., 2002). Intercropping of fruit crops with annual crops such as vegetables is a common practice worldwide to increase land-use efficiency of smallholder farmers and provide natural control of pests and diseases (Reddy et al., 1992; Roger and Dennis, 1993; Singh et al., 2014). Vegetables intercropped with legumes is also often implemented by smallholder farmers to benefit from the transfer of biologically fixed nitrogen from the roots of legumes to the root zone of the companion crop (Ouma and Jeruto, 2010). Care should be taken to choose appropriate crop species in an intercropping system to minimize competition for sunlight, water and nutrients. These include selecting crops with different heights, size, orientation and distribution of leaves in the plant canopy and root systems (Ouma and Jeruto, 2010). Competition can also be minimized by changing the spatial arrangement of crops (Roger and Dennis, 1993).

2.13 Conclusion and recommendations

Malnutrition, either over- or under-nutrition, is becoming a significant problem in South Africa, especially in the school-age children. This more often leads to poor school attendance and high rates of dropout. The school environment provides an excellent opportunity for children and the community to learn about nutrition and health. Nutrition knowledge greatly influences the dietary behaviours of children and adults. School gardens have an advantage that when learners are taught about gardening and nutrition, they can practically learn how to produce healthy food for a balanced diet. In that way, they will feel connected to their responsibility of ensuring a healthy meal is provided every day; they will also influence food choices in their families. Furthermore, school gardens increase food availability and diversity, can be used to promote micronutrient-rich vegetables and can benefit the mainstream education curriculum.

Nutrition education is one of the main topics in the subject of Life Orientation. Although many schoolchildren have shown knowledge about nutrition and healthy food, the experience gained did not influence their daily healthy food choices. This calls for better interventions, as school gardens can play a more significant role of making nutrition education a participatory exercise where learners will not only learn about the health part of food but also how to grow them, how to choose the crops according to their environment, how to ensure a sustainable supply of a healthy variety of foods. , Besides, they can also learn about protecting the environment for sustainability, how to sustainably and efficiently use scarce resources such as water and fertilizers, thus preparing them for basic knowledge gaining prior their integration into the university curriculum.

School-based food gardens should focus on the cultivation of highly nutritious food crops for increased impact on food, nutrition and income security. This includes African leafy vegetables, which are considerably more nutritious compared to their commercial counterparts, offering them the potential to combat malnutrition amongst the underprivileged rural communities. Further research on pre and postharvest management practices of leafy vegetables, however, is required to improve their crop productivity, storage and shelf life, while maintaining the nutritional content.

Improved pre-harvest crop management practices in irrigated agriculture include the implementation of supplemental irrigation through deficit irrigation strategies, while in dryland agriculture practices such as rainwater harvesting within the field or from rooftops can markedly contribute to improved productivity of leafy vegetables. The benefits of deficit irrigation for leafy vegetables are well documented in terms of increased water use efficiency and nutritional water productivity, but under dryland conditions, more research should be done to identify the best practices of cultivation through the implementation of rainwater harvesting technologies. Intercropping vegetables with fruit trees is another pre-harvest management practice that can be done to secure all year year-round crop production and maximize land productivity whereas vegetables intercropped with legumes may offer an excellent strategy to improve soil nutrition naturally, leading to decreased use of fertilizer inputs. Since fresh vegetables are highly perishable, post-harvest processing practices such as fresh-cut produce and product development should be encouraged to maintain all year round nutrients supply, for improved human health.

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CHAPTER THREE

SITUATIONAL ANALYSIS OF THE STUDY SITES AND TARGETTED BENEFICIARIES CHARACTERISTICS

3.1 Introduction

School garden programmes should take into account local customs and needs, to specific socio-economic, climate and environmental situations (FAO, 2004a). School gardens contribute significantly to increasing the relevance and quality of nutrition education in schools, improves society's knowledge of food production techniques and nutritional benefits while motivating the development of home gardens (FAO, 2004b). School gardens can create a connection between the school learners, community and nature, which will have a positive impact towards the children's health, for their growth and development and their opportunities, over time, by preserving a healthy society. Influencing the mind-set of the learners from an early age will impact the community's habits regarding healthful nutrition and producing their food since the young ones have a significant influence on their families. A school garden can play an essential role into the long-term human impact on the natural environment including the protection of soil and water resources by reducing nutrient leaching, proper nutrient and irrigation management, from the water shortage to the over-use of pesticides. School gardens can teach schoolchildren who are engaged in gardening to have first-hand opportunities to observe the importance of conservation and intelligent allocation of resources.

Malnutrition is still rife in South Africa, where the country faces both under- and over nutrition. The prevalence of under-nutrition is mostly in children, especially in rural areas and disadvantaged communities such as those living in informal settlements, both in the rural and urban communities. Over-nutrition is highly prevalent in adults and some adolescence and urban children. Thus, the issue of malnutrition should address both under- and over-nutrition. The School garden projects in South Africa are in line with the strategic plan of the Nutrition for Rural Education and Development (Tech4RED) projects of the South African government, which started in 2013. The project's intervention addresses critical areas in improving the nutritional status of the learners. These areas include providing breakfast to learners, develop functional school gardens that would supply the school with vegetables and legumes, improving kitchen facilities for preparation and storage of food, training meal servers on food safety and hygiene, and provide nutrition awareness through nutrition education to learners, teachers and caregivers. Research is needed to expand the current crop-based model, and school gardens in South Africa to (i) ensure year-round availability of vitamin A rich crops and (ii) expand to a more comprehensive approach that includes macro- and micronutrients. For this, it is needed to identify and test additional crops and new technologies to be included to provide variety in the diet spread the potential risk and extend the period of availability. In the current project, the introduction of different vegetable crops (e.g. amaranth, cleome, sweet potato) and water-efficient production systems (i.e. production of vegetables with infield rainwater and rainwater harvesting, bag system and veggie tunnels) were investigated. Indigenous food crops are widely available and can potentially supply essential nutrients to the diet of learners. Most of these crops are drought tolerant and hardy (Flyman and Afolayan, 2006).

Malnutrition particularly Vitamins and micronutrients (especially Fe and Zn) are common problems in children and woman. According to world health organization (WHO, 2020), vitamin A and micronutrient deficiency remain a huge spread problem and causes of cardiovascular disease, cancer, chronic respiratory diseases and diabetes that cause 60% of all deaths and are increasing globally. In South Africa, vitamin A deficiency is a severe health problem, particularly in women and children. A school garden is an innovative teaching tool and strategy that incorporates hands-on activities into classroom-based lessons by providing a dynamic environment in which learners observe, discover, experiment, nurture and learn. Learners' unhealthy eating habits with no or less consumption of fruits and vegetables is a significant health concern (Naidoo et al., 2009). School-based vegetable gardens can have a positive impact on learners' health, education and awareness of the physical environment (FAO, 2019). Knowledge and skills gained by learners can potentially contribute to household food and nutrition security through the implementation of healthy eating and lifestyle habits (Laurie et al. 2013). Thus, school gardens can further be used as a vehicle to spread knowledge of food production and link with nutrition (Laurie et al., 2017). The general aim of the assessment was to get insights in terms of learners and household characteristics. Household characteristics involve socio-economic factors and food security indicators. Socio-economic factors and food security indicators will assist in determining the essence of school garden establishment. In other words, the establishment of a school garden should be supported by the results of learners household characteristics.

3.2 Methodology

In March 2018, a team of experts from the ARC-VOP visited Bula Dikgoro and Mahlasedi Masana public primary schools, in the Mamelodi East to assess the situations. Based on the assessment, the necessities required infrastructure, gardening tools, agricultural inputs, training and potential crops to be produced in summer and winter months were identified. The infrastructure assessment included the following information for both schools:

Bula Dikgoro and Mahlasedi Masana Public Primary Schools

- Water source;
- Rainwater harvesting potential through the roof;
- Existence of irrigation infrastructure;
- The proposed garden size;
- The presence of a garden committee;
- Fencing requirement;
- Basic training needs of beneficiaries;
- Agricultural inputs requirement.

From the assessment report, it was identified basic gardening tools will be required to carry out the daily activities during vegetable production (Table 3.1).

Table 3-1: Gardening tools required based on the assessment.

	Item	The number needed per school
1	Wheelbarrows	2
2	Hoes	5
3	Spades	5
4	Watering cans	5
5	Hosepipe	1
6	Rakes	5
7	Garden forks	5
8	Hand shovels	5
9	Pruning shears	5
10	Personal protective equipment for each worker (pairs of gloves, hats and work suits)	10
11	T-Markers	50
12	Wetting front detectors (WFD)	20
13	5 in 1 weather sensor	1

3.2.1 Establishment of school gardens

This study focused on measuring water use and growth parameters of vegetable crops concerning weather variability and irrigation applications in two schools in Mamelodi East, City of Tshwane Metropolitan Municipality, Gauteng Province. These schools are Mahlasedi Masana (25° 42′ 58.669″ S, 28° 25′ 8.22″ E) and Bula Dikgoro (25° 42′ 15.649″ S, 28° 23′ 55.673″ E) Public Primary Schools (Figures 3.1 and 3.2, respectively). Mamelodi is 1328 m above the sea level and has an annual rainfall of about 500 mm, with mean daily maximum temperatures during the summer season of 29˚C and mean daily minimum temperatures during the winter season of 4˚C. The study site has a semi-arid climate. The soil of Bula Dikgoro is sandy clay loam in texture and sandy clay texture for Mahlasedi Masana. Generally, the soils have high magnesium content.

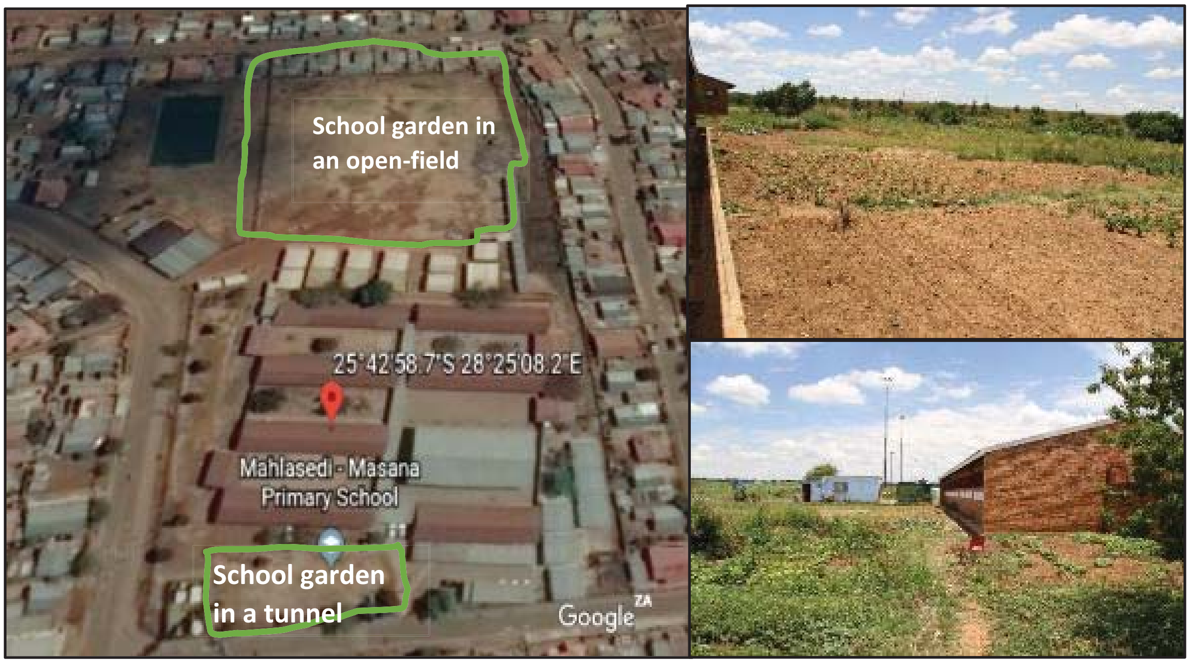

Figure 3-1: Area available for vegetable garden production at Bula Dikgoro Public Primary.

Figure 3-2: Area available for vegetable garden production at Mahlasedi Masana Public Primary School.

Good land preparation was done per school garden, through a mouldboard plough, disc harrow and ridge maker (Figure 3.3). The installation of a non-pressure regulated drip irrigation system was also required. The total area available for crop production for both schools was 0.36 ha, which was not fully utilized prior to the beginning of the project. Municipality water was used to irrigate the growing vegetable crops, with a low irrigation delivery rate of 5ℓ hr^{-1}. Therefore, maximization of water supply for crop production through techniques such as rooftop rainwater harvesting is highly important and with great potential. For an adequate collection of rooftop rainwater harvesting, predictions of runoff collection were made based on on-site measurements of roof size and estimates of crop water requirements (Table 3.2).

Figure 3-3: Illustration of land preparation.

Table 3-2: Expected contribution of rainwater harvested through the roof area for supplemental irrigation of vegetable crops.

Growing season	Crop type	Area of cultivation (m^2)	Rainfall amount (mm)	Total expected runoff collection (L)	Crop water requirements (mm)	Expected contribution by rainwater harvesting (%)
Winter	Spinach (*Spinacia oleracea*)				300*	
	Chinese cabbage (*Brassica rapa*)	300 m^2 for each crop	None	None	500**	None
	Carrots (*Daucus carota*)				500*	
	Beetroot (*Beta vulgaris*)				400*	
	Kale (*Brassica oleracea*)				300**	
Summer	Spinach (*Spinacia oleracea*)				400*	32
	Okra (*Abelmoschus esculentus*)	300 m^2 for each crop	500	378 541	300**	42
	Butternut (*Cucurbita moschata*)				300*	42
	Amaranth (*Amaranthus cruentus*)				300**	42
	Sweet potato (*Ipomoea batatas*)				350**	36

**Measured at ARC – VOP

*Estimated using the FAO-56 crop factors

The irrigation system to be used for vegetable production was drip irrigation system (non-pressure regulated dripper). The total area for both schools was 0.36 ha, which was not fully utilized for vegetable production at the time of assessment, and municipality water was used to irrigate the grown vegetable crops. Therefore, the development of water-saving techniques such as rooftop rainwater harvest was highly important. To help with such decision-making situations, the probability distribution of annual rainfall was analysed, using long-term rainfall data of the study site (Figure 3.4). This graph-related the probability of exceedance of a certain annual rainfall amount to its return period. For the semi-arid area, the drier the rainfall season, the higher the probability of exceedance of that particular amount of rainfall in the season, with an expected occurrence at a higher frequency.

The long-term average annual rainfall of Mamelodi is about 500 mm. As observed in the normal probability distribution curve for the study site, shown in Figure 3.4, the probability of exceeding 500 mm of rain in a season was about 80%. This means the exceedance of total seasonal rainfall of about 500 mm was very high but still not enough to support vegetable production in the school gardens. Therefore, rooftop rainwater harvesting could be utilized for supplemental irrigation (Table 3.2).

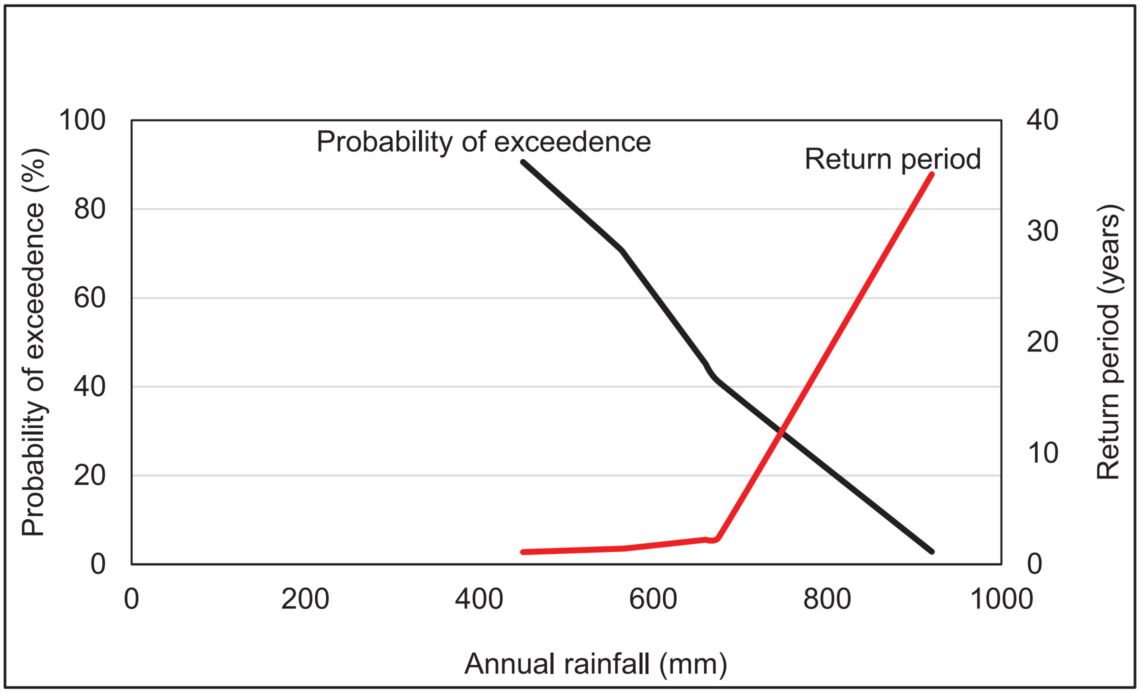

Figure 3-4: Probability distribution of annual rainfall for the study site.

Irrigation scheduling was monitored using ECH_2O 5TE soil water sensors and wetting front detectors (Figure 3.5). The ECH_2O 5TE sensors were installed to the depth of 0.8 m in the soil profile and measurements were taken at 0.2 m intervals. The ECH_2O 5TE sensors measured soil moisture, soil temperature, and electrical conductivity (EC). Wetting front detectors (WFD) was installed in the soil profile (Figure 3.3) to detect how deep water infiltrated to the soil after irrigation or rainfall. The tool has the ability to trap soil solution at the bottom, and the soil solution can be collected after every irrigation or rainfall after activation of the WFDs (wetting front detectors) to monitor for plant nutrients and salt concentrations (Stevens & Stirzaker, 2010). The cumulative water deficit of the profile was calculated over a soil depth of 0.8 m. Installation of wetting front detectors was done within and below the root zone (0.3 and 0.6 m below the soil surface).

Figure 3-5: Illustration of wetting front detector (WFD) and ECH2O 5TE soil moisture sensor.

Soil samples were collected for analyses of soil physical properties (texture, water holding capacity, 1.5 mm/cm depth of soil and bulk density, 1.28-1.35 g/cm^3) and chemical properties, i.e. soil nutrient content. These results were used to draw fertiliser recommendations. Fertiliser recommendations were done based on the soil analyses and crop management practices were followed, as indicated in Table 3.3 and 3.4.

Table 3-3: Crop management practices for winter vegetable crop production.

Winter crops	Target yield	LAN (28%N)	Calcium phosphate (12% P)	Potassium chloride (50%K)	Plant population	Planting date
	t ha^{-1}	kg N ha^{-1}	kg P ha^{-1}	kg K ha^{-1}	plants ha^{-1}	
Beetroot *Crimson globe*	40	100	80	60	100 000	April
Swiss chard *Ford hook Giant*	60	150	80	80	97 666	
Cabbage *Drum head*	60	150	80	120	100 000	
ALVs *Kale, Mustard spinach*	55	150	80	80	100 000	

Table 3-4: Crop management practices for winter vegetable crop production

Summer Crops	Target yield	LAN (28% N)	Calcium phosphate (12% P)	Potassium chloride (50% K)	Plant population	Planting date
	t ha^{-1}	kg N ha^{-1}	kg P ha^{-1}	kg K ha^{-1}	plants ha^{-1}	
Sweet potato *Bophelo*	50	150	80	106	14 015	September
Cowpea *Vigna ONB*	45	30	30	50	113 636	
Swiss chard *Food hook Giant*	60	50	30	50	97 666	
Squash butternut *Waltham*	20-25	50	50	30	33 636	
ALVs *Kale*	15	100	80	80	100 000	

Long-term weather data was collected from an automatic weather station located around the proximity of the schools. The automatic weather stations consisted of an LI 200X pyranometer (LiCor, Lincoln, Nebraska, USA) for measuring solar radiation, an electronic relative humidity and temperature sensor installed in a Gill screen, an electronic cup anemometer (MET ONE, Inc. USA) to measure wind speed, an electronic rain gauge (RIMCO, R/TBR tipping bucket rain gauge, Rauchfuss Instruments Division, Australia) and a CR 10X data-logger (Campbell Scientific Inc., USA).

The vegetable production included open field and controlled (veggie tunnels and bag system) vegetable production systems. The combined production systems of the project were to optimize the accessibility of vegetable crops within the limited available space. In the open-field production system, vegetables were planted in a systematic approach to help manage soil fertility and also to help avoid or reduce problems with soil-borne pathogens and some soil-dwelling insects, such as rootworms. All pre-plant inputs were applied before direct seeding, and seedbed preparation such as Kraal manure was applied to ensure soil health and was incorporated into the soil. The vegetable garden was divided into plots and each plot was designated for a crop. Crops were rotated for the next growing season, which means crops were moved through the same garden bed over time. The production system was linked with the spraying of plant extracts as a measure of disease and pest control, rainwater harvesting, and use of organic mulching.

The veggie tunnels vegetable production system was introduced to promote a food garden model with a variety of conventional and traditional vegetables in intensive vegetable production using a 5 m^2 x 12 m^2 netted tunnel structure (Figure 3.6). The purpose of the veggie tunnel model was to produce a variety of nutritious vegetables as part of a food broader approach to address malnutrition on a small area. A rigorous crop rotation system was followed, and Bio-extract (garlic, chillies and moringa leaves) was used to suppress pest and diseases.

Figure 3-6: Illustration of a veggie tunnel that will be installed in the school gardens.

The bag system has been recently used to grow vegetables with minimum water supply requirements at ARC-VOP. Preliminary research findings showed promising performance of the bag system for improved yield and quality of several commercial vegetables including tomatoes, spinach and lettuce (Figure 3.7). Producing vegetables using a bag system would significantly contribute to improved food and nutrition security, while requiring less input, with reduced risk of crop failure in the school gardens.

Figure 3-7: Illustration of a bag system planted with Swiss chard.

3.2.2 Learners and household characteristic assessment

Quantitative and qualitative methods were employed in the assessment. An interviewed sample size of 232 people was drawn from school registers using stratified sampling technique, and class grades were used as different strata to draw samples from each stratum randomly. The essence of the technique was to ensure various grades or strata were adequately represented in the sample. An approved structured questionnaire was used to collect data from the participants in different locations of Mamelodi Township of City of Tshwane Metropolitan in Gauteng province. Before beginning the questionnaires, a consent form was signed by the participants, permitting to involve them in research, as well as indicating an agreement between the researcher and research participant outlining the roles and responsibilities they were taking towards one another. The data collection exercise was conducted from March to April 2018, where questionnaires were issued to learners to complete with their guardians. Data collected was analysed quantitatively using the Statistical Package for Social Sciences (SPSS), version 24 and Microsoft excel.

Correlation is a bivariate analysis that measures the strengths of association between two variables and the direction of the relationship. In terms of the strength of the relationship, the value of the correlation coefficient varies between +1 and -1. When the value of the correlation coefficient lies around ± 1, then it is said to be a perfect degree of association between the two variables. As the correlation coefficient value goes towards 0, the relationship between the two variables will be weaker. The direction of the relationship is simply the + (indicating a positive relationship between the variables) or - (indicating a negative relationship between the variables) sign of the correlation. Correlation is significant at the 0.05 level, using Pearson correlation, was done and included in the report.

3.3 Results and discussion

3.3.1 Study sites biophysical characteristics

3.3.1.1 Soils

Before the establishment of the vegetable gardens, soil macro and micronutrient levels were analysed, and results are presented in Table 3.5. The soil pH in water was slightly higher at Bula Dikgoro School (8.05 to 8.26) compared to that of Mahlasedi Masana School (7.62 to 7.89), while an opposite trend was observed for soil resistances (440-500 ohm for Bula Dikgoro and 520 ohms for Mahlasedi Masana). The soil analysis indicated that the soils have high potassium, calcium and magnesium content. The uptake of these nutrients by plants not only depends on their concentration but also by their ratio in the soils (Nguyen et al., 2017). This imbalance was corrected through the application of organic matter such as organic fertilizer and manure.

Table 3-5: Soil chemical properties at Bula Dikgoro and Mahlasedi Masana Primary Schools.

Soil nutrients		Study schools			
		Bula Dikgoro		Mahlasedi Masana	
		Topsoil	Subsoil	Topsoil	Subsoil
Macronutrients (mg/kg)	Ca	2350	2090	2730	2490
	Mg	660	838	871	821
	Na	29.2	30.1	55.1	51.6
	P	19.8	2.2	7.2	4.5
	K	247	174	285	133

The soils at Bula Dikgoro Primary School had a sandy clay loam texture, while at Mahlasedi Masana Primary School they had a sandy-clay texture. Table 3.6 gives details of clay content for the top and sub-layers soil profile. Soils at Mahlasedi Masana have slightly higher clay content compared to that at Bula Dikgoro.

Table 3-6: Clay content for the top and sub-soil layers at Bula Dikgoro and Mahlasedi Masana Primary Schools.

Soil layer	Clay content in soils of the study schools (%)	
	Bula Dikgoro	Mahlasedi Masana
Top (0-20 cm)	32	42
Sub top (20-40 cm)	36	40

3.3.1.2 Climate

Vegetable crops are highly sensitive to an extreme climatic condition such as fluctuation in soil moisture content and temperature, which negatively impact their yield and nutritional quality (Naik et al., 2017). To understand the climatic condition of the school gardens, long-term meteorological data that was collected from an automatic weather station situated in close proximity to the site is presented in Figure 3.8. The following sets of data were collected: Minimum and maximum temperature (°C), minimum and maximum relative humidity (%), rainfall amount (mm), wind speed (m s^{-1}), solar radiation, and sunshine duration (hours), evapotranspiration and Vapour pressure deficit. The data was subsequently used to determine grass reference evapotranspiration using the Penman-Monteith method.

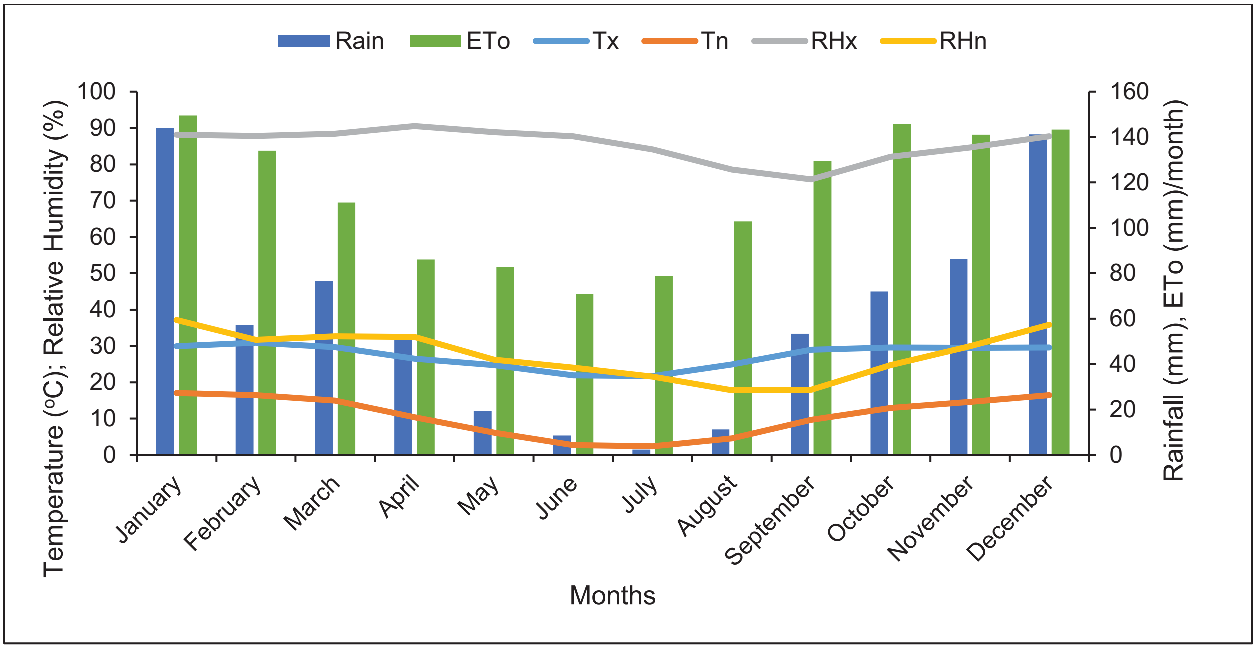

Figure 3-8: Long-term (2007-2019) weather information of the study site**.**

Note: Eto = Evapotranspiration; Tx = maximum temperature; Tn = minimum temperature; RHx = maximum relative humidity; RHn = Minimum relative humidity

3.3.1.3 Crop suitability

Crop suitability assessment is an essential component of vegetable production in school gardens. The evaluation looked at vegetables that are suitable for the school garden growing condition, drought tolerant and with high nutritional value (Figure 3.9). The project promoted the production of green leafy vegetables (commercial exotic and African leafy), sweet potato and legume crops. These crops are high in micronutrients (Fe, Zn and Beta-carotene) that are often lacking in children's diet. Vegetables with targeted nutrients included the following:

- Beta-carotene – orange-fleshed sweet potato
- Iron – legumes, indigenous leafy crops, green vegetables
- Folic acid – dark green leafy vegetables
- Energy – Orange-fleshed sweet potato

- Vitamin C – tomato (inclusion of vitamin C in the same meal)
- Protein (from vegetable source) – legumes (cowpea, green peas)
- Zinc – Pumpkin and squash seed, soybean

Winter vegetables	Summer vegetables
Head forming vegetable (Cabbage)	Legume vegetable (Cowpea)
Leafy green vegetable (Swiss chard)	Leafy green vegetable (Swiss chard)
Root vegetable (Beetroot)	Root vegetable (Sweet potatoes)
ALVs (Kale, rape and Mustard spinach)	Fruiting vegetable (Squash)

Figure 3-9: General layouts of the garden for the schools.

3.3.2 Schools infrastructure availability

The schools were assessed for the availability of existing infrastructure to establish the gardens. Based on the assessment the basic required infrastructure, gendering tools and inputs were identified. The assessments information for each school were as follows:

Bula Dikgoro public primary school

- The water source was from municipal water
- There was no existing irrigation infrastructure-therefore new drip irrigation system, including one 5000 L and one 20^3 L JOJO tank, with two disc filters at the inlet of the JOJO tank and one for each tank at the outlet that extends to the field was installed

- Gutter installation on the roofs of buildings for rainwater harvesting was considered as an option to capture rainwater from the rooftop with the addition of two 5000 L JOJO tanks
- Irrigation pump was supplied to pump water from the JOJO tanks to the vegetable garden
- JOJO tank stand was constructed
- Size of the garden proposed was 0.25 ha
- There was an existing garden committee in the school
- No fence was required

Mahlasedi Masana public primary school

- The water source was from municipal water
- There was no existing irrigation infrastructure-therefore new drip irrigation system, including one 5000 L and one 20^3 L JOJO tanks, with two disc filters required at the inlet of the JOJO tank and one for each tank at the outlet that extends to the field was installed
- Gutter installation for rainwater harvesting was also considered as an option to capture rainwater from the rooftop with the addition of one 5000 L JOJO tank
- Irrigation pump was supplied to pump water from the JOJO tank to the vegetable garden
- JOJO tank stand was constructed
- Size of the garden proposed was 0.11 ha
- There was an existing garden committee in the school
- No fence was required

3.3.2.1 Irrigation system

There was no irrigation infrastructure at the respective school gardens. Drip irrigation (non-pressure regulated dripper) was installed including JOJO tanks (Table 3.7). Wetting front detectors (WFD) and 5 in 1 weather sensor were provided to the schools in order to assist with irrigation and fertilizer management in the gardens.

Table 3-7: JOJO tank supplied for irrigation and rainwater harvesting at the schools.

Infrastructures development	Rainwater harvesting	
	Field	Veggie tunnel
Bula Dikgoro primary school	3	1
Mahlasedi Masana primary school	2	1

3.3.2.2 Gardening tools

From the assessment, it was found that the schools would need some basic gardening tools to carry out the daily activities of vegetable production (Table 2.2). Each school was supplied with the following garden tools:

Table 3-8: Gardening tools that were supplied to the school garden.

Items		Number of an item supplied per school
1	Wheelbarrows	2
2	Hoes	5
3	Spades	5
4	Watering cans	5
5	Hosepipe	1
6	Rakes	5
7	Garden forks	5
8	Hand shovels	5
9	Pruning shears	5
11	Personal protective equipment for each worker	8
12	T-Markers	50
13	Wetting front detectors (WFD)	20
14	5 in 1 weather sensor	1

3.3.3 Learners and household socio-economic characteristics

The demographics collected were an essential component of any survey and provide information on the background of the population studied for readers and policymakers alike, against which the findings were interpreted. Demographics set the scene of the entire survey, as most variables were analysed with the specific demographic characteristics of the population. In this survey, the demographic characteristics that were described include age, gender, education, employment status, number of current household members, kids at primary school, household head and household expenditure per month, income and sources of income. Other demographic information, were also collected but not presented in this report, include race, locality and household language.

Figure 3.10 illustrates sample size distribution from the schools under study. Bula Dikgoro had the highest number of respondents namely 159 and 73 from Mahlasedi Masana, which gives a total sample size of 232 respondents. The sample size was not evenly distributed among the schools. This was due to most parents or guardians from Mahlasedi Masana Primary Schools were unwilling to participate in the interview.

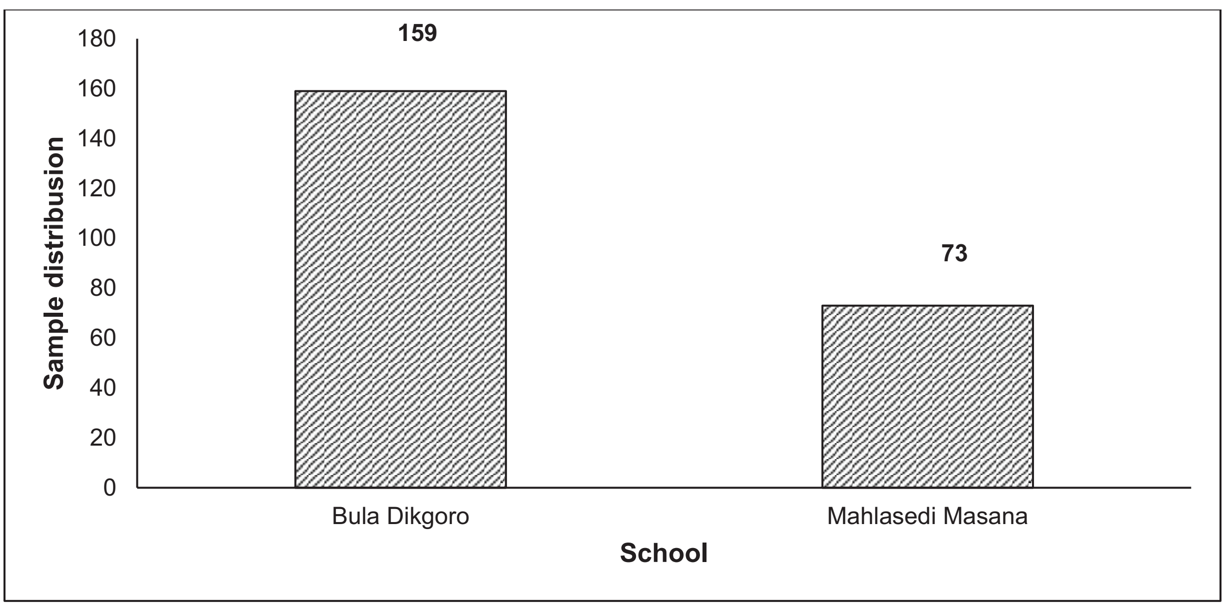

Figure 3-10: Sample distribution at Bula Dikgoro and Mahlasedi Masana Primary Schools.

3.3.3.1 Gender and age group composition

The gender composition represents the guardian gender of the school leaner. The distribution of guardian gender among respondents indicates a higher percentage for females (77%) than males (23%) (Table 3.9). The results were not surprising since mothers are the immediate guardians even in the male-headed households. The same view was indicated in an article by Marjorie and Starrels (1994) that examines levels and correlates husbands' involvement in traditionally female household chores. The analyses reveal that the vast majority of women assume primary responsibility for these daily and non-daily tasks. As indicated in Table 3.9, most of the respondents were less than 35 years of age (59%) as compared to other age groups 35-43 (23%), 44-52 (12%), 53-61 (3%) and >62 (3%). The result indicates that most leaners guardians were falling under the youth category.

Table 3-9: Socio-economic characteristic of participants.

Variable	Category	Distribution Percentage (%)
Gender	Male	77
	Female	23
Age	<35	59
	35-43	23
	44-52	12
	53-61	3
	>62	3
Education level	No formal education	2
	Primary	29
	Secondary	50
	Post-secondary	19
Employment status	Unemployed	57
	Part-time employment	15
	Full-time employment	28
Household size	1-5	63
	6-10	34
	11-15	3
Sources of income	Social grand	54
	Full-time employment	23
	Part-time employment	10
	No income	13

3.3.3.2 Education level

Education level is another tool, which was used to measure household food security. People with higher education level are generally less vulnerable to food insecurity as compared to people without education. People with qualifications had better chances of securing sustainable job opportunities as an opposed non-qualified group. Results indicated that most of the respondents acquired secondary education (50%) as compared to other education level categories primary (15%) and no formal education (2%) (Table 3.9).

3.3.3.3 Employment status

Employment status in urban households is an essential factor for household food security. According to Ruel et al. (1998), urban households purchase most of their food as compared to rural household who produce most of their household food. Given the explanation, the presence of employed members in the household would contribute to household food security. The results indicated that 57% of the respondents were unemployed as compared to 28% full-time employment and 15% part-time employment (Table 3.9). The results were alarming, considering that participants under observation were urban dwellers; hence they rely on purchased food.

3.3.3.4 Household food availability and access

Food security is a global issue and remains a significant challenge for developing countries, such as South Africa (Chakona & Shackleton, 2017). According to DAFF (2012), Food security is presumed to exist when there is adequate and continuous food availability, access, and utilisation in a sustainable manner. It is clear from the definition of those three dimensions of food security: availability, access and utilisation, that for food security objectives to be realised, all three aspects must be fulfilled simultaneously. The measurement of the three dimensions of food security followed a Household Food Insecurity Access Scale measure (HFIAS) by Coates et al. (2007).

Food availability in the definition implies that a country must have sufficient quantities of food available consistently at both the national and household level (HSRC, 2004 and DAFF, 2011). Table 3.10 illustrate food availability status of respondents and the results generally indicate that households are experiencing food availability challenges when comparing percentages for never against other three levels of food availability occurrence (sometimes, often and always). It is worth noting the percentage of the household experiencing severe food unavailability, which was observed on the percentage for always. There were many household experiencing anxieties about not having enough food. It was also observed from the results that although the households were experiencing food availability challenges, there was still higher percentage (75% children and 69% adults) of household not sleeping with an empty stomach as compared to those who sleep with an empty stomach. The results are alarming, especially 18% and 23% for both children and adults going to bed feeling hungry, meaning some leaners go to school with an empty stomach.

Table 3-10: Food availability status of respondents.

An impression of the availability of food at the household level	**N**	**S**	**O**	**A**	**M**
			%		
My food runs out before I get money to buy more	19	52	6	19	4
I do not know where the next day`s food is going to come from	41	4	42	6	7
The food that I buy is not enough to feed my family	28	42	12	13	5
I am often hungry	46	38	6	2	8
I eat less than I think I should	36	39	10	7	8
I don’t` have enough money for food	26	47	10	11	6
I cannot afford to feed my children	46	33	6	9	6
My children are not getting enough food to eat	44	38	7	5	6
My children go to bed feeling hungry	75	14	3	1	7
I go to bed feeling hungry	69	18	3	2	8
I know where tomorrow`s food is going to come from	22	37	9	24	8
I can afford to eat enough every day	25	40	8	18	9
I have enough money for food	26	42	7	16	9
I have enough food to last until I get money to buy more	25	43	9	14	9
I still have food in the house the day before someone gets paid	30	35	9	16	10

N=Never, S=Sometimes, O=Often, A=Always, M=Missing information

The South African Constitution asserts that every citizen has the right to have access to sufficient food and water and that the state must take reasonable legislative and other measures, within its available resources, to achieve the progressive realization of this right to sufficient food (HSRC, 2004). However, there are various factors influencing food accessibility at household level such as resource endowment which may include income or land for own production. In view of the results in Table 3.10, there was still a percentage of households struggling to access food to satisfy their daily requirement although a higher percentage of the respondents were unwilling to participate during the interview. This could be either the response felt the questions were sensitive or wasting their time since no incentive was included to the participants. Furthermore, with regards to the duration of exposure to inability to food access, it can be observed that there was an alarming percentage of the household which were unable to access food on an often basis (more than ten times in the past four weeks) (Table 3.11). In light of the results, it is evident that the rights of people to have access to sufficient food at the household level was yet to be realized by the sampled households.

Table 3-11: Food access status of respondents.

Household Food Access	R	S	O	M
		%		
In the past four weeks, were you or any household member not able to eat the kinds of foods you preferred because of lack of resources?	24	19	4	53
In the past four weeks, did you or any household member have to eat a limited variety of foods due to lack of resources?	30	20	7	43
In the past four weeks, did you or any household member have to eat some foods that you/they really did not want to eat because of lack of resources to obtain other types of foods?	28	22	8	42
In the past four weeks, did you or any household members have to eat a smaller meal than you felt you needed because there was not enough food?	24	22	5	49
In the past four weeks, did you or any household members have to eat fewer meals in a day because there was not enough food?	27	16	4	53
In the past four weeks, was there ever no food to eat of any kind in your household because of lack of resources to get food?	23	9	2	66
In the past four weeks, did you or any household members go to sleep at night hungry because there was not enough food?	26	6		68
In the past four weeks, did you or any household member go a whole day and night without eating anything because there was not enough food?	17	5		78

R=Rarely (once or twice in the past four weeks), S=Sometimes (three to ten times in the past four weeks), O=Often (more than ten times in the past four weeks), M=Missing information

Food use refers to the appropriate use based on knowledge of basic nutrition and care, as well as adequate water and sanitation (DAFF 2011). Whilst it is predictable that insufficient food quantity would result in inadequate dietary intake, dietary intake might also be a problem even in households where there appears to be sufficient volume of food. Key manifestations of malnutrition include wasting (thinness), stunting (shortness) and being underweight (HSRC 2004). Figure 3.11 illustrates diversification of food utilization by the household and the results indicate the majority of the household were diversifying their food intake for seven days before the assessment. It was no surprise to observe cereals as the most consumed food among other food groups since cereals food included (maize, rice, wheat, sorghum, millet or any other grains or foods made from these sources). Despite a high percentage of food diversification among the households, there was no evidence to confirm if the quantity consumed meet the dietary requirement.

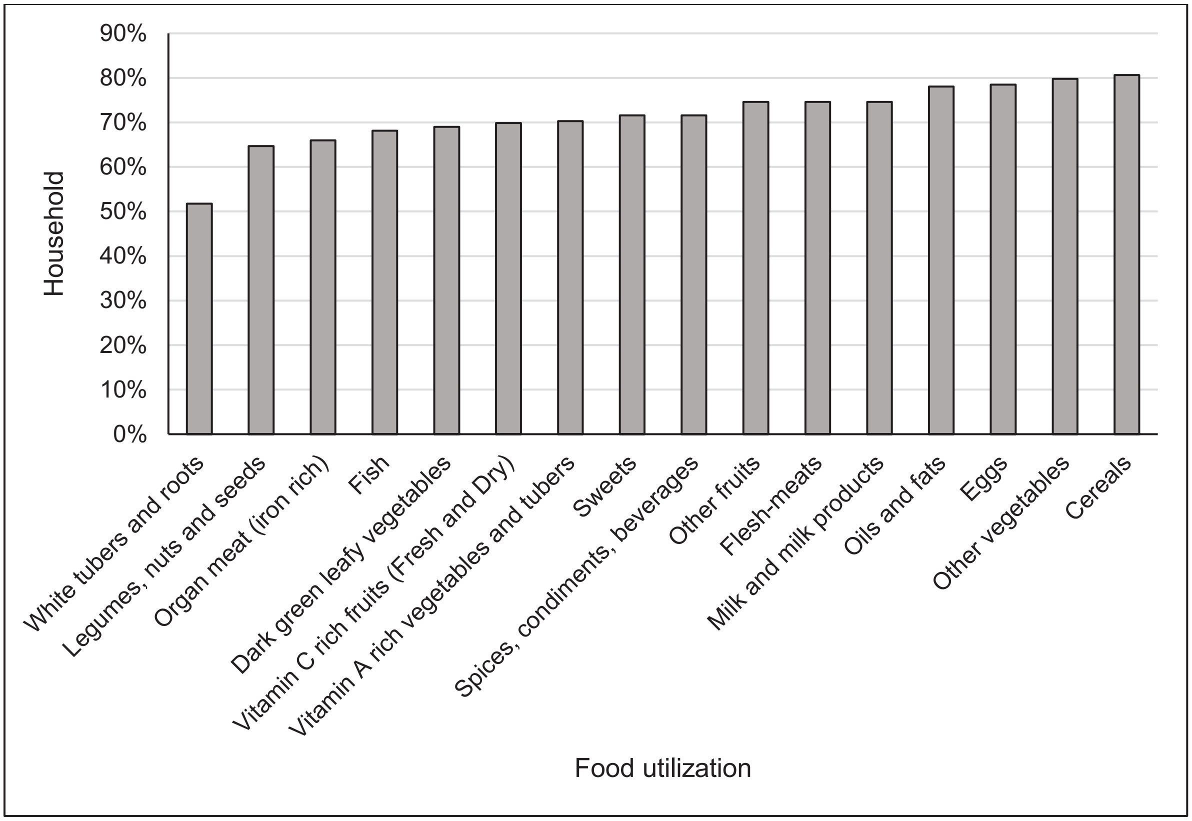

Figure 3-11: Food utilization of respondents within seven days before the assessment.

Three measures of food security, food availability, food access and food utilization were correlated with main indicators of household food security which are, employment status and education of the level of respondents. The independent variables were selected based on their relevance to the sample under study since urban dwellers are net buyers of food. In other words, a household needs to constant income to maintain household food supply from the market. Even though food is available at the market, many households do not have money to purchase food hence employment and education were used as an independent variable since they complement each other. Employment status was binary variable coded 0 for employed and 1 for unemployed meaning variation from zero to one explain changes in the food security status. Education level is a continuous variable starting from zero for no formal education.

A positive significant relationship between employment status, food access and availability were observed (Table 3.12), which means changes in employment status was positively correlated to increase food access and availability in the household, Zakari Ying and Song (2014) obtained similar results. Another significant but inverse correlation was observed between education level and food utilization, which means that a change in educational level has a negative impact on household food utilization. Similar results reported in a study by Lasheras et al (2001). The assessment indicated that the educational level of people has a strong influence on their quality of life, nutrient intake and food consumption. The results are surprising and rather controversial since prior expectations were as people get more educated they grow conscious about healthy diet and hence consume more nutritious food.

Table 3-12: Correlations between Household food availability, access, utilization, and employment status and education level

	Coefficients	P-value	χ^2
	Food availability		
Employment status	0,177818	0,000243*	0,056971
Educational level	-0,00665	0,219839	0,006538
	Food utilization		
Employment	-0,00092	0,982926	0.0000002
Education level	-0,01041	0,027897*	0,020845
	Food access		
Educational level	0,00111	0,876603	0,000105
Employment	0,154905	0,016082*	0,02493

3.4 Conclusion and recommendations

School nutrition gardens are a long-term strategy that complements supplementation and food fortification programs. Running a school garden requires not only horticultural knowledge but the availability of infrastructure, agricultural inputs and ability to mobilize parents and community members in the area Before the establishment of the vegetable school gardens, the gardens were assessed for the availability of land, physical and chemical characteristics of the soil, available infrastructure and suitable vegetable crops. Gardens were then demarcated and the area was prepared with a tractor. Organic fertilizer was incorporated based on the soil analysis recommendation. Low-pressure drip irrigation system with JOJO tanks and irrigation pumps were installed. Vegetables were selected on suitability to the area and nutritional value. The selected vegetables included commercial exotic such Cabbage, Swiss chard, beetroot, onion, tomato butternut and ALVs included Kale, Mustard spinach and Rape. New biofortified crops (e.g. orange-fleshed sweet potatoes), as well as healthy new crops (e.g. moringa), were also introduced in order to promote consumption in the schools and the community. Open field vegetable production system was supplemented with veggie tunnel and bag system vegetable production systems to improve vegetable accessibility, pest and disease management and resource use.

Learners and household socio-economic characteristics assessment were done in both schools. Quantitative and qualitative methods were employed in the assessment. The collected data was analysed quantitatively using the Statistical Package for Social Sciences (SPSS) version 24 and Microsoft excel. The results indicated that 77% of the respondents were female, 54% of the household receives income from social grant, and 18% and 23% for both children and adults going to bed feeling hungry, meaning there are leaners who go to school with an empty stomach.

Given the survey results, it was evident from both socio-economic and household food security status that there were leaners who comes from a food-insecure household. Further empirical findings also indicated a correlation between measures of food security and household food security indicators. The results warrant the establishment of a food garden at school in order to supplement leaners with daily dietary requirements. It is recommended that schools can encourage children to report at home what they are doing at school, invite families to visit the gardens, create pilot gardens and distribute seedlings to the households.

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CHAPTER FOUR
SET-UP AND IMPLEMENTATION OF SUMMER AND WINTER VEGETABLE GARDENS IN SELECTED STUDY SCHOOLS

4.1 Introduction

School-vegetable gardens are becoming increasingly common in South Africa, in both public and private schools. The benefits of gardening with learners are undoubtedly clear, as school gardens can serve as demonstration sites to learners on how to grow and harvest nutritious vegetable crops. The practical demonstration of implementing a school-vegetable garden can increase the variety of nutritious food in the learners' diets, which leads to the development of a taste for a range of food. In addition, it can extend and balance school meals, promote new initiatives in children on how to prepare healthy snacks from garden harvested produce, and build awareness in children and their families of healthy diets (FAO, 2005).

The Setting-up and implementing a school-based vegetable garden involves knowing who will manage the garden, which tools and research consumables will be needed, the size of the garden, identification of training needs and selection of vegetable crops to grow. Vegetables are generally rich in many different vitamins and minerals, especially dark green leafy vegetables, and yellow or orange tuber or root vegetables. Therefore, this project aimed to set-up and implement winter and summer vegetable gardens in two public primary schools in Mamelodi East namely, Bula Dikgoro and Mahlasedi Masana.

4.2 Methodology

4.2.1 Selection of production systems/techniques and vegetable crops

The following systems/techniques were tested for school-based vegetable production at the study schools: (1) veggie tunnels; (2) bag system; (3) in-field rainwater harvesting; (4) in-situ rainwater harvesting; (5) conventional flat cultivation and (6) rooftop rainwater harvesting. Veggie tunnels and bag production systems were implemented in both winter and summer rainfall seasons, while rainwater harvesting techniques were only conducted during the summer season. Vegetable crops such as carrots, beetroots, Swiss chard, kale and onion were planted during the winter season, while during the summer season crops such as sweet potato, green peas, tomatoes and Swiss chard were planted.

4.2.1.1 Veggie tunnel production system

The veggie tunnel production system promotes a food garden model with a variety of conventional and traditional vegetables, using an intensive vegetable production set-up in an 8 m x 12 m (96 m^2) netted tunnel structure (Figure 4.1). The primary purpose of the veggie tunnel model was to produce a variety of nutritious vegetables in a small area as part of a broader approach to address malnutrition. For this purpose, two veggie tunnels were installed per study school. The area inside the tunnel was divided into two long beds. Each bed was further divided into five plots. A variety of crops were planted, which were irrigated through sprinkler irrigation, at an application rate of 5 mm per hour.

Figure 4-1: Veggie tunnels installed at the study school gardens.

4.2.1.2 Bag production system

The bag system is an alternative way of growing vegetables while optimising yield per unit of area utilized. This is critical in South African arid and semi-arid regions, as the availability of good soil and land/space for vegetable production is becoming a significant concern, particularly in school gardens. In a bag system, plants are grown vertically, which results in efficient utilization of space/land (Figure 4.2). Besides, the system allows for more precise irrigation water applications, which results in limited water being lost through drainage, thus minimizing leaching of nutrients. Furthermore, plant leaves are not in contact with the soil, resulting in less effort to clean the leaves before consumption or marketing. The bag system can also be implemented anywhere in the garden and does not require weeding. In this study, the bag system was tested for the production of leafy vegetables such as Swiss chard and kale. Swiss chard was planted at two planting densities (20 and 40 plants per bag), while kale was planted at a density of 30 plants per bag. The spacing of bags per unit of area utilized was also investigated, were treatments consisted of 5 bags versus 9 bags per 2.6 m x 2.6 m plots. The bags were irrigated manually, at an application rate of 2.0-4.0 L per bag per day.

Figure 4-2: Introduction of a bag vegetable production system at Bula Dikgoro Primary School.

4.2.1.3 In-field rainwater harvesting technique

The in-field rainwater harvesting technique consisted of a bare catchment area for runoff collection and a cropping area located adjacent to it, which allows the stoppage of ex-field runoff, maximizes infiltration and stores the collected water in the soil layers below the evaporation sensitive zone. Ridges were made directly below each cropping area to allow better conservation of water in the soil profile. Mulch was placed in the cropping area to minimize evaporative losses. The ratio between the catchment area and the cropping area was kept at 3:1 (Figure 4.3). Weeding in the catchment area was done manually.

Figure 4-3: Construction of the in-field rainwater harvesting technique at Bula Dikgoro Primary School.

4.2.1.4 In-situ rainwater harvesting technique

The in-situ rainwater harvesting technique often referred to as soil-water conservation, involved the use of methods that increase the amount of water stored in the soil profile by trapping or holding the rain where it falls. In this application, there is no separation between the runoff collection area and its storage area; the water is collected and stored where it is going to be utilized. The land was divided into alternated stripes of ridges and furrows of approximately 50 cm wide and 15 cm deep, making small earthen ties along furrows at about 1 m apart from each other to ensure even storage of runoff water (Figure 4.4). Planting was done on top of the ridges.

Figure 4-4: In-situ rainwater harvesting technique implemented at Bula Dikgoro and Mahlasedi Masana Primary Schools

4.2.1.5 Conventional flat cultivation technique

The conventional flat cultivation (open field) technique consisted of reversing and stirring a deep layer of soil while incorporating and destroying plant debris. Land preparation was composed primarily of harrowing for removing the residues of previous crop or debris. The soil was ploughed to an average depth of 15-30 cm using a disk harrow and a moldboard plough. Inorganic fertilizers such as lime and NPK were applied together with the first ploughing and harrowing. Crops were irrigated using drip irrigation at an application rate of 250 to 500 ml per day per plant (Figure 4.5).

Figure 4-5: Swiss chard cultivated using the conventional flat cultivation technique at Bula Dikgoro Primary School.

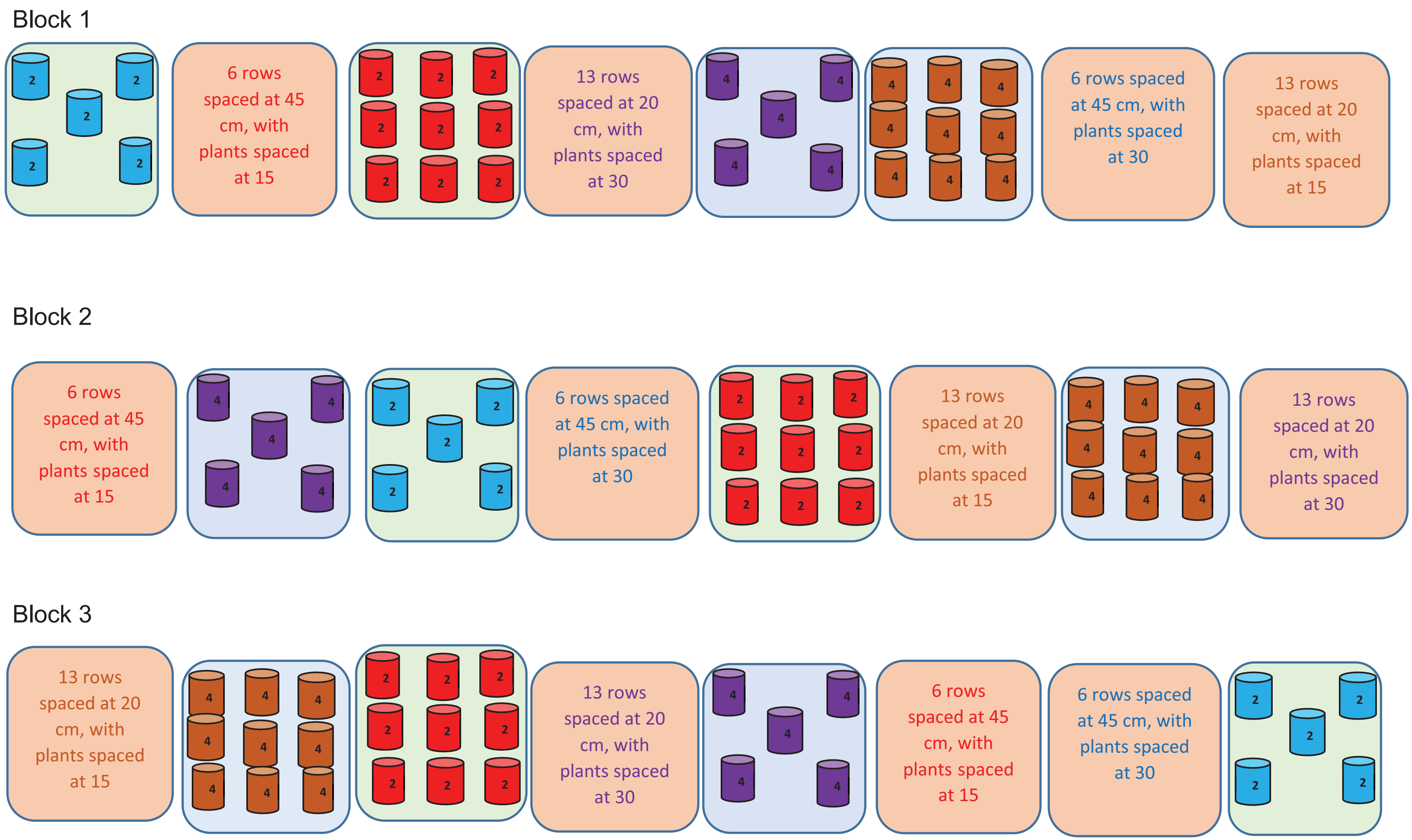
4.2.1.6 Rooftop rainwater harvesting technique

A complete field trial was implemented during the summer rainfall season of 2019/2020 at Bula Dikgoro Primary School. The trial formed part of an MSc study conducted at Tshwane University of Technology (Appendix 1). The trial tested the potential of the rooftop rainwater harvesting technique for supplementary irrigation of Swiss chard grown in two different production systems (bag and conventional flat cultivation) as shown in Figure 4.6.

Figure 4-6: Comparison between the bag and conventional flat cultivation of Swiss chard irrigated through supplementary irrigation using rainwater harvested from the rooftop at Bula Dikgoro Primary School.

The experimental design was a randomized complete block design. Treatments were arranged on a 2 x 2 x 2 factorial design with 3 replicates: (1) Production system: bag and flat cultivation; (2) Planting density – 20 and 40 plants per 50 kg bag of soil (80 cm long x 40 cm wide) or per 9 m row of crops; (3) Spacing – 1 m x 1 m x 0.7 m bag/30 cm per plant and 0.3 m x 0.3 m bag/0.15 m per plant. The treatment control for conventional flat cultivation was planting Swiss chard at 0.3 m spacing between rows x 0.3 m spacing between plants. The treatment control for the bag hydroponic system was planting 20 seedlings of Swiss chard per bag and bags spaced at 1 m x 1 m x 0.7 m.

Experimental Layout:



Propylene bags of (105 cm × 72 cm) were filled with sawdust and placed upright. Small holes of (3 cm × 3 cm) were uniformly perforated around the bags depending on the desired planting density using a scissor for insertion of the transplanted seedlings. A seedbed was prepared for the conventional flat cultivation with the same spacing between plants and rows per plot of 2.6 m x 2.6 m as for the bag. The planting densities on the bags were composed of 20 and 40 plants on 5 and 9 bags per plot, respectively. Hence, the following experimental treatments were assigned to both bag and conventional flat cultivation systems:

1. Bag-20-standard: 20 plants per bag, with 5 bags spaced at the standard spacing of 1 m x 1 m x 0.7 m
2. Bag-20-half: 20 plants per bag, with 9 bags spaced at half the standard spacing
3. Bag-40-standard: 40 plants per bag, 5 with bags spaced at the standard spacing of 1 m x 1 m x 0.7 m
4. Bag-40-half: 40 plants per bag, with 9 bags spaced at half the standard spacing of 1 m x 1 m x 0.7 m
5. Flat-20-standard: 20 plants per row, with plants spaced at 0.45 m x 0.3 m
6. Flat-20-half: 20 plants per row, with plants spaced at 0.45 m x 0.15 m
7. Flat-40-standard: 40 plants per row, with plants spaced at 0.2 m x 0.3 m
8. Flat-40-half: 40 plants per row, with plants spaced at 0.2 m x 0.15 m

The conventional flat cultivation system was irrigated using drip irrigation, while the bag system was irrigated using spaghetti tubes (0.5 mm) connected to the drip mainline of 14.2 mm. The frequency and amount of irrigation were determined based on soil water content monitoring using automatic water sensors which were inserted within the root zone of the crop and connected to a datalogger. A 20% depletion of plant available water was allowed. Soil fertilization on both flat and bag systems was conducted optimally, based on plant requirement recommendations and growing substrate laboratory analyses. In the bag system all the required nutrients (nitrogen – N, phosphorus – P, potassium – K, magnesium – Mg, sulfur – S, iron – Fe, boron – B, copper – Cu, zinc – Zn, manganese – Mn and molybdenum – Mo) were applied through fertigation, using Multifeed® or hygroponics in combination with calcium nitrate to meet 100% crop nutrient requirements, while maintaining an EC level of 2.8-3.0 dS m^{-1} and pH of 5.5-6.0.

JoJo tanks were installed at the school at the end of the selected classrooms block (37 m × 11 m), which was positioned near the garden and site of field measurements. The selected block was equipped with gutters for collection and diversion of runoff from the catchment area (roof) into 3 tanks of 5000 litres connected in series for water storage. Storage tanks were equipped with disc filters to ensure adequate water quality. Water meters and water pumps were connected to the tanks for easy calculation of the discharged water for supplementary irrigation and to ensure adequate irrigation water pressure.

The amount of rainwater harvested was determined using the following formula:

$$RWHP = P \times A \times RE \times 10 \quad (1)$$

Where:

RWHP is the amount of rainwater harvested from the roof (L/year);

P is local precipitation (mm/year);

A is the catchment area (m^2) and

RE is the runoff coefficient (non-dimensional) which depends on the roof material

The runoff efficiency (RE) was calculated as the ratio between runoff volume (L) collected in the tank and respective rainfall amount which was converted to volume by multiplying by the roof catchment area. This was done for 5 rainfall events, and an average was subsequently calculated to represent a typical RE during the entire growing season. The collected runoff amount during each rainfall event was estimated by measuring the depth of water collected in the tank using a calibrated stick, multiplied by the area of the tank to obtain runoff volume.

4.2.2 Supply of fertilizers and protective clothing to the schools

Fertilizers are essential for improving the yield and nutritional value of all crops. It was found that the schools were lacking the main input fertilizers. Therefore, the schools were supported with the following organic and inorganic fertilizers: kraal manure, LAN (28% N), superphosphate (10% P), potassium chloride (50%K) and organic pesticides. The Mamelodi community members involved in assisting with school garden activities received protective clothing in addition to fertilizers (Figure 4.7).

Figure 4-7: Supply of protective clothing to Mamelodi community members involved in school garden activities.

4.2.3 Installation of JoJo tanks and gutters

Prior to the beginning of the project, the main water source for irrigation of crops at the study schools was municipal water. However, when the project began, the research team installed JoJo tanks for rooftop rainwater harvesting in order to minimize the dependency on municipal water for crop production in gardens. Construction of concrete slabs below the irrigation tank stands was done using concrete ready mix to strengthen the tank stand. The concrete slab maintained the irrigation tanks levelled, providing good support to the tanks to withstand the weight of water during the rainy season (Figure 4.8a). Gutters were installed for rooftop rainwater harvesting collection at both study schools (Figure 4.8b). The amount of rainwater harvested was stored in JoJo tanks connected in series for increased water storage during heavy rainfall events.

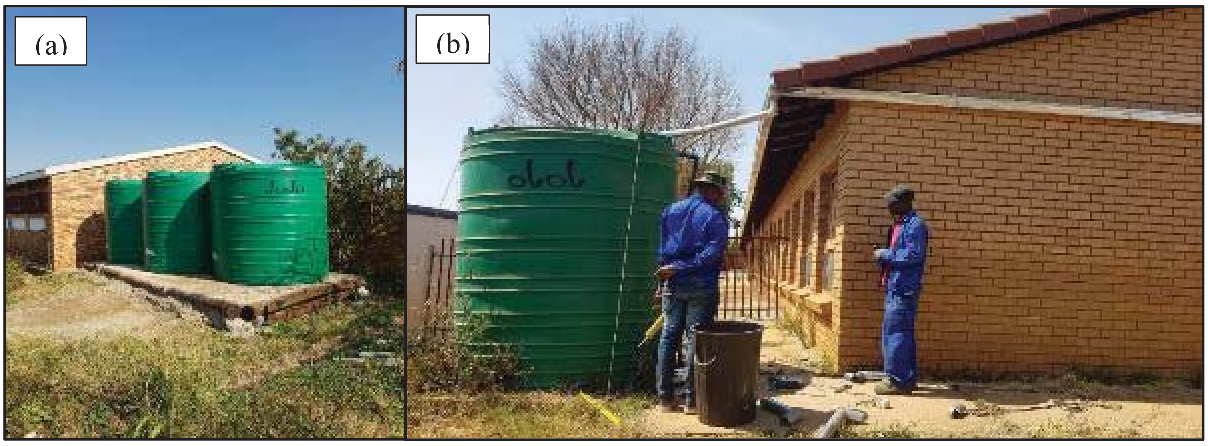


Figure 4-8: Concrete slab constructed to support water storage tanks (a) and gutter installation for rooftop runoff collection (b) at the study schools.

4.2.4 Field data collection

The collected field data included fresh harvestable yield measured using a scale, plant height obtained with a measuring tape, fractional interception of photosynthetic active radiation and leaf area index using a ceptometer, leaf area using a leaf area meter, chlorophyll content using a SPAD-502 chlorophyll meter and leaf stomatal conductance using a porometer. The fresh harvestable yield was measured at each harvest, while the other growth and physiological parameters were measured once per week throughout the experimental period. Irrigation scheduling was monitored using 10-HS and GS-1 automatic water sensors for soil and soilless substrates, respectively (Figure 4.9). Wetting front detectors (a device that indicates how deep water infiltrates into the soil after irrigation or rain), was installed within the 0.2 m root zone (Figure 4.10). The same device was also used to monitor changes in soil electrical conductivity and nitrate content. Weather variability at the study sites was recorded by the nearest available weather station for the majority of the trial period. However, in January 2020 the research team installed a portable 5-in-1 weather station at Bula Dikgoro Primary School (Figure 4.11).

Figure 4-9: 10-HS automatic soil water sensors installed within the root zone of winter vegetable crops at the study schools.

Figure 4-10: Installation of wetting front detectors (Stevens & Stirzaker, 2010) within the root zone of winter vegetable crops at the study schools.

Figure 4-11: A 5-in-1 weather station installed at Bula Dikgoro Primary School.

4.2.5 Supply of leafy vegetables to the kitchen for school feeding

Fresh harvestable produce of Swiss chard, sweet potato, cabbage, tomato, onion, carrot, butternut, beetroot, green peas and Kale was harvested from randomly selected plots, weighed, washed and supplied to the schools' kitchen for meal preparation as part of the school feeding scheme (Figure 4.12). The number of learners fed was recorded. A sample of the prepared food was kept and sent for laboratory analysis.

Figure 4-12: Supply of fresh leafy vegetables to the kitchen and learners feeding at Bula Dikgoro Primary School.

4.3 Results and discussion

4.3.1 Winter vegetable production

During the winter growing season of 2018/19, field measurements were conducted across different vegetable production systems tested namely, veggie tunnel, bag and conventional flat cultivation systems. Crop selection consisted of Swiss chard, kale, carrot and beetroot under veggie tunnels and conventional flat cultivation systems, while only Swiss chard and kale were evaluated under the bag system since the system is appropriate for leafy vegetables due to crop arrangement configuration as well as limited space available within the bag. Leafy vegetables can also be harvested frequently, which reduces crop competition for solar radiation, water and nutrients availability.

4.3.1.1 Weather variability during the growing period

Weather variables at the study sites were obtained from the nearest weather station (Figure 4.13). Daily values of reference evapotranspiration calculated using the method developed by Allen et al. (1998) are presented in Figure 4.14. The coldest period was generally around June with minimum temperatures reaching -6.18°C, while the hottest with a higher incidence of solar radiation and increased atmospheric evaporative demand was around August (maximum values of temperature = 31.7°C, solar radiation = 19.6 MJ m^{-2} day^{-1} and ETo = 4.2 mm day^{-1}).

Wind speeds remained low practically throughout the entire period of measurements (average of 0.88 m s^{-1}).

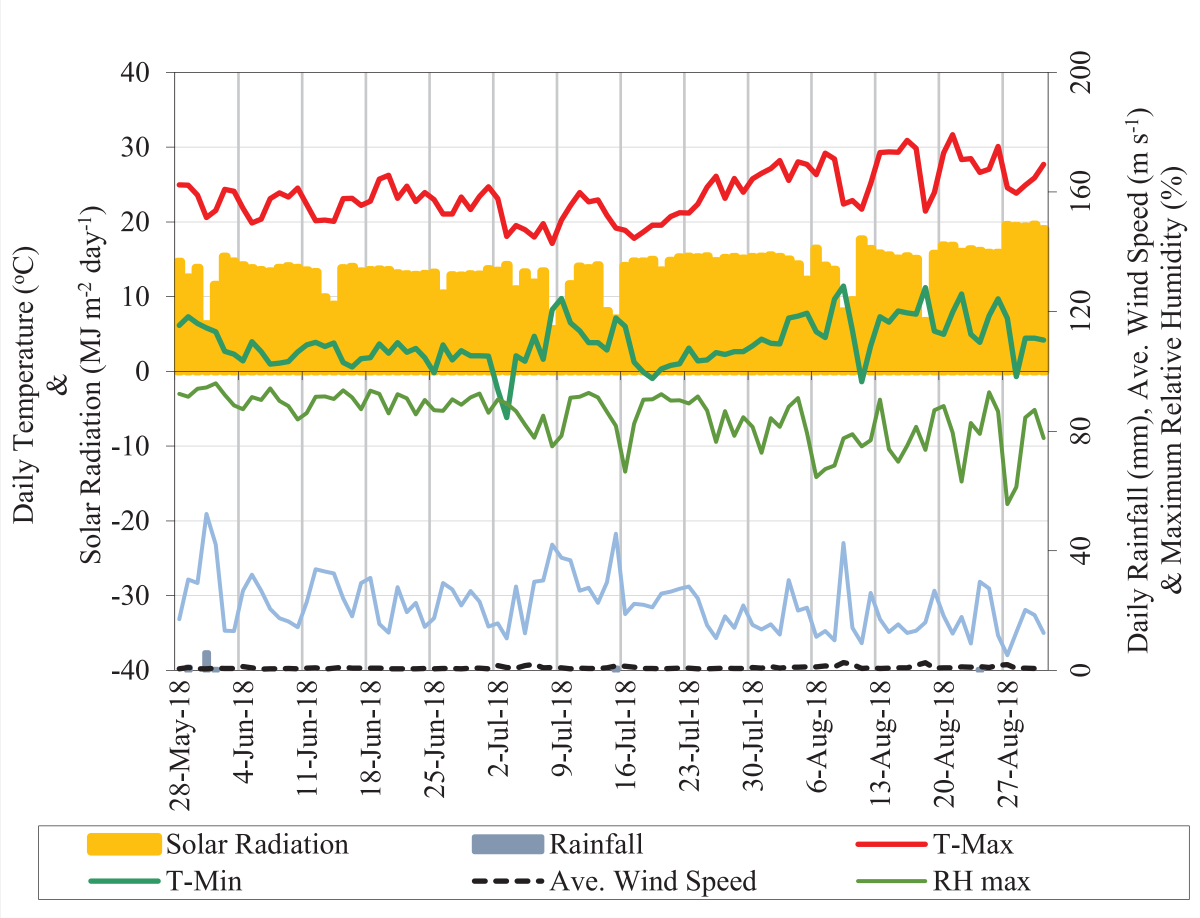


Figure 4-13: Weather variability during the 2018/19 winter season at the study sites.

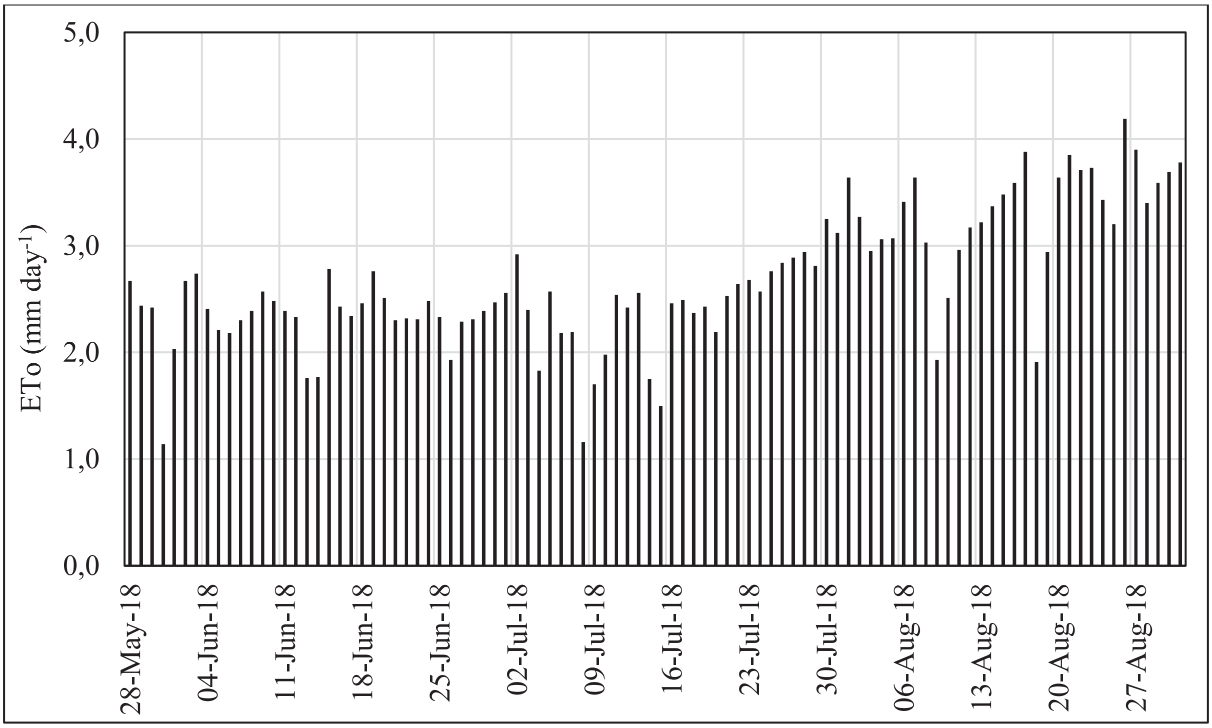


Figure 4-14: Daily reference evapotranspiration (Eto) fluctuations during the 2018/19 winter season at the study sites.

4.3.1.2 Irrigation applications

Irrigation was typically scheduled every second day, in order to refill the soil profile up to 60% of plant-available water. This irrigation strategy was chosen due to the limited water availability at the study schools, which restricted irrigation of crops growing in the garden. The amount of irrigation water applied was relatively low in the beginning and end of the growing season due to low canopy growth, as the crop was either during its initial growth stage or during leaf senescence. Seasonal irrigation water applied varied amongst the three production systems studied, as follows: 218 mm for open-field production, 162 mm for tunnel production and 129 mm for a bag system. Figure 4.15 shows irrigation distribution under an open-field production.

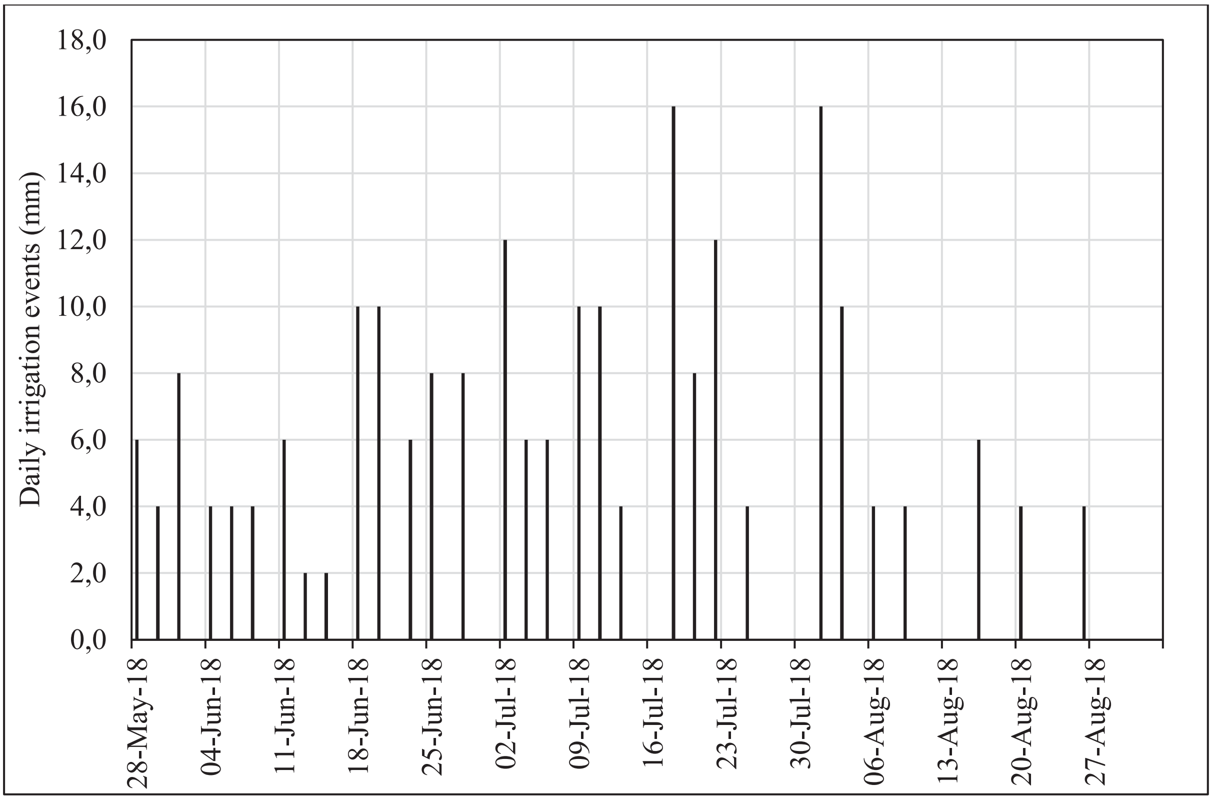


Figure 4-15: Daily irrigation events on the open field production of vegetable crops.

4.3.1.3 Changes in soil water content

Changes in soil water content within the crop root zone followed the same pattern of irrigation distribution. Figure 4.16 illustrates results obtained for Swiss chard, where soil water content varied between 148-190 mm under open-field production and 132-205 mm under the veggie tunnel. Higher soil water content was generally observed under tunnel production, which can be mainly attributed to the lower incidence of solar radiation, cooler temperatures and low wind speed, thus resulting in lower soil evaporation losses. Measurement results obtained for kale were slightly higher compared to Swiss chard in both tunnel and open-field production systems, which can be due to lower crop water use. Root crops like carrot and beetroot showed even lower changes in soil water content (Figure 4.17), indicating low crop water use.

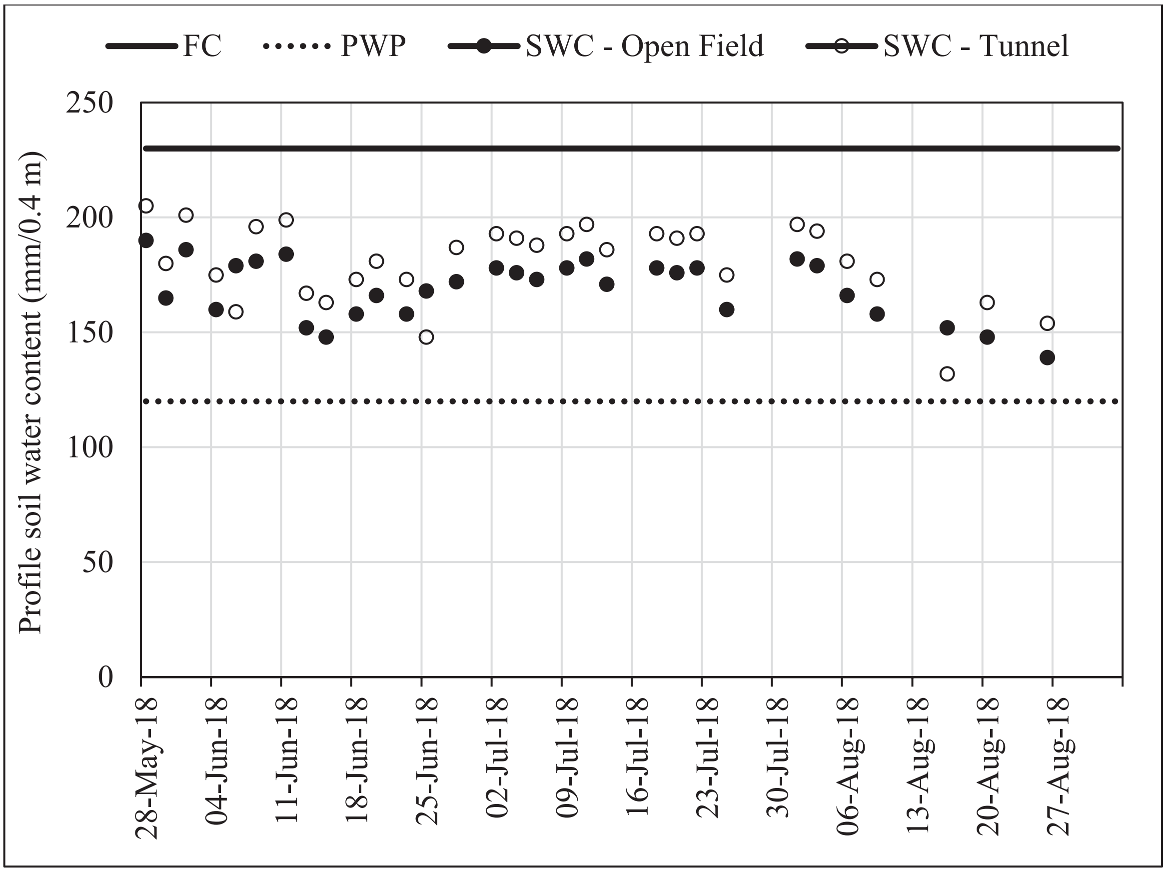


Figure 4-16: Changes in profile soil water content within Swiss chard root zone during the 2018/19 winter growing season.

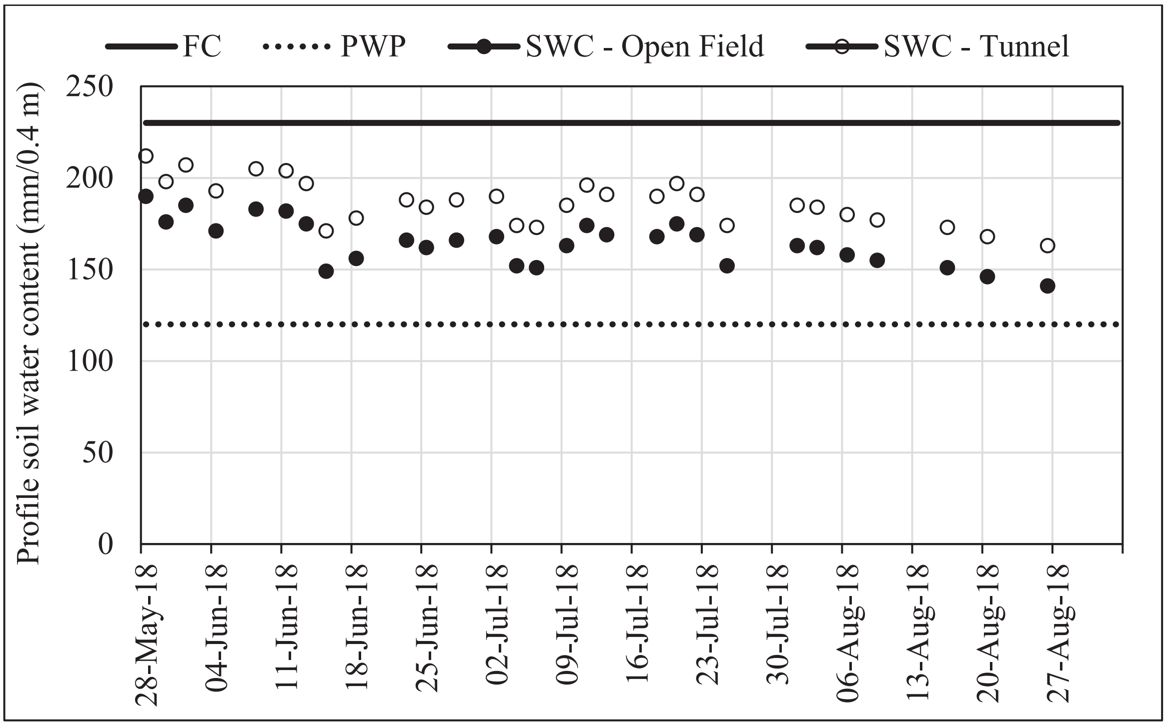


Figure 4-17: Changes in profile soil water content within beetroot root zone during the 2018/19 winter growing season.

4.3.1.4 Soil electrical conductivity and nitrate content

The production of winter vegetables at the study sites was mainly dependent on organic fertilization using kraal and chicken manure. Inorganic fertilizers (Lime Ammonium Nitrate and Potassium sulphate) were applied at minimum quantities (25% of the recommended rate for N and P) to ensure reduced chemical contamination of the product to be supplied to the kitchen. As a result, soil electrical conductivity and nitrate content were generally quite low for all the different winter vegetable crops (Figure 4.18).

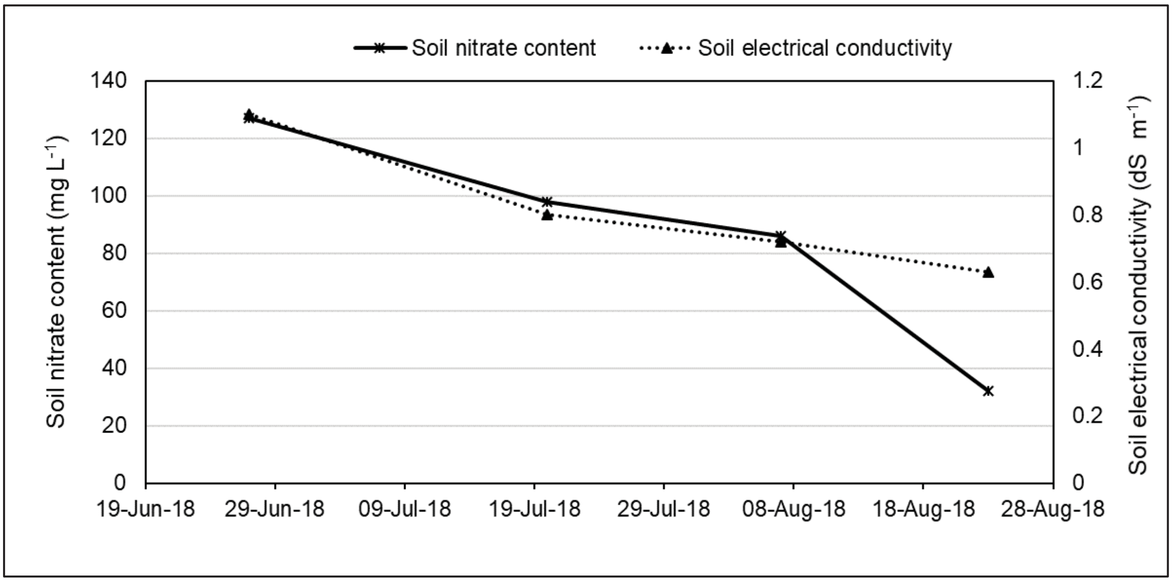


Figure 4-18: Changes in soil nitrate content and soil electrical conductivity in Swiss chard cultivated field during the 2018/19 winter growing season.

4.3.1.5 Crop water use

Crop water use or evapotranspiration was estimated using the shortened soil water balance equation, assuming negligible runoff and deep percolation losses (Annandale et al., 1999). The estimated values determined for Swiss chard, kale, carrot and beetroot produced under open-field and veggie tunnels are presented in Table 4.1. Water use of Swiss chard and kale cultivated using a bag system is also included. For the bag system, crop water use was estimated using a lysimeter method, by weighing mass changes before and after irrigation events, while recording the volume of irrigation water applied. Values of field capacity of sawdust growth medium were also determined through the lysimeter method.

Table 4-1: Seasonal crop water use for different vegetables produced under open-field, tunnel and bag systems.

Vegetable crops	Seasonal crop water use(mm) under varying production systems		
	Open-field	**Tunnel**	**Bag**
Swiss chard	301	288	32
Kale	266	249	29
Carrot	241	225	-
Beetroot	239	231	-

As indicated in Table 4.1, leafy vegetables (Swiss chard and kale) used more water when compared to root vegetables (carrot and beetroot). This was observed in both open-field and tunnel production systems. Expectedly, water use of leafy vegetables produced using a bag system was considerably lower (approximately 90% lower) compared to that of open-field and tunnel production. This is likely the result of better land utilization with the bag system (223 880 plants ha^{-1}) in which the crop is cultivated vertically, as compared to the open-field and tunnel systems (166 667 plants ha^{-1}) with horizontal cultivation. In addition, in the bag system, lower irrigation amounts are applied during each event, which optimizes the effective crop water consumption due to reduced drainage losses. Moreover, there are no runoff losses in the bag system, as opposed to the open-field and tunnel systems.

4.3.1.6 Fresh harvestable yield and canopy growth

Table 4.2 illustrates total fresh harvestable yield for Swiss chard, kale, carrot and beetroot produced under the open-field, tunnel and a bag system. The highest yields observed for leafy vegetables were obtained with the bag system (39 to 58 ton ha^{-1}), followed by the tunnel (25 to 36 ton ha^{-1}) and open-field (19 to 28 ton ha^{-1}) production system. Canopy growth per plant was lower under the bag system (leaf area from 17 to 26 m^2), as compared to the open-field (leaf area from 22 to 31 m^2 and leaf area index from 0.3 to 0.9 m^2 m^{-2}) and tunnel (leaf area from 28 to 38 m^2 and leaf area index from 0.5 to 1.3 m^2 m^{-2}). Nevertheless, the bag system resulted in higher crop yield as compared to the other systems due to increased planting densities (223 880 plants ha^{-1}), as compared to the tunnel and open-field systems (166 667 plants ha^{-1}). Total fresh harvestable yield in the bag system was twice the yield recorded in the open field production system for both leafy vegetables. Root vegetable crops also showed higher yield under the tunnel production system (50 to 68 ton ha^{-1}) as compared to the open-field (39 to 42 ton ha^{-1}).

Table 4-2: Total fresh harvestable yield for different winter vegetables produced under open-field, tunnel and bag systems.

Vegetable crops	Seasonal fresh harvestable yield (ton ha^{-1}) under various production systems		
	Open-field	**Tunnel**	**Bag**
Swiss chard	19	25	39
Kale	28	36	58
Carrot	39	50	
Beetroot	42	68	

4.3.1.7 Crop water use efficiency

Crop water use efficiency (the ratio between fresh harvestable yield per unit area and crop water use) was also evaluated for different crops and production systems (Table 4.3). Crop water use efficiency using a bag system was considerably higher compared to that of the open-field and tunnel production (approximately 20 times more). A cost-benefit economic analysis will be required to identify whether it is indeed beneficial to produce using a bag system, since the system involves bags and soilless growing medium for cultivation, in addition to soluble inorganic fertilizers containing all the macro and micronutrients required for plant nutrition. Alternatively, tunnels may be a second option to cultivate vegetable crops under limited water resources. Results presented in Table 4. 3 show higher values of water use efficiency than those published by Nyathi (2016) for amaranth and spider flower (maximum of 1.24 kg m^{-3}), most likely because Swiss chard, kale, beetroot and carrot have much higher yields per unit of cultivated area, while Wenhold et al. (2012) published values of water use efficiency for Swiss chard (5.5-9.1 kg m^{-3}) that are closer to the range of those obtained in this study for the same crop.

Table 4-3: Water use efficiency for selected winter vegetable crops determined from measurements at the study site.

Vegetable crops	Water use efficiency (kg m^{-3}) under various production systems		
	Open-field	Tunnel	Bag
Swiss chard	6.3	8.7	121.8
Kale	10.5	14.5	200
Carrot	16.1	22.2	
Beetroot	17.5	29.4	

4.3.2 Summer vegetable production

Summer vegetable production was assessed during the growing seasons 2018/19 and 2019/20 at the study sites. During the summer growing season of 2018/19, field measurements and data recording focused mainly on implemented field rainwater harvesting techniques (in-situ and in-field rainwater harvesting as compared to the conventional flat cultivation). While in the second summer season, reporting of results focused on rooftop rainwater harvesting for supplementary irrigation of Swiss chard grown under two different production systems (bag and conventional flat cultivation).

4.3.2.1 Weather variability

Weather variability during the 2018/19 and 2019/20 summer seasons was quite similar, with averages of maximum temperature between 30.5 and 30.8°C, minimum temperature between 13.2 and 14.5°C, solar radiation between 21.2 and 22.4 MJ m^{-2} day^{-1}, maximum relative humidity between 80 and 82% and minimum relative humidity between 24 and 27% from September to January (Figure 4.19). This resulted in similar daily fluctuations of the atmospheric evaporative demand across the two experimental seasons as observed in Figure 4.20 (with total ETo = 745 mm in 2018/19 and 746 mm in 2019/20 for the period between September and January). However, the 2018/19 summer rainfall season was much drier (total rainfall between September and January = 268 mm) when compared to the subsequent season (total rainfall between September and January = 312 mm).

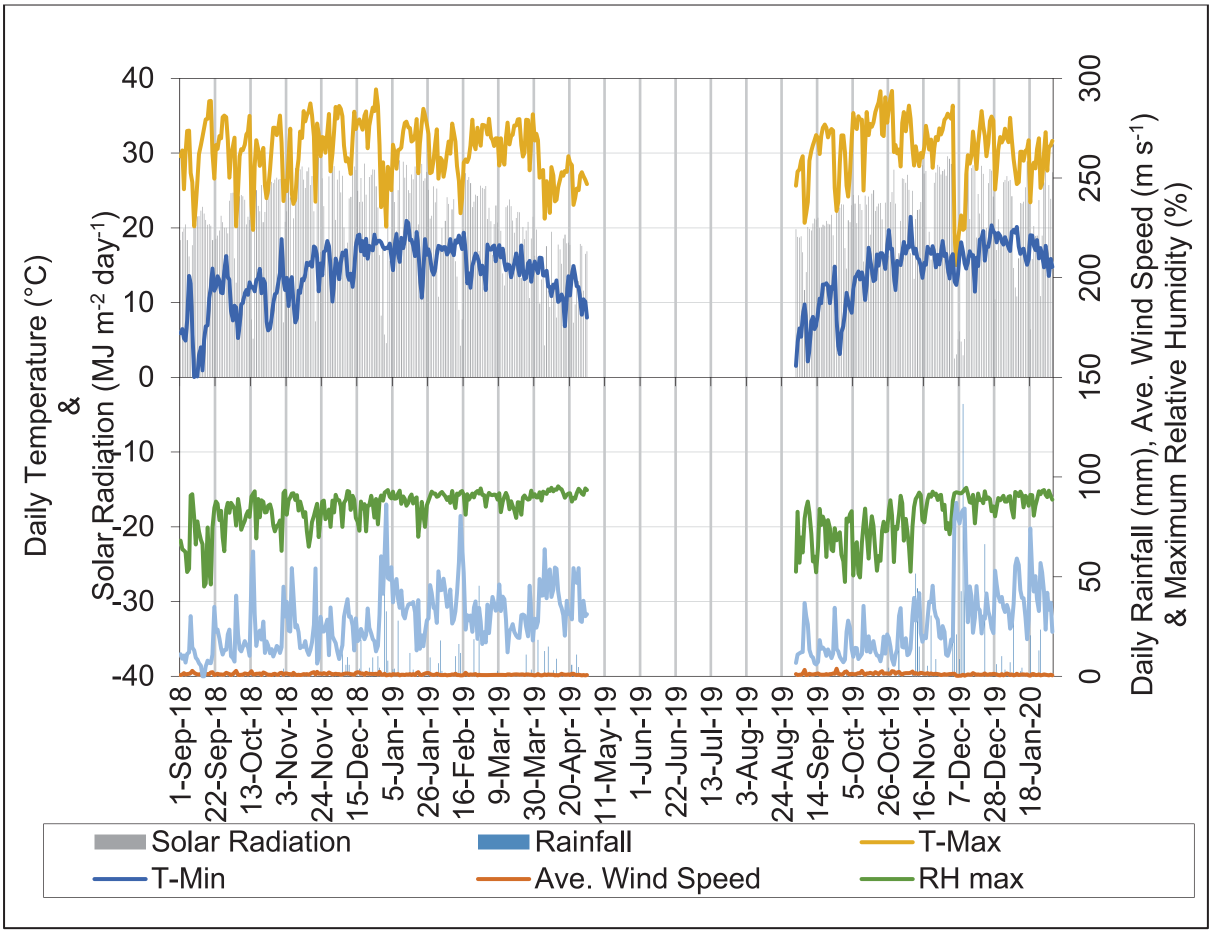


Figure 4-19: Weather variability during the 2018/19 and 2019/20 summer seasons at the study sites.

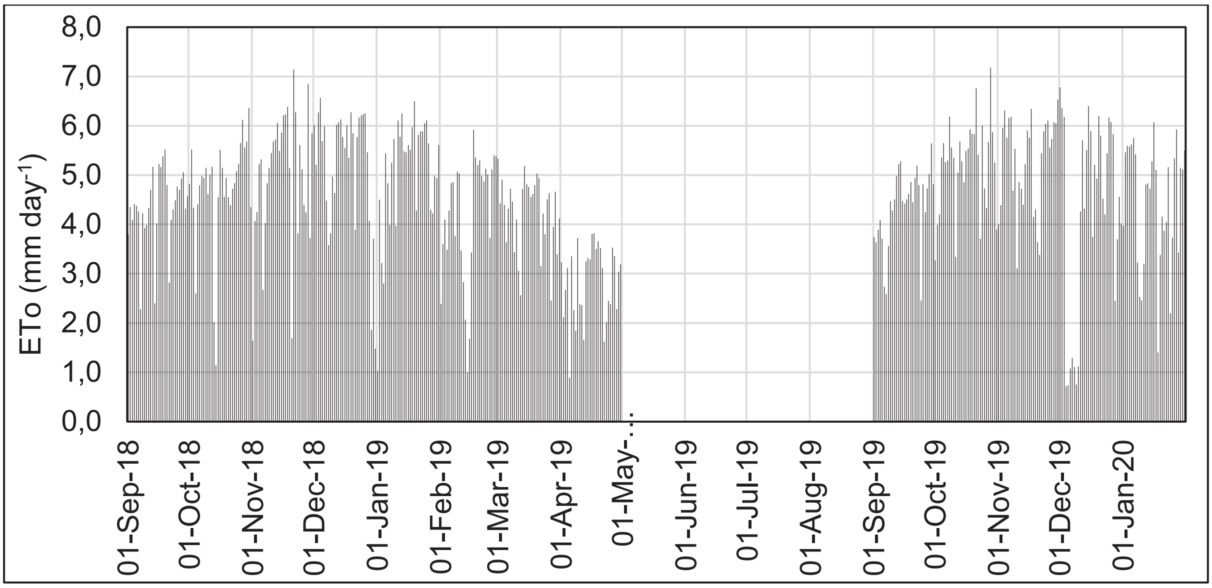


Figure 4-20: Daily reference evapotranspiration (ET_o) fluctuations during the 2018/19 and 2019/20 summer seasons at the study sites.

4.3.2.2 Runoff collection

The amount of runoff collected using the rooftop rainwater harvesting technique was monitored during the 2019/20 experimental season (Figure 4.21). The total amount of runoff collected from the planting date (25 October 2019) to the second harvest date (8 January 2020) was 74 131 litres, which is equivalent to 224 mm, considering an average runoff efficiency of 72% across the various rainfall events and a metal roof surface area of 330 m^2. A sample of the runoff water collected was kept and sent for laboratory analysis in February 2020, to assess water quality parameters such as pH, total hardness and aluminium concentration.

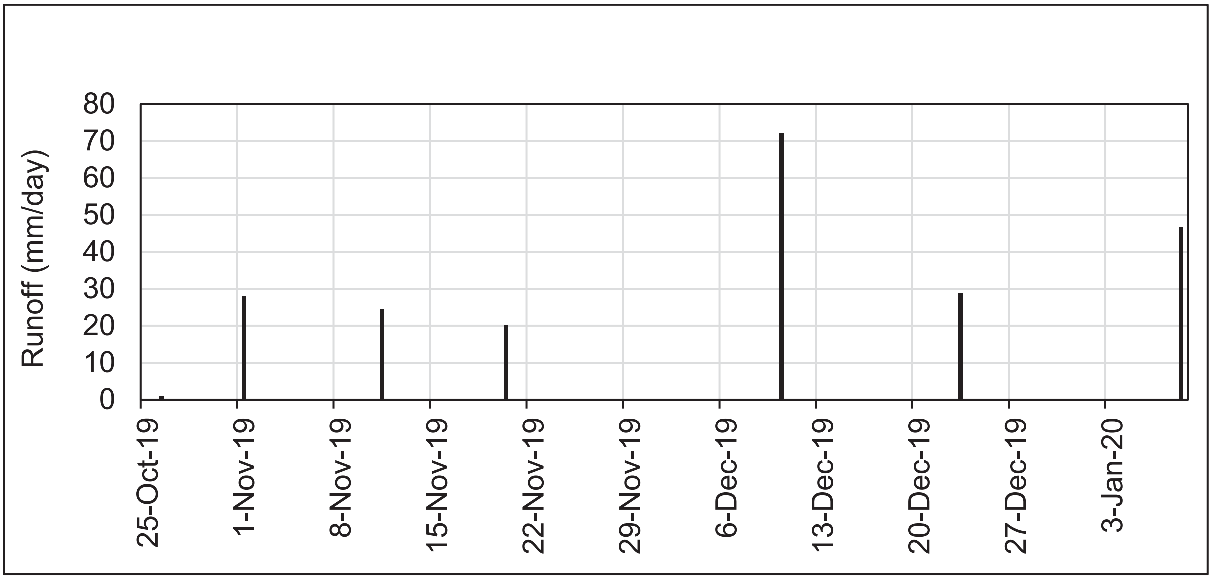


Figure 4-21: Daily runoff fluctuations during the 2019/20 summer growing season at Bula Dikgoro Primary School.

4.3.2.3 Irrigation applications

Irrigation or fertigation applications in both bag (soilless substrate) and conventional flat cultivation (soil substrate) systems were monitored and recorded during the rooftop rainwater harvesting trial. The bag system was irrigated using four spaghetti tubes per bag, each with a delivery rate of 50 ml min^{-1}, giving a total of 200 ml min^{-1}. In the bag system, irrigation was applied every day, 6 cycles per day, 2 to 4 minutes per cycle depending planting density within the bag. The conventional flat cultivation system, on the other hand, was typically irrigated every second day, 15 to 30 minutes per irrigation event depending on planting density of each research treatment (Table 4.4). The bag system resulted in irrigation water savings since each bag containing 24 to 48 plants was irrigated with approximately 2 to 5 litres of water per day, giving a total of 7 litres of water per plant from the planting date (25 October) to the second harvest (8 January). Whereas, for the conventional flat cultivation, total irrigation water applied per plant was on average 60% higher (12 L per plant) when compared to the application on the bag system.

Table 4-4: Irrigation/fertigation scheduling on the bag and conventional flat cultivation systems planted with Swiss chard.

System	Frequencies	Number of plants	Harvest	Discharge (L/day)
Bag	6 cycles/2-4 min/200 ml per min	24-48	1	2.4-4.8
Conventional	every second day/15-30 min/0.9 L per hr	1		0.23-0.45
Bag	5 cycles/2-4 min/200 ml per min	24-48	2	2.4-4.0
Conventional	every second day/10-20 min/0.9 L per hr	1		0.15-0.30

4.3.2.4 Changes in substrate water content

Hourly changes in substrate water content were monitored in both bag (soilless substrate) and conventional flat cultivation (soil substrate) using Decagon automatic sensors. Sensors were installed in various positions along with the bag and different planting densities in both systems (Figure 4.22). Substrate water content was generally higher in the conventional flat cultivation system, which is attributed to higher water holding capacity and retention of the soil used as the substrate for crop production. It was observed that, under conventional flat cultivation, treatments with higher population density had lower water content in comparing to the opposite treatment, which is due to higher crop water use. Concerning the bag system, as expected growing media on top of the bag dries out faster in comparison to the bottom part. Besides, water moves at a faster rate from the top to the bottom of the bag where it remains steadily unchangeable. This might have somewhat affected the crop's ability to uptake water for transpiration and photosynthesis.

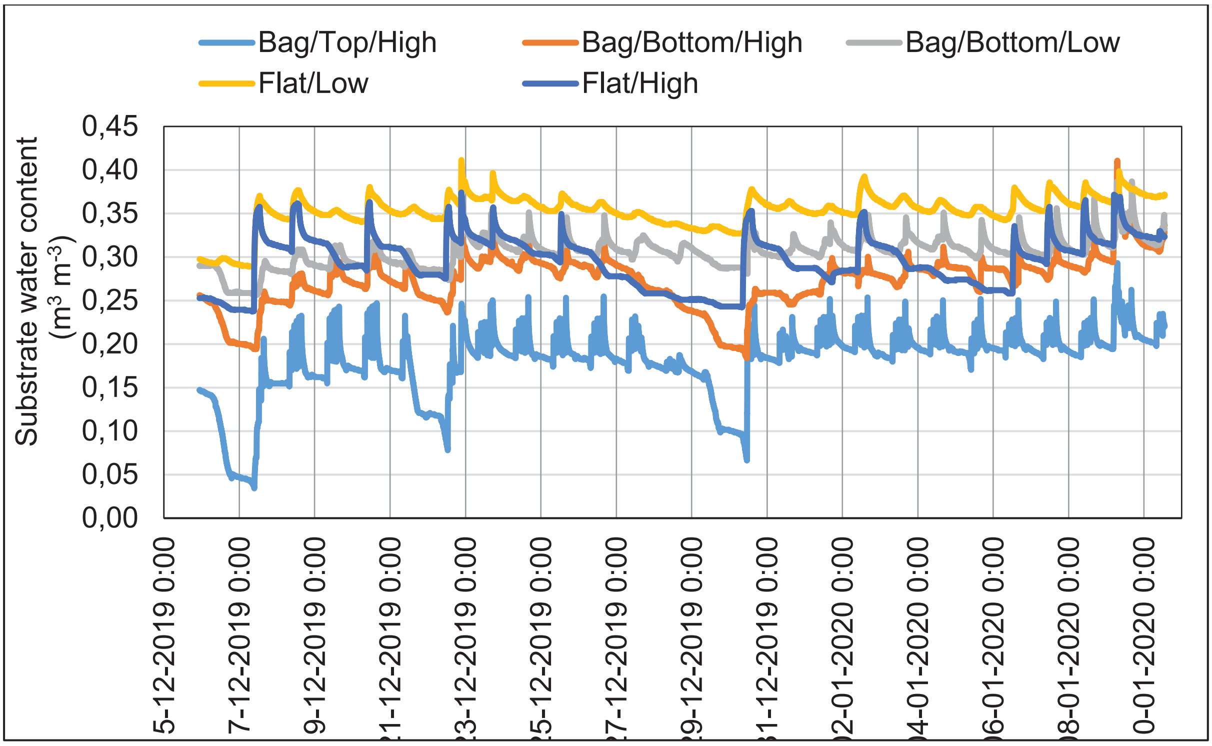


Figure 4-22: Daily runoff fluctuations during the 2019/20 summer growing season at Bula Dikgoro Primary School.

4.3.2.5 Fresh harvestable yield

Field rainwater harvesting and conservation techniques

Experimental results obtained during the 2018/19 summer rainfall season for the various field rainwater harvesting techniques tested for dryland production of Swiss chard (in-situ and in-field with and without mulching application, compared to the conventional flat cultivation), showed considerably higher yields under the in-field with mulching application (5.2-8.0 ton ha^{-1}), followed by the in-situ with mulching application (2.9-4.1 ton ha^{-1}) as compared to the conventional flat cultivation without the application of mulching (1.2-1.5 ton ha^{-1}) (Table 4.5). The benefits of applying mulching were evident, as it helps with soil water conservation through reduction of soil evaporation, runoff and drainage, which leads to improved soil structure and soil fertility. The implementation of the in-field rainwater harvesting technique resulted in the highest fresh harvestable yield since an additional rainfall amount is collected through the catchment area, which contributes to increased soil water content and plant available water for crop production. It is important to note that, the Swiss chard yield presented in Table 4.5 was obtained under dryland conditions, without any fertilization application, which is the main reason explaining yield differences when compared to irrigated open-field production.

Table 4-5: Swiss chard fresh harvestable yield under various field rainwater harvesting and conservation techniques at Bula Dikgoro Primary School.

Technique	Swiss chard fresh harvestable yield	
	Harvest 1 (t ha^{-1})	Harvest 2 (t ha^{-1})
In-situ + mulching	2.9	4.1
In-situ without mulching	2.1	3.2
In-field + mulching	5.2	8.0
In-field without mulching	4.0	6.5
Flat cultivation + mulching	2.0	4.0
Flat cultivation without mulching	1.2	1.5

Rooftop rainwater harvesting technique

The rooftop rainwater harvesting technique was implemented as a supplementary irrigation strategy on Swiss chard cultivated using two different production systems (bag and conventional flat cultivation). As evident in Figure 4.23, the highest fresh harvestable yield per plant was obtained under low planting densities in both conventional flat cultivation (45F30 = 277 g $plant^{-1}$) and bag (5B24 = 245 g $plant^{-1}$) systems. Although the conventional system over-performed the bag system, the difference in yield per plant was not significant. Higher yields per plant under the conventional system may be the result of increased planting densities within the bag system, which resulted in higher plant competition for solar radiation, water and nutrients. In addition, the type of sawdust particle size distribution may have had an influence on water movement and distribution within the bag (sawdust water content was much higher at the bottom of the bag when compared to the top). Nevertheless, fresh harvestable yield per m^2 of land utilized for crop production showed opposite results (Figure 4.24). The yields per m^2 under the bag system were generally significantly higher than those obtained with the conventional system, which is mainly attributed to higher planting densities within the bag system.

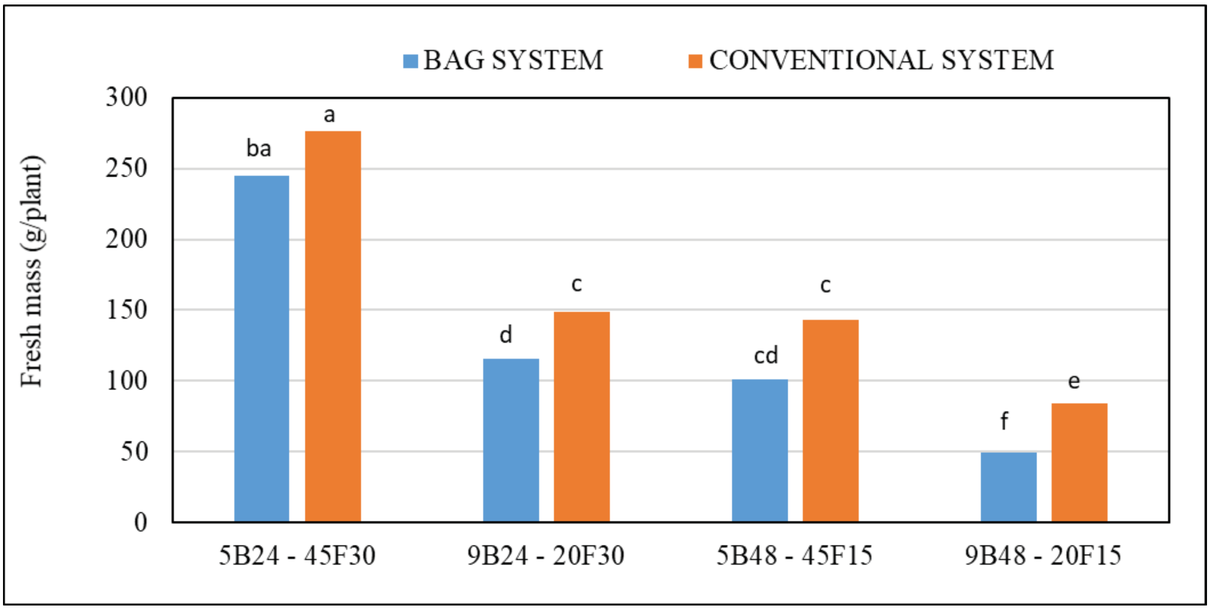


Figure 4-23: Total fresh harvestable yield of Swiss chard (3 harvests) per plant cultivated under various planting densities with the bag (5 or 9 bags per 2.6 m x 2.6 m plot, with 24 or 48 plants per bag) and conventional system (spacing of 20 or 45 cm between rows and 15 or 30 cm between plants) at Bula Dikgoro Primary School.

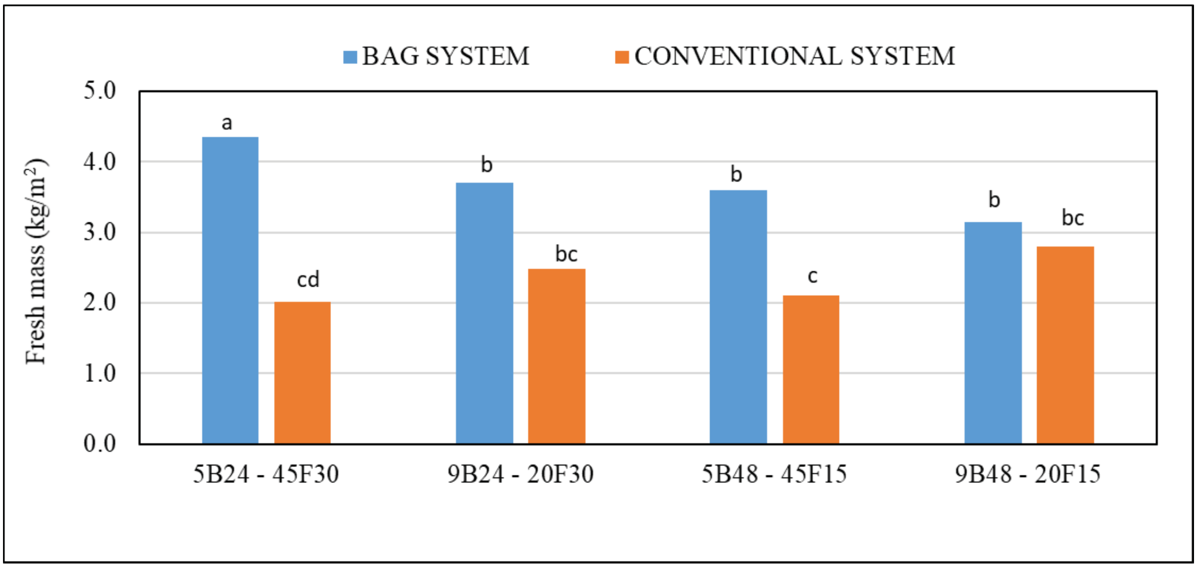


Figure 4-24: Total fresh harvestable yield of Swiss chard (3 harvests) per m^2 cultivated under various planting densities with the bag (5 or 9 bags per 2.6 m x 2.6 m plot, with 24 or 48 plants per bag) and conventional system (spacing of 20 or 45 cm between rows and 15 or 30 cm between plants) at Bula Dikgoro Primary School.

4.3.2.6 Crop water use efficiency

Swiss chard water use efficiency was considerably higher under the bag system (81.2-91.1 kg m^{-3}) when compared to the conventional system (6.3-8.5 kg m^{-3}), as shown in Table 4.6. This is the result of higher crop yields and lower crop water use with the bag system when compared to the conventional system. The bag system with vertical cultivation is capable of holding higher planting densities per unit of land utilized for crop production, which allows for more effective utilization of rainfall and irrigation water applied as compared to the conventional system with horizontal cultivation. This study provides the first time assessment on the performance of a bag system in comparison to the conventional cultivation system. However, further studies on the economic viability of implementing a bag system need to be conducted. Aspects such as the life span of a polypropylene bag, fertilizer usage, electricity for pumping irrigation water need to be taken into consideration when assessing the economic viability of implementing the bag system.

Table 4-6: Seasonal fresh harvestable yield, crop water use and water use efficiency of Swiss chard cultivated using the rooftop rainwater harvesting technique under two different production systems.

Parameters	Bag system				Conventional system			
	5B24	**5B48**	**9B24**	**9B48**	**20F15**	**20F30**	**45F15**	**45F30**
Crop yield (kg/ha)	43491.1	35858.0	37065.1	31313.6	27958.6	24686.4	21153.8	20473.4
Crop water use (mm)	47.7	41.8	41.0	38.56	330.8	330.0	324.2	323.8
Water use efficiency (kg/m^3)	91.1	85.8	90.4	81.2	8.5	7.5	6.5	6.3

4.3.3. Potential of school gardens to meet learners feeding needs

Fresh harvestable leaves of Swiss chard were harvested from the various production techniques tested and supplied to the school kitchen for feeding of learners. On average, each learner was served a portion of the cooked vegetable equivalent to 67 g of fresh harvestable yield per day of the cooked vegetable, together with pap and soup or milk and rice per meal per day. The biomass produced was highly variable, depending on the type of production technique used. For example, if the schools opt to produce leafy vegetables (example of Swiss chard) under dryland conventional flat cultivation without any soil water conservation practice, the schools will require 354.6-584.3 m^2 vegetable garden sizes to feed 1182-1753 learners. But, if the school invests on a climate-smart production practice, such as the bag system, the total garden area required will be much smaller (a maximum of 35.6 m^2) to feed the same number of learners, due to increased crop yields and reduced risk of crop failure with the latter system. According to the USDA National Nutrient Database, a portion of 67 g of fresh Swiss chard leaves contains 1.25 g protein, which is 95% of the protein requirement per kg of food intake per day in school-age children (Elango et al. 2011). However, considering learners' consumption needs for the whole growing period of vegetables (90 days on average), a total garden size of 1080 m^2 would be required using a vertical climate-smart production system and taking into account that multiple harvests would be done throughout the growing period.

Table 4-7: Potential of school gardens to meet learners feeding programmes.

Parameter	Study site							
	Bula Dikgoro Primary School				Mahlasedi Masana Primary School			
	Swiss chard cultivated using various techniques				Swiss chard cultivated using various techniques			
	Conventional dryland	Conventional irrigated	Field RWH	Bag system	Conventional dryland	Conventional irrigated	Field RWH	Bag system
Plot size (m^2)	12							
Fresh harvestable yield (kg)	2.7	33.6	13.4	52.83	2.4	26.12	11.6	38.45
Number of learners fed at a time	40	501	200	787	36	402	173	592
Total Number of learners in each school	1182				1753			
Total fresh harvestable yield required at a time (kg)	79.3				114.0			
Total land area required in the garden (m^2)	354.6	28.3	70.9	18.0	584.3	52.4	121.6	35.6

4.4 Conclusions and recommendations

School-based vegetable gardens were successfully set-up and implemented during winter and summer growing seasons in two public primary schools in Mamelodi East, South Africa. Several production techniques were tested, including in-situ, in-field and rooftop rainwater harvesting, as well as bag and veggie tunnel systems. Rooftop rainwater harvesting showed the highest potential to mitigate the effects of climate change for increased crop productivity, as the amount of rainwater collected can be stored in tanks for supplementary irrigation of crops at critical periods of the crop growing season, or in the event of prolonged dry spells. The metal roof tested at the study schools had an average runoff collection efficiency of 72%, which indicates a potential for the collection of at least 95 00 litres of water during a normal rainfall season, with a total rainfall of 400 mm during the growing season and a roof catchment area of at least 330 m^2. The potential amount of rainfall collected through the rooftop rainwater harvesting technique is, however, dependent on the availability of water storage tanks at the schools. Thus, it is recommended that schools invest in water storage infrastructure, including equipping the roofs with gutters for runoff diversion and collection. The research team suggests that water quality analysis be conducted to assess whether the rainwater harvested through metal rooftop catchments can safely be used for crop productivity or domestic use at the schools. The adoption of a climate-smart production system is also critical, as this can be implemented in combination with rooftop rainwater harvesting for maximum crop productivity and reduced risk of crop failure. Thus, this study recommends the implementation of a bag system, due to its capability of cultivating a considerably higher number of plants per unit of land/area utilized for crop production. The implementation of a bag system resulted in increased crop yield per m^2 of land utilized and reduced crop water consumption per plant, which resulted in higher crop water use efficiency. The amount of irrigation water used per m^2 of the produce was also considerably lower with the bag system. However, it is recommended that economic viability studies be conducted to assess the cost-benefit ratio with the implementation of the bag system. The research team also recommends the introduction of protected crop production practices, such as the implementation of a bag system under shade nets.

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CHAPTER FIVE
STAKEHOLDER ENGAGEMENT AND TRAINING ON VEGETABLE PRODUCTION

5.1 Introduction

Stakeholder engagement is an essential component for sustainability and independency of school gardens. The commitment should involve the participation of teachers, learners, school governing body, funders, government organization, ministry of education, department of agriculture, etc. to ensure the programmes are implemented as national priorities (FAO, 2019). Political commitment plays a strategic role in the success of a school garden as well. It forms the basis from which national strategies can be influenced, programmes can be designed, and budgets can be aligned. School gardens can have several interrelated objectives at the school, community and country levels. Engagement of the community members in which the school is located, e.g. through parent-teacher associations (PTAs), in the development and management of the school garden, including the provision of local expertise and advice, land and voluntary labour is essential for successful implementation of school gardens (Food and Agriculture Organization, 2004). A component of the training of educators and garden personnel, provision of gardening equipment and technical advice, as well as support by government and various role players for their increased effectiveness as a nutrition-learning tool (Laurie et al., 2017). Successful school-based physical activity and nutrition intervention necessitates the involvement of parents and other community members (Pérez-Rodrigo and Aranceta, 2003).

School gardens can contribute significantly to increasing the relevance and quality of nutrition education in schools while improving society's knowledge of food production techniques and nutritional benefits and motivate the development of home gardens as well (Food and Agriculture Organization, 2004). The community can benefit through nutrition education – school gardens have a positive impact on nutrition understanding and provide a practical learning environment. Communities can be empowerment through training, especially for women, who have greater control of food provision in the families. They can create social cohesion through the establishment of social networks and motivation for community development and reduction in social alienation and family disintegration (Jowell, 2011). Lack of community support and integration into the curriculum – leads to a lack of sustainability school gardens (Food and Agriculture Organisation, 2007). Laurie et al. (2017) mentioned some challenges of establishing and sustaining a school garden as lack or insufficient knowledge skill to manage the garden, lack of resources, lack of support from school governing body (SGB) and parents, failure to link school gardens to the core- or extra-curriculum activities. In order to increase the success of school-based vegetable gardens, involvement of different stakeholders including training of teachers, school canteen cooks and volunteers from within the community in the planning and management of school gardens and their use for teaching and school feeding, as well as the preparation of practical training guidelines is essential. To minimize these risks, the team mobilized stakeholders who would be engaged in the gardens to provide an accredited training course by the Agriculture Sector Education Training Authority (AgriSETA), module “Plant the crop under supervision 116200”.

5.2 Methodology

The school gardening committee and community members were requested to attend the AgriSETA accredited training on vegetable production offered by the ARC team to learn basic gardening practices (planting, fertilization, watering, harvesting, storage, and nutritional values), gardening and irrigation management at their respective schools. Fourteen school beneficiaries participated in the training. Participants also included children, parents, and volunteer workers. The training was carried out between 19 and 22 November 2018 (Table 5.1) at Bula Dikgoro Primary School, Mamelodi (Figure 5.1). The training also included a basic understanding of vegetables and health, growing of a range of crops including sweet potato, potatoes, indigenous crops, cowpea, onions, carrots, butternut, spinach, tomatoes, pumpkin and squash. The training included a practical demonstration in the afternoon after each theory

Table 5-1: Vegetable Production Training program for the schools (19-22 November 2018).

DAY 1			
TIME	**ACTIVITY**	**PURPOSE**	**PRESENTER**
8:00-8:30	*Opening & Welcome*	*Opening Remarks*	*ARC*
8:30-09:00	*Induction*	*Course Overview & Orientation*	*Facilitator Lerato*
09:00-10:30		• *Course expectation & Ground rules* • *Course outcomes*	*Facilitator: Ngwanamalekana Mamadi*
10:30-11:00	*COFFEE/TEA*		
11:00-12:00	*Session 1 : US 116200 Tools*	• *Use and care for the tools and equipment in the planting of a specific crop.* *Group Activity Worksheet: Garden tools activity*	*Facilitator: Ngwanamalekana Mamadi*
12:00-13:30	*Session 2 : US 116200 Theoretical Presentation Planting Crop*	• *Prepare planting area* • *Planting specific crop*	*Facilitator: Ngwanamalekana Mamadi*
13:30-14:30	*LUNCH*		
14:30-15:30	*Session 2: Continue…..*	• *Handling Planting Materials* • *For planting different planting materials (seed, seedlings, cuttings and tubers*	*Facilitator: Ngwanamalekana Mamadi*
15:30-16:30	*Session 3: Theoretical Presentation Planting Crop*	• *Care of Planting material* • *Watering of the planting materials*	*Facilitator: Ngwanamalekana Mamadi*

Day 2			
08:30-09:30	*Theoretical Presentation Planting Crop*	• *The use of the back of the seed packet*	*Facilitator: Alfred Tema*
09:30-10:30	*Practical Demonstration*	• *Prepare planting area* • *Planting specific crop* • *Handling Planting Materials*	*Alfred Tema, Neo Malahlela, Ngwanamalekana & Lerato Sebego*
10:30-11:00	**COFFEE/TEA**		
11:00-13:30	*Practical Demonstration*	• *Growing Nutritious Leafy Vegetables in an old maize bag*	*Afred Tema*
13:30-14:30	**LUNCH**		
	Session 4:Theoretical Presentation Planting Crop	• *Describe the basic effects of the environment on specific crops*	*Ngwanamalekana Mamadi*
Day 3			
08:30-10:30	*Practical Observation*	*Observation checklist*	*Neo Malahlela & Lerato Sebego*
10:30-11:00	*COFFEE/TEA*		
11:00-13:00	*Test Based Assessment US116200*	*Administration of the Test Based Assessment*	*Neo Malahlela, Ngwanamalekana & Afred Tema*
13:00-14:00	*LUNCH*		
14:00-15:00	*Theoretical Presentation*	• *Crop Rotation* • *Planting Programme*	*Afred Tema*
15:00-16:00	*Completion of PoE*	*Learners PoE*	*Lerato & Neo*
16:00-16:30	*Evaluation of the course*	*Completion of the course evaluation forms*	*Lerato Sebego*
16:30	*Vote of Thanks and Closure*		*Neo Malahlela*

Figure 5-1: School gardening team during the training in November 2018.

5.3 Results and discussion

5.3.1 Stakeholder engagement

Stakeholder meeting (school principals, teachers, volunteer workers, school garden beneficiaries and ARC) were held at the schools on the 7th of November 2018 to discuss progress and way forward of the project. The meeting discussed project objectives, purpose, scope, risks and approach to be followed. The school beneficiaries/members understood and agreed to the project implementation. It was made clear to the members that the objective of the project was to produce vegetables for supply to the school in order to improve the feeding scheme programme. It was made clear to the members from the beginning that they will be no payment of any monetary incentive that they will receive from the project, except if they have harvested enough vegetables to supply the school and their consumption, and if there is any surplus remaining it could then be sold to generate income. Since the inception of the project, two members left the project due to other personal domestic commitment and only four members were left to maintain the gardens at each study school. Regardless of the challenge they faced, they were able to get a good harvest for the seasons. Project members expressed their gratitude for the implementation of school-based gardens, even though there were challenges encountered. This included their appreciation towards the team and funder for the support and help with the supply of production inputs such as seedlings, fertilisers and protective clothing. The stakeholder engagement meeting emphasised the importance of communication between all stakeholders involved. It was encouraged that stakeholders (project members, ARC, and the schools) need to work together, alert and participation another when issues and challenges are arising so that they could together engage and discuss for possible solutions. In several instances, ARC worked together with community garden members during the implementation of various gardening activities to strengthen relationships, increase trust and demonstrate exemplary behaviour and attitude. This also helped increase confidence across the project environment, minimise uncertainty, and speed problem solving and decision-making.

5.3.2 Contents of vegetable production training

Throughout the winter and summer growing seasons, crop management and garden planning were offered to the school garden committee to ensure sustainable growth of the crops. The training was continuous on basic gardening practices such as seedbed preparation (low-tech seedling production), direct seeding planting, inorganic and organic fertilizer application, irrigation application, nutritional values, gardening and irrigation management at their respective schools. School garden beneficiaries were also taught on how to produce vegetables using climate-smart production techniques to minimize the risk of crop failure due to shortage of water supply or increased atmospheric evaporative demand.

5.3.2.1 Fertilizer applications

School gardening teams at both study schools have received training on types and application methods of fertilizers. Figure 5.2 shows school garden beneficiaries applying organic fertilizers. The training included both organic and inorganic fertilizers, application methods (split application, top dressing, side dressing, broadcasting, foliar application and pre-plant application). In addition, the advantages and disadvantages of each application method were also explained. The ARC staff also revealed the long-term plan for the schools, which was to introduce low input conservation agriculture practices such as no-till and use of locally available inputs (manure and compost) to improve vegetable production sustainability at the schools.

Figure 5-2: School gardening beneficiaries during fertilizer application training.

5.3.2.2 Seedling production

The production of quality seedlings is essential to improve yield and nutritional quality of vegetables. Therefore, practical training was given to the participants on low-tech seedling production, which involves selecting a shielding area in the garden with easy access to water supply to protect the plants from harsh environmental conditions, raise a bed of approximately 30 cm in height to avoid waterlogging by improving drainage, regular manual weed control, application of locally available organic manure or compost and mulching to reduce soil evaporation losses. Figure 5.3 shows the different participants during the training session.

Figure 5-3: School gardening beneficiaries during seedling preparation training.

5.3.2.3 Soil available water for crop production

Practices to improve soil available water for crop production such as irrigation system maintenance and scheduling were taught to school gardening beneficiaries to increase the garden crop productivity. The implementation of adequate water management practices was encouraged for both irrigated and dryland crop production. The training included practices such as deficit irrigation and rainwater harvesting, which are particularly important in dry countries like South Africa, where the available rainfall is in general not sufficient to meet crop water requirements. The advantage of using a drip irrigation system; appropriate time of irrigation (morning and late afternoon); the use of organic mulching, collection of rainwater through rooftops were presented. Training on irrigation installation and management was therefore offered to participants. This included diagnose of essential irrigation problems, maintenance of drip irrigation system, vegetable watering frequencies and amounts for different soil types and weather conditions (for example, the use of high watering frequencies in sandy soils versus the opposite in clay soils, high irrigation amounts during hot, sunny days versus the opposite in cold, cloudy days) (Figure 5.4).

Figure 5-4: On-site training of irrigation system maintenance and scheduling at the selected study schools.

5.4 Conclusions and recommendation

The stakeholder engagement at the selected study schools involved a component of the training of educators and garden personnel, provision of gardening equipment and technical advice. Stakeholder engagement involved (school principals, teachers, volunteer workers, school garden beneficiaries and ARC) in both study schools. The ARC expressed appreciation for their participation and contribution and gathered relevant inputs from stakeholders on engagement experience to evaluate the process. The learning lessons were applied to community members during the implementation of various gardening activities. This resulted in increased enthusiasm and commitment by project members to continue with project activities, regardless of the challenges encountered. Project members became aware and clear of the project objectives, which encouraged willingness and motivation to stay in the project. They also became mindful that the vegetables produced would be shared with the school feeding programme, and in the event of a surplus, it could be sold to generate income to the schools and for themselves. The research team recommends that governmental entities be included in stakeholder engagement sessions to facilitate policy-making decisions and school garden support initiatives.

The AgriSETA accredited vegetable production training provided to school gardening beneficiaries was able to capacitate the community members on production of seedlings at the schools, improved water use efficiency practices, fertilizer management, effective weed control, pest and disease management and increased water supply for irrigation through the rooftop rainwater collection. The team believes that the implementation of Stakeholder engagement and stakeholder management sessions is essential to ensure successful project delivery and sustainability post project completion.

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CHAPTER SIX
TESTING OF A SCHOOL-BASED VEGETABLE GARDEN PILOT CONCEPT

6.1 Introduction

School-based vegetable gardens can have a positive impact on learners' health, education and awareness of the physical environment (FAO, 2019). The extent to which school garden programmes are successfully implemented plays a critical role in the rate at which poverty and widespread malnutrition can be reduced. Several school nutrition programmes have been introduced in South Africa to improve learners' performance by providing nutritious meals through the cultivation of vegetable gardens (Moletsane, 2016). Several school food garden projects have been successfully implemented across various provinces of South Africa (Mongwa, 2005; Tundzi, 2008; Laurie et al., 2013; Moletsane, 2016).

A school garden is an innovative teaching tool and strategy that incorporates hands-on activities into classroom-based lessons by providing a dynamic environment in which learners observe, discover, experiment, nurture, harvest, learn and often consume produce grown in the schoolyard. These programs may promote academic achievement, vegetable consumption, physical activity and positive youth development (Graham et al., 2005). Thus, school gardens can further be used as a vehicle to spread knowledge of food production and a link with nutrition (Laurie et al., 2017). The extent to which school gardening programs are successfully implemented plays a critical role in the rate at which poverty and widespread malnutrition can be reduced. Although several school nutrition programs have been successfully introduced in South Africa to improve learners performance, only a few of these interventions have involved setting-up school-based vegetable gardens on-site with school beneficiaries involved, which is essential to ensure sustainable access and supply of vegetables to school feeding schemes. Therefore, this project aimed to develop and test a pilot concept of school-based vegetable gardens with school beneficiaries involvement for sustainable increase of access and consumption of vegetables at schools.

6.2 Methodology

The first step in the implementation of a sustainable school-based vegetable garden was to conduct a situational analysis of the selected study schools and targeted beneficiary characteristics to assess crop selection suitability and identify potential nutritional needs in the learner's diets. Secondly, the research team conducted an assessment and identification of input needs for the establishment of the school gardens, as these are essential for improved yields and nutritional value of crops. The input needs included fertilizers, seeds, chemicals, protective clothing, etc. per season, irrigating systems and gardening tool kits. Vegetable gardens were subsequently established in both summer and winter growing seasons in both study schools. Crop selection and production techniques tested were primarily determined by the site characteristics and beneficiary's priority needs. The supply of production inputs followed this. Before the establishment of vegetable gardens, there was a need to do land preparation and clearing, using mechanical and manual operations. Subsequently, the research team conducted stakeholder engagement/mobilization, followed by basic gardening training involving various beneficiaries (school principals, teachers, volunteer workers, school garden beneficiaries and ARC). This was crucial to achieve project outcomes successfully and to ensure sustainable implementation of the school gardens post project completion. During such sessions, the research team shared with the participants the garden program goals, benefits of a school garden and basic principles of its implementation. These engagement sessions helped promote the integration of community members, parents and voluntaries, which were essential to save the cost of gardening operations and introduce the concept of compensation after each harvest of vegetables to ensure the continuation of gardening activities without the inclusion of monetary payment.

6.3 Results and discussion

6.3.1 Social benefits of implementing school-based vegetable gardens

The implemented school-based vegetable gardens addressed food security and malnutrition issues of targeted beneficiaries connected to the selected study schools through a crop-based research approach. This included the development and testing of appropriate production systems and technologies to be used in such interventions for improved crop productivity. The surplus of vegetable production could be sold in local markets to generate income.

The school gardens produced nutrient-rich food through the implementation of vegetable gardens at the community level. There was a strong focus on addressing vitamin A, Zn and Fe deficiencies, as the crop-based research approach is an effective method to address such types of malnutrition (Underwood, 2000; Faber & Van Jaarsveld, 2007), which are amongst those of public health significance in South Africa (Labadarios et al., 2007).

The school gardens created a connection between school learners, community and nature, which resulted in a positive impact towards the children's health, their growth and development, as well as their opportunities over time, by preserving a healthy society. The gardens played an important role in influencing the mindset of learners from an early age, which could have an impact on community's habits regarding healthful nutrition and production of their food since the young ones have a significant influence in their families. In addition to improving children’s health and education, schools and beneficiaries can even generate income by selling the extra produce, which minimizes the school's dependency on government funds and the National School Nutrition Programme.

The project demonstrated and implemented an integrated and comprehensive nutrition intervention model at the selected study schools, with great potential to enhance highly nutritious vegetable accessibility to children, while educating the learners and teachers about healthy living and wellness. The school gardens offered many occasions for achieving insight into the long-term human impact on the natural environment, including protection of soil and water resources by reducing nutrient leaching, runoff and soil evaporation, as well as proper nutrient and irrigation management. Learners at the selected study schools had first-hand opportunities to observe the importance of land preparation, conservation, efficient allocation of natural resources (Figure 6.1) and were fascinated with the soilless growing of vegetables such as the bag system.

Figure 6-5: Involvement of school principal and children during gardening activities at the study schools.

The implemented school gardens promoted women’s empowerment as well. A total of six women were involved in the project from both schools, and they were hands-on on the project. Positive changes in the accessibility of vegetables to the school feeding programme were observed over the two years of the project intervention, particularly with women’s intervention in the gardening activities. The involved women were capacitated with AgriSETA accredited vegetable production training to ensure the sustainability of the school gardens, which generated knowledge and skills on how to improve crop water use efficiency, seedling preparation, fertilizer applications and pest and disease management on a wide range of vegetable crops. The project provided the schools with irrigation systems, water storage tanks, gutters for rooftop rainwater harvesting, irrigation pumps and agricultural tools. At the end of the project implementation, the school committee members and learners could grow vegetable crops using climate-smart production techniques. The project has also created an excellent linkage between the school principals, the gardening committee members, ARC and WRC.

6.3.2 Development of school-based vegetable garden production input guidelines

Inputs for the production of selected vegetables were developed and shared with the school beneficiaries (Table 6.1). Fertilizer recommendations were determined based on target crop yields.

Table 6-2: Production inputs for selected vegetables in school gardens

Production inputs for selected vegetables in school gardens
Sweet potato plant population and number of cuttings required Plant density = 0.30 m x 1.0 m = 0.96 m^{-2} Plant population = 10 000 m^2/ 0.30 m^{-2} 33 333 plants ha^{-1} N° of sweet potato cuttings = 33 333 plants ha^{-1} **Quantity of seed required for the garden per season per school** Squash butternut :WALTHAM 1 kg Swiss chard: Ford hook Giant 1 kg Cowpea: Black eyed 1 kg
Land preparation operations
Ploughing, Discing and Ridging
Fertilization N:P:K with a target yield of 30 t ha^{-1} for selected leafy vegetable (Swiss chard, Kale, Cowpea) and 80 t ha^{-1} target yield for sweet potato
150 kg N ha^{-1}; LAN (28%) 150 X 100/28% = 536 kg of LAN ha^{-1} = 11 bags (50 kg) of LAN (28%)
40 kg P ha^{-1} Superphosphate (12.5% P) will be applied a month prior to planting 40X100/12.5% = 320 kg of Superphosphate ha^{-1} 320 kg of P ha^{-1} / 50 kg = 7 bags of superphosphate (12.5% P)
30 kg K ha^{-1} Potassium chloride (50% K) will be applied a month prior planting 30X100/50% = 60 kg of K kg of Potassium chloride ha^{-1} 60 kg of k ha^{-1} / 50 kg = 2 bags of Potassium Chloride (50% K)
40% of N will be applied at pre-planting
20% of N will be applied as top-dressing every three weeks
Labour
Four people will be required for planting, weeding, trial/site management and harvesting for an average garden size of 0.25 ha Protective clothing should be provided
Irrigation system (Using non-pressure regulated drip irrigation wetting radius of 360°)

Production inputs for selected vegetables in school gardens
Irrigation scheduling: meteorological weather data from the nearest weather station could be used in combination with crop coefficients to generate irrigation scheduling calendars.
Harvesting equipment
Pruning shears and forks

6.3.3 School-based vegetable gardens financial implications

A demonstration of school garden financial implications was done for different garden sizes as shown in Table 6.2. The initial investment cost in infrastructure requirements forms the most significant expense in the implementation of a school-based vegetable garden (R74 600-R204 770 for 0.25-1.00 ha garden sizes).

Table 6-3: School garden financial demonstration for different garden sizes.

Agricultural inputs required	0.25ha	0.5ha	1ha
	Amount (Rand)		
Capital cost (irrigation material and garden tools, once every 10 years)	74 600.00	124 310.00	204 770.00
Running cost per year (fertilizers, seeds, chemicals, electricity and protective clothing)	12 303.13	22 295.38	34 473.00
Total	**86 903.00**	**146 605.38**	**239 243.00**
VAT (15%)	13 035.45	21 990.81	35 886.45
Grand Total (incl. VAT)	**99 938.45**	**146 605.38**	**275 129.45**

6.4 Conclusions and recommendations

A school-based vegetable garden pilot project was successfully tested in two public primary schools in Mamelodi, South Africa. The implementation of the project demonstrated several social benefits on targeted beneficiaries, including improved knowledge and skills on vegetable production, increased access to highly nutritious vegetables, a potential source of income generation through the selling of the surplus in produce, women empowerment, learners positive attitudes towards conserving the natural resources and environment. The gardening infrastructure and vegetable production were enhanced through the installation of irrigation systems and rooftop rainwater harvesting equipment, provision of gardening tools and agricultural inputs. Schools representatives were trained on primary vegetable production, including planting, fertilizer application, irrigation installation and management, pre and post-harvest practices. The representatives were also trained on the essential health benefits of adding vegetables to their daily diets.

The team believes that schools teachers must be knowledgeable enough to teach the community and learners, and these, on the other hand, should be prepared to learn from them. Until this is achieved, the team recommends the school teachers to encourage children to report at home about their daily activities at school including the accessibility of vegetables in the school feeding programme, invite families to visit the school gardens and use this opportunity to give them seedlings of various vegetable crops to promote the implementation of household vegetable gardens.

Each school garden team can face challenges that are unique to the circumstances of its school community. The trained school garden team must remain committed throughout the growing season, irrespective of the challenges encountered. When the school staff leaves for school holidays, it is recommended that the chair of the garden committee delegates someone who can manage the garden following the guidance provided.

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CHAPTER SEVEN
GENERAL SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

7.1 General summary

A school garden is a teaching tool that incorporates hands-on activities into classroom-based lessons by providing a dynamic environment in which learners observe, discover, experiment, nurture and learn. The knowledge and skills gained by learners can potentially contribute to household food and nutrition security through the implementation of healthy eating and lifestyle habits. Thus, school gardens can further be used as a vehicle to spread knowledge of food production and a link with nutrition. The extent to which school garden programs are successfully implemented plays a critical role in the rate at which poverty and widespread malnutrition can be reduced. Several school nutrition programs have been introduced in South Africa to improve learners' performance by providing nutritious meals through the cultivation of vegetables.

Most successful school gardens have at least one paid employee to maintain them, particularly during school holidays. If schools have to fund garden activities, then there is a challenge of rightfully prioritizing educational needs before the garden needs. Without funding, there will be no dedicated school garden coordinator. Where there is poor or no voluntary participation of adults, it further leads to the overburdening of teachers, as they have to continue with teaching with an added responsibility of the garden. This challenge is exacerbated by the fact that teachers often have limited time for "extra" activities after teaching, pointing a need for adult participants. As a result, this project proposed a pilot school-based vegetable garden concept whereby gardening community members receive compensation through a surplus in crop production, which can be sold in local markets as a source of income generation.

From a resource point of view, lack of land can be another challenge for school gardens. This has an impact on the capacity of the school garden to produce enough for the learners. Coupled to that, a piece of land allocated to the garden can be changed to use for other projects such as building classes as this become a higher priority for education. In addition, a lack of water poses a serious challenge to the success of the garden. Where the schools have to pay for municipal water, which links to the funding of the garden, a decision may be to cut water supply to the garden to save on costs. Therefore, this project has identified and tested climate-smart agricultural practices for increased production of vegetables in school gardens under limited water resources.

Political commitment plays a strategic role in the success of a school garden. It forms the basis from which national strategies can be influenced, programmes can be designed, and budgets can be allocated. School gardens can have several interrelated objectives at the school, community and country levels. Engagement of the community members in which the school is located, e.g. through parent-teacher associations (PTAs), in the development and management of the school garden, including the provision of local expertise and advice, land and voluntary labour is important for successful implementation of school gardens. Successful school-based physical activity and nutrition intervention necessitates the involvement of parents and other community members. School gardens can contribute significantly to increasing the relevance and quality of nutrition education in schools while improving society's knowledge of food production techniques and nutritional benefits and motivate the development of home gardens as well. The community can benefit through nutrition education as school gardens have a positive impact on nutrition understanding and provide a practical learning environment. Communities can be empowered through training, especially for women, who have greater control of food provision in the families. They can create social cohesion through the establishment of social networks and motivation for community development and reduction in social alienation and family disintegration. Lack of community support and integration into the curriculum leads to a lack of sustainable school gardens. Some challenges of establishing and sustaining a school garden are mentioned as lack or insufficient knowledge and skill to manage the garden, lack of resources, lack of support from school governing body (SGB) and parents, failure to link school gardens to the core- or extra-curriculum activities. To increase the success of school-based vegetable gardens, the involvement of different stakeholders including teachers, school cafeteria cooks and volunteers from the community are needed for planning and management of school gardens and their use for teaching and school feeding, as well, the preparation of practical training guidelines is essential. This project has demonstrated social benefits on school beneficiaries by involving various stakeholders through engagement/mobilization sessions.

7.2 Conclusions

The school garden can create a connection between the school learners, community and nature which can have a positive impact towards the children's health, for their growth and development and their opportunities, over time, by contributing a healthy society. School garden activities influence the mindset of the learners from an early age with an impact on the community's habits regarding healthful nutrition and producing their food since the young ones have a significant influence on their families. In addition to improving children's health and education, schools can grow vegetables for income generation by selling the extra produce and also minimize the school from being dependent on government funds. The school garden can offer many occasions for achieving insight into the long-term human impact on the natural environment including the protection of soil and water resources by reducing nutrient leaching, proper nutrient and irrigation management, from the water shortage to the over-use of pesticides. Children who engage in gardening can have first-hand opportunities to observe the importance of conservation and intelligent allocation of resources.

The project successfully demonstrated a pilot concept of school-based vegetable gardens with the integrated intervention of stakeholders in schools to enhance vegetable accessibility to the school feeding programme, which may result in improved nutritional status of children and increased education of learners and teachers about healthy living and wellness. The establishment of food gardens at schools to supplement learners and households to reach daily dietary requirements is a step in the right direction. Experimental results obtained from trials at the selected study schools showed the promising potential of school gardens to improve food and nutrition security of school children. Introduction of various climate-smart production systems such as veggie tunnels and vertical bag systems can enhance the intensive production of vegetables in a limited space, with a limited water supply and increased water use efficiency.

7.3 Recommendations

School-based food gardens should focus on the cultivation of highly nutritious food crops for increased impact on food, nutrition security. This includes African leafy vegetables, which are considerably more nutritious compared to their commercial counterparts, offering them the potential to combat malnutrition amongst the underprivileged rural communities. Further research on Plant Growth-Promoting Rhizobacteria (PGPR's) application to improve climate change resilience of crops, pre and post-harvest management practices of leafy vegetables are, however, required to enhance their crop (including legumes) productivity and utilization, storage and shelf life, while maintaining the nutritional content. Improved pre-harvest crop management practices in irrigated agriculture include the implementation of supplemental irrigation through deficit irrigation strategies, while in dryland agriculture practices, for instance, rainwater harvesting within the field or from rooftops can markedly contribute to improved productivity of crops (leafy vegetables, tuber crops such as orange flesh sweet potato, legumes, etc.). The benefits of deficit irrigation for leafy vegetables are well documented in terms of increased water use efficiency and nutritional water productivity, but under dryland conditions, more research should be conducted to identify the best practices of cultivation through the implementation of rainwater harvesting technologies. Intercropping vegetables with fruit trees and health plants such as moringa is another pre-harvest management practice that can be done to secure year-round food production and maximize land productivity. Whereas vegetables intercropped with legumes may offer an excellent strategy to improve soil nutrition naturally, leading to decreased use of fertilizer inputs. Since fresh vegetables are highly perishable, post-harvest processing practices such as fresh-cut produce and product development should be encouraged to maintain all year round nutrients supply, for improved human health.

Future research should focus on-site climate-smart research, the establishment of household gardens, support the schools with infrastructure such as boreholes and water storage tanks, the introduction of green technology such as solar-driven irrigation systems and shade nets for protective farming to improve sustainability and vertical vegetable production system where availability of open field is limited. This should further explore towards vegetable gardens meeting dietary requirements of learners as well as pre-processing at the school level to introduce nutritious products such as soup and veggie drink, and to include high-value crops in the gardens for income generation. This will support the financial needs of the garden and inspire community participation in the gardens as well. The pilot project has been successfully implemented and had shown excellent potential to be rolled-out to other schools around the country, to combat hidden hunger which is prevalent in school children and women in South Africa

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APPENDIX I: CAPACITY DEVELOPMENT REPORT

Student name and Surname	Student registration No	Youth (0=No; 1=Yes) 35 and younger	Gender	Race	Qualification	Country of origin	Country where citizenship	South African permanent resident? (0 = No; 1 = Yes)	SA province of origin	Nearest town	Name of Community	Settlement (Is it Rural/ Urban/Peri -Urban/ Informal)	E-mail address
Hunadi Chaba	219602740	1	Female	Black	BSc Hons Degree (Agric)	South Africa	South Africa	1=Yes	Limpopo	Polokwane	Lebowakgomo	Peri-Urban	HunadiH@arc.agric.za
Simon Kgathatso Maleka	213195298	1	Male	Black	BTech: Agri Development and Extension.	South Africa	South Africa	1=Yes	Limpopo	Polokwane	Moletjie Ga-Mabiloane	Rural	skgathatso@gmail.com malekas@arc.agric.za
Ramorola Khumo	211226978	1	Female	Black	National Diploma	South Africa	South Africa	1	Gauteng	Pretoria	Hammanskraal	Peri-Urban	khumo.ramorola@gmail.com

APPENDIX II: REPORT ON RESEARCH DISSEMINATION

Information Dissemination

Information dissemination is one of the key outputs of the project. The project has drafted few information dissemination technologies packaged to date. The information dissemination packages that are under internal review are as follows: one popular article, which will be submitted either to the ARC-VOP Newsletter or WRC Water Wheel; a review on school gardens will be submitted to *Sustainability Journal*; an article on learners and household characteristics assessment will be submitted to *Journal of Human Ecology*.

School-based Vegetable Gardens: A Promising Approach to Enhance School Feeding Scheme and Well-being of Children in South Africa

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[2]Water Research Commission (WRC), Private Bag X03, Gezina, 0031, South Africa; sylvesterm@wrc.org.za (S.M.)

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Abstract: School nutrition gardens are a long-term strategy that complements supplementation and food fortification programs. Running a school garden requires not only horticultural knowledge but also common sense, enthusiasm, organizational capacity and ability to mobilize parents and people in the area. The success of school gardens is, dependent on existing political commitment and national policies that support and provide an enabling environment for development and implementation of garden activities in schools. Addressing constraints such as supplies, technical support, infrastructure, tools and the

involvement of parents and other community members is critical for the success of school gardens. School gardens implemented in South Africa to date lack the involvement of governmental institutions and parents, which are also essential components of a successful school garden programme. The identification of problems and challenges of school garden programmes in this knowledge review document will assist towards the development of a more complete school garden model, by creating a stronger involvement of different community members.

This article is a review and it will be submitted to *Sustainability* Journal. Currently, the review is under internal review.

Learners and household characteristics assessment at Bula Dikgoro and Mahlasedi Masana public primary schools in the Mamelodi East, Pretoria, Gauteng Province, South Africa

Versity Kekana[1], Nadia Alcina Araya[1], Manaka Makgato[1], Stephen Amoo[1], Michael Bairu[1], Sylvester Mpandeli[2], Sonja Venter[1], Christian du Plooy[1] and Hintsa Araya[1]*

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Abstract: School nutrition gardens are a long-term strategy that complements supplementation and food fortification programs. Agricultural Research Council – Vegetable and Ornamental Plants (ARC-VOP) was commissioned by Water Research Commission (WRC) to establish vegetable school gardens in two schools (Bula Dikgoro and Mahlasedi Masana public primary schools) in the Mamelodi East, Pretoria, Gauteng Province, South Africa. Vegetable gardens were be established at the schools as a pilot study. The learners and household from the two school gardens were assessed and quantitative and qualitative methods were employed in the assessment. The collected data was analysed quantitatively using the Statistical Package for Social Sciences (SPSS) version 24 and Microsoft excel. The results indicated that 77% of the respondents were female, 54% of the household receive income from social grant, and 18% and 23% for both children and adults going to bed feeling hungry, meaning there are leaners who goes to school with empty stomach. Therefore, establishment of food garden at

the schools can play an important role in supplementing leaners with daily dietary requirements.

This article will be submitted to *Journal of Human Ecology*. Currently, the article is under internal review.

Establishing of school based vegetables garden with community involvement at two primary schools in Mamelodi East of Pretoria (Tshwane), South Africa

This is a popular article that will be submitted either to the ARC-VOP Newsletter or WRC Water Wheel. Currently, the popular article is under internal review.

Infotoons used during the training of beneficiaries

Planning Food Garden

How to grow a bag garden

How to grow your own seedling

Lest grow African Leafy Vegetables

APPENDIX III: CONSENT FORM TO CONDUCT RESEARCH

CONSENT TO PARTICIPATE IN A RESEARCH STUDY

Agricultural Research Council, Vegetable and Ornamental Plant, Pretoria

Title of study: Situational analysis on past, present and ongoing work on school – based vegetable gardens

Investigators:

Name:……………………………………………Dept.:………………………………Phone:……………

Name:……………………………………………Dept.:………………………………Phone:……………

Name:……………………………………………Dept.:………………………………Phone:……………

Introduction

- You are being asked to participate in a research study about school-based vegetable gardens for increased accessibility of vegetable consumption.
- You were selected as a possible participant because (*explain how subject was identified, include the selection criteria*).
- We ask that you read this form and ask any questions that you may have before agreeing to be in the study.

Purpose of Study

- The purpose of the study is (*explain research questions and purpose in a simple language*).
- Ultimately, this research may be (*published as part of a book on…, presented as a paper, etc.*).

Description of the Study Procedures

- If you agree to be in this study, you will be asked to do the following things: (*explain procedures and tasks; identify any procedures that are experimental; describe length of time for participation, frequency and duration of procedures; etc.*)

Risks/Discomforts of Being in this Study

- The study has the following risks: (*explain if there are any risks involved*)
- If there are no foreseeable risks, state that there are no reasonably foreseeable (or expected) risks. There may be unknown risks.

Benefits of Being in the Study

- The benefits of participation are (*explain benefits of participation that will be gained by the participants and/or other*). If a benefit is not likely to occur to each participant do not include.

- If there are no expected benefits, state as such.

Confidentiality

- This study is anonymous. We will not be collecting or retaining any information about your identity.

Payments

- There will be no payment/reimbursement for your participation.

Right to Refuse or Withdraw

- The decision to participate in this study is entirely up to you. You may refuse to take part in the study at any time without affecting your relationship with the investigators of this study.

Right to Ask Questions and Report Concerns

- You have the right to ask questions about this research study and to have those questions answered by me before, during or after the research. If you have any further questions about the study, at any time feel free to contact me, (*name*) by telephone at (*phone number*).

Consent

- Your signature below indicates that you have decided to volunteer as a research participant for this study, and that you have read and understood the information provided above. You will be given a signed and dated copy of this form to keep, along with any other printed materials deemed necessary by the study investigators.

Participant's name: (*Print*)………………………………

Participant's signature:…………………………..Date:…………………….Place:…………….

Investigator's signature:…………………………Date:…………………….Place:…………….

APPENDIX IV: QUESTIONNAIRE ON THE CURRENT SITUATION OF SELECTED SCHOOL GARDENS

QUESTIONNAIRE

The Agricultural Research Council VOP will conduct a detailed questionnaire on the current situation of selected school gardens in South Africa (Bula Dikgoro and Mahlasedi Masana primary schools located in the Mamelodi District, Gauteng Province). The interview will be conducted randomly, using a convenient sample size. The rule of Thumb will be applied, in which a selection of 10% of the population is considered as a good sample size. In the case of this study, a minimum of 10% of each grade will cover representativeness. Stratified – Purposive sampling will be used, since the various grades will be divided into stratus and choosing only individuals who are involved in school gardens (Purposive). The interview process will involve enumerators who understand the local language to facilitate data collection. The study will incorporate both quantitative and qualitative methods in order to capture the relevant and appropriate information and facilitate data analysis and interpretation.

SECTION A: Demographics Characteristics (All)			
No.	**Variables**	**Code**	**Selected Code**
1	Respondent	1 = SGB member 2 = School Principal 3 = Parent 4 = Community member 5 = Learner 6 = Other	
2	Gender	1= Female 2 = Male	
3	Race	1= Black African 2= White 3= Asian or Indian 4= Coloured 5=Others (Specify) ……………………	
4	Age	Specify number ……………………	

5	Education level	0=No formal school		11=Grade 11	
		1=Grade 1	6=Grade 6	12=Grade 12	
		2=Grade 2	7=Grade 7	13=Post matric certificates	
		3= Grade 3	8=Grade 8	14=Diploma	
		4= Grade 4	9=Grade 9	15=Degree	
		5=Grade 5	10=Grade 10	16=Post graduate degree	
6	Employment status	1= Unemployed 2= Full time employment 3= Part-time employment 4 = Not Applicable			
7	Sources of income in the household (tick √)	Social grant			
		Full time employment			
		Part-time employment			
		No income			
8	Total household income per month	1 = <R500 2 = R501-R1000 3 = R1001-R2500 4 = >R2501 5 = N/A			
9	Household expenditure per month	Water and electricity		1 = <R200 2 = R201-R400 3 = R401-R600 4 = >R601 5 = N/A	
		Food		1 = <R200 2 = R201-R400 3 = R401-R600 4 = >R601 5 = N/A	
		School transport		1 = <R200 2 = R201-R400 3 = R401-R600 4 = >R601 5 = N/A	

		Transport costs	1 = <R200 2 = R201-R400 3 = R401-R600 4 = >R601 5 = N/A	
10	Number of current household members	Specify number ……………………………		
11	How many kids at primary school	Specify number ……………………………		
12	The lowest grade your kid is on (grade R to grade 7)	Specify grade …………………………….		
13	Household language	1 = Setswana 2 = Sepedi 3 = Zulu 4 = Xhosa 5 = Tsonga 6 = Venda 7 = Sesotho 8 = Ndebele 9= Swati 10=Other (Specify) ………………………		
14	Household head	1 = Mother 2 = Father 3 = Brother 4= Sister 5=Extended family member 6= Other …………………………………….		

SECTION B: Household Food Availability (Leaners Parent/Community Member)				
An impression of the availability of food at household level	**1 Never**	**2 sometimes**	**3 Often**	**4 Always**
B1. My food runs out before I get money to buy more				
B2. I do not know where the next day`s food is going to come from				
B3. The food that I buy is not enough to feed my family				
B4. I am often hungry				
B5. I eat less than I think I should				
B6. I don't` have enough money for food				
B7. I cannot afford to feed my children				
B8. My children are not getting enough food to eat				
B9. My children go to bed feeling hungry				
B10. I go to bed feeling hungry				
B11. I know where tomorrow`s food is going to come from				
B12. I can afford to eat enough everyday				
B13. I have enough money for food				
B14. I have enough food to last until I get money to buy more				
B15. I still have food in the house the day before someone gets paid				

SECTION C: Household Food Access (Learners Parent/Community member)			
NO	QUESTION	RESPONSE OPTION	Selected Code
C2A	In the past four weeks, were you or any household member not able to eat the kinds of foods you preferred because of lack of resources?	0 = No (skip to question C3A) 1 = Yes	
C2B	How often did this happen?	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks)	
C3A	In the past four weeks, did you or any household member have to eat a limited variety of foods due to lack of resources?	0 = No (skip to question C4A) 1 = Yes	
C3B	How often did this happen?	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks)	
C4A	In the past four weeks, did you or any household member have to eat some foods that you/they really did not want to eat because of lack of resources to obtain other types of foods?	0 = No (skip to question C5A) 1 = Yes	
C4B	How often did this happen?	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks)	
C5A	In the past four weeks, did you or any household members have to eat a smaller meal than you felt you needed because there was not enough food?	0 = No (skip to question C6A) 1 = Yes	

C5B	How often did this happen?	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks)	
C6A	In the past four weeks, did you or any household members have to eat fewer meals in a day because there was not enough food?	0 = No (skip to question C7A) 1 = Yes	
C6B	How often did this happen?	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks)	
C7A	In the past four weeks, was there ever no food to eat of any kind in your household because of lack of resources to get food?	0 = No (skip to question C8A) 1 = Yes	
C7B	How often did this happen?	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks)	
C8A	In the past four weeks, did you or any household members go to sleep at night hungry because there was not enough food?	0 = No (skip to question C9A) 1 = Yes	
C8B	How often did this happen?	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks)	

C9A	In the past four weeks, did you or any household member go a whole day and night without eating anything because there was not enough food?	0 = No (questionnaire is finished) 1 = Yes	
C9B	How often did this happen?	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks)	

SECTION D: Household Food Utilization & Diversity (Learner Parent/ Community Member)					
Question number	**Food group**	**Ate in the last 7 days, past season, past month (1 = Yes & 2 = No)**	**Past 7days**	**Past Season**	**Past month**
D1	Cereals	Corn/maize, rice, wheat, sorghum, millet or any other grains or foods made from these (e.g. bread, noodles, porridge, oats)			
D2	Vitamin A rich vegetables and tubers	Pumpkin, carrots, squash orange sweet potatoes, red sweet peppers			
D3	White tubers and roots	White potatoes, white cassava, white yams			
D4	Dark green leafy vegetables	Including wild ones, e.g. amaranth, cleome, spinach, cassava leaves, kale, green peppers, lattice, etc.			
D5	Other vegetables	Cabbage, cauliflower, tomato, onion, eggplant.			
D6	Vitamin C rich fruits (Fresh and Dry)	Mangoes, apricots, papaya, dried peaches or any locally available fruit			
D7	Other fruits	Other fruits apples, bananas, guavas, pears, grapes, pineapples, figs, etc.			
D8	Organ meat (iron rich)	Liver, kidney, heart, mala-offal, other organ meet or blood based foods.			
D9	Flesh-meats	Beef, pork, lamb, goat, rabbit, wild game, chicken, duck or other birds			
D10	Eggs	Chicken, duck, guinea hen			
D11	Fish	Tinned, fresh, dried or shellfish			
D12	Legumes, nuts and seeds	Beans, peas, lentils, nuts, seeds, or food made from these.			
D13	Milk and milk products	Milk, cheese, yogurt or other milk products			
D14	Oils and fats	Oil, fats or butter added to food or used in cooking			
D15	Sweets	Sugar, honey, sweetened soda or sugary foods such as chocolates, candies, cookies and cakes.			
D16	Spices, condiments, beverages	Spices (black or red pepper, salt) condiments (soy sauce, hot sauce, tomato sauce, achar, mayonnaise,) coffee, tea (black, green or herbal),			

SECTION E: School Garden Status (SGB member/Principal)	
Do you have a garden in your school?	1= Yes 2= No
School garden/ land size	1 = <100 m^2 2 = 101-900 m^2 3 = 901-1600 m^2 4= > 1601 m^2
Year school garden established	1= Specify ……………………….
Number of workers/volunteers in the school garden	1 = Specify …………………………..
Does the school have a guard?	1= Yes 2= No
Current condition of the school garden	1 = Good 2 = Fair 3 = Neglected
Has the school garden soil/ water been tested for texture, pH, fertility, etc.	1 = Yes 2 = No
Who is responsible for day to day running of the garden (Including Weekends & Holidays)	1 = SGB member 2 = School Principal 3 = Parent 4 = Community member 5 = Learner 6 = Other, Specify ……………………………..
Do you have access to irrigation water?	1 = Yes 2 = No
If yes, what kind of water sources for irrigation do you have access to?	1= Municipal Water 2 = River/stream 3 = Well 4 = Dam

	5 = Rain 6 = Boreholes 7= Lake/Pond 8 = Other , Specify …………..………………………
What kind of irrigation is used?	1 = Watering Can 2 = Sprinkler 3 = Drip 4 = Other, Specify …………………………….
Do you experience problems with your irrigation system?	1 = Low pressure 2 = Accessories broken 3 = Accessories stolen 4 = Quality of water 5 = Other, Specify …………………………………
Is water available year-round/every day from this source of irrigation water?	1 = Yes 2 = No
Do you have any knowledge on water requirements of crops (how much to apply & when?)	1 = Yes 2 = No
If Yes, How much do you irrigate at a time? and when?	1 = Specify, ……………………………………….
Do you have any knowledge on rainwater harvesting?	1 = Yes 2 = No
Have you heard of any school or community member practicing rainfall harvesting?	1 = Yes 2 = No
Do you have access to weather information before and during planting season?	1= Yes 2 = No

If yes, what is your source of information?	1 = Government agricultural extension service 2 = Private agricultural extension service 3 = Agricultural COOP /farmers' association 4 = Peer farmer 5=(Neighbour/Relative) 6 = Electronic media (TV, Radio, etc.) 7= Paper media 8 = Other , Specify …………………………………….
Did you received any agricultural training	1 = Yes 2 = No
If Yes, What type of training	1= Vegetable production 2 = Nutrition 3 = Water management 4 = Other, Specify ……………………………………
From which service provider	1 = GDARD 2 = DAFF 3 = ARC 4 = Other, Specify ………………………………………
Training needs	1 = Soil Preparation 2 = Seed Sowing and Transplanting 3 = Pest and Disease 4 = Irrigation 5 = Fertilization 6 = 1,2,3,4 & 5 7 = Other , Specify ……………………………………….
	1 = Harvesting 2 = Post Harvesting/ Storage 3 = Both 1&2 4= Other, Specify

	…………………………………..
	1 = Marketing 2 = Business Management 3 = Both 1&2 3 = Other, Specify ……………………………………….
Causal Factors of Training needs	1 = Poor crop yield & quality 2 = Poor gardening management 3 = High crop spoilage 4 = Just need extra knowledge 5 = Other, Specify ………………………………….
Vegetables / Fruits grown & harvested past season	1 = List, ………………………………….. ……………………………………. …………………………………….
Are you still growing these crops?	1 = Yes 2 = No
If No, Why	1 = Specify …………………………..
How do you decide on which crops to grow?	1 = Specify …………………………..
How do you decide on how much each crop to cultivate?	1 = Specify …………………………..
What are your major challenges regarding your school garden?	1 = No time 2 = No interest 3 = No one available to do the Work

	4 = Crop losses 5 = Loss of land 6 = No technical assistance 7 = No supplies/equipment
	8 = Lack of water 9 = lack of production inputs 10 = Other (specify
List four major vegetables that learners consume throughout the year	1…………………………………… 2…………………………………… 3…………………………………… 4……………………………………
Do you have a school feeding scheme	1= Yes 2= No
How many children are supported by the scheme?	1 = Specify ……………………………
Does the scheme support all different grades?	1= Yes 2= No
Do parents play any role in the scheme?	1= Yes 2= No
Would you like the school garden to supplement the school feeding scheme?	1 = Yes 2 = No
How is the scheme sustained?	1 = Specify, …………………………………

Where do the funds come from?	1 = Specify, ……………………………………
How do you ensure continuation of the feeding scheme programme?	1 = Specify ……………………………………
What kind of crops would you like to be planted in the school garden to supplement the school feeding scheme?	1 = Specify ……………………………….….
What criteria do you use to identify support-needing children?	1 = Specify ……………………………….….
How many meals do children receive per day (In Numbers)?	1 = Specify ……………………………………..
Who is your food/vegetable supplier?	1 = Specify …………………………………….
Why?	1 = Specify …………………………………….
Annual cost to procure vegetables	1 = Specify ……………………………………
Amount and cost of all vegetables needed per day or per week/month	1= Specify/ Supply yearly vegetable purchase order ………………………………………….
Do you use or consume any indigenous vegetables?	1 = Yes 2 = No
Which indigenous vegetables do you consume?	1 = Specify ……………………………………………..
Where do you get your indigenous vegetables?	1 = Specify ……………………………………………..

Overall feeling of the school garden initiative	1 = Very good 2 = Good 3 = Fair 4 = Poor 5= Very poor
Overall impression of the support you received in terms of school gardening	1 = Very good 2 = Good 3 = Fair 4 = Poor 5= Very poor

SECTION F: School Infrastructure (SGB members/ Principal)	
Is the school fenced?	1 = Yes 2 = No
Current condition of the fence	1=Very good 2=Good 3=Bad 4=Very bad
Which type of fence?	1 = Specify …………………………………………….
Is the area for school garden fenced?	1= Yes 2= No
Is the area for school garden under irrigation?	1= Yes 2= No
Does the school have a borehole?	1 = Yes 2 = No
If so, was it ever tested for delivery rate and consumption/irrigation suitability?	1= Specify ……………………………………………
For which purposes is the borehole water used for?	1= Specify ……………………………………………
Amount of available water (delivery rate of borehole, other sources)	1 = Specify …………………………………………….
What type of irrigation system do you have?	1 = Specify ……………………………………………….
Condition of irrigation system	1=Very good 2=Good 3=Bad 4=Very bad
Size of school buildings roof area in square meter	1 = Specify ……………………………………………….

How big is the floor area of your school?	1 = Specify ……………………………………..
Which type of roof does it have?	1 = Specify ………………………………………
Is the roof in good condition?	1 = Yes 2 = No
How far is the school building to the garden?	1 = Specify ………………………………………
School building roof has gutter for rainwater	1=Yes 2= No
If yes, which type of material is it made of?	1 = Specify, ………………………………………..
How many gutter outlets are there?	1 = Specify ………………………………………
Conditions of gutters	1=Very good 2=Good 3=Bad 4=Very bad
What is the height of the position of the gutter from the ground?	1 = Specify ………………………………………
Do you harvest rainwater?	1= Yes 2 = No
If yes, do you have water storage tanks?	1= Yes 2 = No
If yes, how far are these located?	1 = Specify ………………………………………
Do you have access to market of your produce?	1= Yes 2 = No
Where do you store your produce?	1 = Specify ……………………………………………………

Explain the size and condition of the storage facility	1 = Specify ……………………………………………………
For how long (on average) is produce kept before being sold or consumed?	1 = Specify …………………………………………………….
Under what condition is produce stored due to unavailability of facility	1 = Specify …………………………………………………….
What is the produce utilized for?	1 = School Feeding Scheme Programme 2 = Local market 3 =Income Generation 4 = Other, Specify ……………………………………………
How frequent do you harvest each crop	1 = Specify ………………………………………………. ………………………………………………. ……………………………………………….
Volume/quantity harvested per each crop	1 = Specify ………………………………………………. ………………………………………………. ……………………………………………….
Did the school receive any gardening tools	1 = Yes 2 = No
If yes, how often do you receive tools, and from which institution?	1 = Specify ……………………………………………….
Which tools did you receive	1 = Specify ……………………………………………….

	…………………………………………… ……………………………………………
Do you still have gardening tools	1 = Yes 2 = No
Which tools are not available?	1 = Specify …………………………………………… …………………………………………… ……………………………………………
If no, what happened to some of the tools	1 = Stolen 2 = Broken 3 = Sold 4 = Specify ……………………………………………………
Do you use fertilizers?	1 = Yes 2 = No
Indicate type of fertilizers used	1 = Specify ……………………………………………………

SECTION G: School Gardens Perceptions (SGB member/Principal/Learner Parent/Community member)					
Views The following factors are causing decrease in school gardens success.	**Responses**				
	1	**2**	**3**	**4**	**5**
	Strongly disagree	Disagree	Not sure	Strongly agree	Agree
Cost of production					
Poor crop productivity					
Production getting stolen					
Poor soils					
Difficult to maintain					
Labour					
Administration costs associated with school gardens					
Insufficient water source					
Lack of knowledge and capacity on school gardening					
Lack of infrastructure					
Lack of finance/capital					
Lack of technology					
Lack of interest from learners					
Lack of interest from parents/community members					
Poor institutional support					
Lack of knowledge on cultivation/ postharvest handling					
Lack of market availability					
Lack of logistics for the produce					

SECTION H: Sites Visits Observations (Enumerator)

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……………………………………………………………