Application of research findings to support the empowerment of Agri-parks farmers to increase irrigated food production and market access

Report
to the Water Research Commission

by

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EXECUTIVE SUMMARY

This Water Research Commission project was undertaken to identify barriers hindering the success of government efforts to empower emerging farmers. The South African government developed the Agri-parks model to support emerging farmers in becoming commercial, but the initiative's success has been limited. This report presents the findings from implementing an alternative, bottom-up management approach at the Rooiwal Agricultural Hub.

Aim 1: The overall aim was to introduce innovative strategies to support Agri-park farmers. This was achieved through the following sub-aims:

Agri-park level development

- Aim 2: Strengthen the Rural Urban Marketing Centre by building a network of role-players to support crop selection, marketing, and agro-processing.
- Aim 3. Establish a mentorship network to help farmers engage in the value chain, understand commodity markets, and align production with market timing.

Individual farmer level

- Aim 4. Use a social learning and co-development approach to ensure adoption of water-conservation strategies and agricultural innovations, reducing internal competition for scarce resources.
- Aim 5. Improve farmers' knowledge of sustainable irrigation practices, agricultural techniques, and market literacy.
- Aim 6. Co-design, implement, and evaluate a functional Agri-park model.

UNDERSTANDING CURRENT PROBLEMS IN THE AGRI-PARK MODEL

According to officials from the City of Tshwane (CoT) and the Gauteng Department of Agriculture, Rural Development and Environment (GDARDE), the existing system relied on officials providing advice, physical support (e.g., seedlings), and financial assistance to farmers. However, both farmers and officials were frustrated with the outcomes:

- Farmers blamed officials when advice, particularly marketing advice, did not lead to expected profits.
- Officials reported that farmers often ignored guidance and resisted financial oversight.
- Financial support frequently failed: funds intended for infrastructure were sometimes misused or diverted to personal spending (e.g., purchasing luxury cars).
- Equipment issued to farmers was sometimes sold rather than used productively.
- Bureaucratic delays meant seedlings often arrived after planting season.
- Financial and physical support fostered long-term dependency rather than farmer autonomy.

Independent farmers felt overlooked and questioned why some received support while others did not. They saw that those who received assistance often became permanently dependent on the government, limiting opportunities for others.

The problem that government support to emerging farmers leads to dependence is just another example of complex systems that respond in unexpected ways to inputs or changes from outside. The reason for these failures is that the offered solutions do not address the fundamental problems, which are often very poorly understood.

THE ALTERNATIVE MANAGEMENT SYSTEM IMPLEMENTED

The Agricultural Innovation Platform (AIP) developed by van Rooyen et al., (2017) was implemented as part of the search for an alternative model for developing Agri-parks according to Aim 6. The platform connected the farmers, government officials who work directly with them, market agents and other role-players. Typical smallholder problems, such as water shortages, lack of market access, and insufficient infrastructure, are often incorrectly treated as purely technical issues. Van Rooyen argues that the core problem lies in misaligned institutional structures when farmers transition from subsistence to market-oriented systems.

The AIP framework emphasises engaging all relevant stakeholders (government, private sector, researchers, markets, and farmers), building trust, identifying clear roles and forming a shared vision.

IMPORTANT INSIGHTS GAINED THROUGH THE STUDY

Poor understanding of farm and farmer levels between food gardens and commercial farms:
The lack of understanding of the various farming levels between subsistence and large commercial farming is a gap in the current knowledge, and we believe that better information on these levels is needed to address the observed failures of emerging farmers to become successful at commercial levels. The notable increases in responsibility and complexity between levels of farming make gradual progression essential. Currently, due to the poor understanding of the farming levels, which form a growth path for farmers, farmers typically skip one or more of these levels, which results in failure.

Government officials indicated that their programmes work with two levels of farmers, the food garden level and the commercial level. The size of a farm at the commercial level is based on the assumed minimum viable unit for each crop, which usually starts above 1 hectare. To calculate the viability (profitability) of the minimum viable unit, the opportunities of utilising local markets and resources that are currently wasted are disregarded. Contrary to this assumption, we found examples of profitable farms working below the minimum viable unit, because they can minimise expenses and maximise income. It is also clear that the farm levels between food garden and commercial farms are very different in terms of the market that should best be utilised, storage, and transport requirements. For marketing purposes, it is therefore important that a farmer knows at what level he/she currently farm, and what investments are appropriate at that level. Based on actual farms in Rooiwal and Hammanskraal, we identified and characterised distinct farming levels, each requiring different forms of support and networks.

Misaligned visions:
The ability of farmers and the government to formulate a realistic vision is currently greatly limited by a poor definition of the various levels of agriculture before a farmer becomes successful on a large scale.

The government aims to rapidly develop many emerging farmers into large-scale commercial producers. However, not all farmers aspire to this, and many do not yet possess the capacity. It is a question whether the government's vision to develop commercial farmers is the appropriate response to poverty in the country. Many urban and peri-urban communities are food insecure; some lack the financial resources to buy nutritious food, and others do not have access to it. Local communities are best served by smaller-scale farmers who reside in the community and sell directly to consumers. The lack of transport in rural areas can necessitate a decentralised production of food by many smaller farms in each street, rather than one big farm that sells at a central location. The government, therefore, must decide how much attention they want to give to developing more large-scale commercial farmers, or how much attention it wants to give to addressing food security.

During a site visit, a student noted that one of the smallholder farms in this project resembled a "Blue Zone" homestead. Blue Zones are regions known for exceptional longevity and strong community networks, often centred around small-scale farming and local food systems. This comparison offers a positive alternative narrative to the stigma around small-scale farming and suggests the possibility of developing "African Blue Zones" rooted in sustainable local agriculture.

Complex systems and dependency:
Government assistance often increases dependency, because the support offered rarely addresses fundamental constraints such as farmer motivation or realistic capacity. Typically, generic assistance is provided, while farmers benefit more from targeted interventions. However, because of the current lack of understanding of what is required to succeed at each farming level, farmers are also not able to identify what

targeted interventions they need. Any strategy to improve food security must recognise the unique contribution of each farming level and provide level-appropriate support.

WORKING GROUP HIGHLIGHTS

Toward achieving Aim 6 of this project, we have tested the possibility of establishing working groups where farmers can be connected to a network of various stakeholders in the food and agricultural industry, as an alternative to the current Agri-park model. Six working groups were formed, consisting of farmers, officials, experts, and marketing role-players. Each group was tasked to define its vision, identify problems, learn from external examples, and develop and test possible solutions. Their experiences varied, but all groups reported meaningful learning and value in the process. The six groups are shortly discussed below.

Water Use Efficiency:

The water use efficiency group was established to address Aims 4 and 5 of the project. Rooiwal farmers face severe water challenges: poor quality, unreliable supply, and inadequate infrastructure. Many used inefficient methods (hosepipes, watering cans) which restrict farm size and increase shortages. The WUE group provided training, farm visits, and demonstrations of alternative irrigation methods. Challenges included shared borehole conflicts, overuse of free water, and labour-intensive soil management practices. Several management practices have been tested that can successfully improve the water use efficiency and production outcomes on a small scale, including the Sukuma drip system, mulching, adding compost and manure to the soil, etc. However, a misunderstanding of the farming levels impacted on water use efficiency, because farmers operating at a small-scale purchase equipment suitable for large scale, and they are unwilling to make the appropriate, *albeit* small, investments to improve their water use at their current level. The result was poor maintenance of large equipment, while farmers continued to use hosepipes on the farms.

Seed Saving

The seed saving group presented workshops focused on crop selection, pest control, and viable seed production. Farmers received seeds of winter and summer varieties, which they multiplied over the growing season and returned with up to 2 kg per farmer in some cases. The initiative attracted much interest, demonstrating its potential for building self-sufficiency and resilience. Problems with finding markets for non-GMO varieties and the loss of leadership limited the activities of the group.

Agro-Processing and Market Access

The agro-processing and market access working group was established to achieve Aims 2 and 3 of the project. Farmers' market opportunities evolve with farming levels, from self-consumption (food garden) to the local neighbourhood, to the wider community, to the retail markets (large commercial farmers). Infrastructure and transport need to grow accordingly, e.g., from wheelbarrow to small truck, to large truck. Some farmers prematurely invest in trucks without sufficient production volume. A successful outcome of the working group was to connect several small commercial farmers with Simply Garlic, a local processor offering stable markets.

Essential Oils Working Group

Farmers showed much interest in the group, and in Rooiwal, some farmers already produce *Moringa oleifera* and castor beans. The South African Essential Oil Producer Association and a processor provided training and farm assessments. However, commercial viability typically requires 10 to 40 hectares, which exceeds most farmers' land. Shared processing facilities are essential. Although the industry offers advantages (low theft risk, good storage, high demand), it also faces import competition and barriers to entering formal retail markets.

A group of Rooiwal farmers cooperated at the marketing level to supply castor beans to a processor, and after the buyer withdrew, the group found a new market through the working group's network connections. This demonstrates the potential of networks to help farmers to grow to independence.

Farmer Graduation Programme

A farmer graduation programme was discussed as a potential alternative model for the current Agri-parks, towards achieving Aim 6. Farmers proposed a system where support is reduced over 3–5 years and then transferred to another farmer. The government shares this goal but notes that reduced support often leads to declining production, and withdrawing support often results in farmers ceasing production entirely. Key insights emerged through the discussions in the group.

First, it was found that some farmers are committed and growth-oriented, while others seek benefits without the intention to progress. The latter often occupy resources that could support more motivated farmers. This highlights the importance of selecting the right individuals for support. Second, it was found that certain forms of support repeatedly fail, such as once-off capital investments, operational input support, seed provision, and top-down market or advisory support. More effective support includes removing structural barriers (e.g., SA-GAP certification, EIAs) and encouraging partnerships with other role-players. Third, it was found that roles and responsibilities are poorly assigned. The government should provide infrastructure, resources and safety. Farmers should manage inputs, production, and skills. The system collapses when these responsibilities are reversed.

Poultry Working Group

The group identified two major barriers: cheap imports flooding the market and the high cost of EIAs (approx. R200 000) required to scale beyond 5 000 chickens. Participation in the group decreased over time, leading remaining members to pursue a smaller, free-market model centred on building local value chains. In 2025, they focused on locally producing chicken-feed ingredients (grains, soy) to reduce input costs. Challenges remain with member coordination and external market pressures.

FARMERS' SUPPORT TOOL

The Sukuma Transformation Tool was developed to determine at which level a farmer currently operates, assess a farmer's efficiency at that level, and identify constraints that must be addressed before moving to the next level. Based on thriving farms in Rooiwal and Hammanskraal at different levels, we built on the current research by describing a combination of a few key factors: size of land, how much water, the available market, what technology is needed (e.g. solar pump, truck), how much labour is needed, cost of input, the weather. These key factors must fit into each other and combine well. To go to the next level, you must be able to manage a whole new combination of such key factors. Failures in Agri-parks often stem from attempts to push farmers from lower levels directly into large-scale commercial farming.

Once a farmer reaches 75% efficiency, they may choose to scale up. The tool categorises farmers, evaluates key indicators, and highlights key aspects that a farmer is lacking. Verification of the model in Rooiwal confirmed the tool's potential to support farmer growth.

The tool was named Sukuma for two reasons. First, although the tool was developed specifically for this project, it builds on earlier work undertaken by the NGO, Sukuma Community Transformation. Second, Sukuma is a Zulu and Swahili word meaning "to rise" in a figurative sense, a meaning that aligns well with the tool's purpose and intended impact.

WASTEWATER RESEARCH

A literature review on SWE use in hydroponics shows that it can increase yields, recycle nutrients, and reduce water consumption. Success depends on nutrient balancing, pathogen management, and consumer acceptance. Key research gaps include system-to-system performance, responses of fruiting crops, and adoption in African markets. A pilot study was conducted across two hydroponic systems, four crops, and two seasons to assess the potential of SWE in hydroponics in a South African Agri-park context.

Findings included:

- Using untreated SWE without supplementation is unsuitable for lettuce in flood & drain systems.
- Swiss chard performs adequately in drip systems with SWE but has lower profitability.
- Basil shows consistent but reduced performance, indicating potential for partial supplementation.
- Green pepper produced the strongest results and appeared most economically viable.
- Fruiting crops show potential when SWE is combined with nutrient enrichment, EC/pH control, and frequent renewal.

A key outcome of the study is that technologies must fit the farming level that a farmer is currently on. Hydroponics systems are most suitable for large commercial farms, because of the high input and maintenance costs, management and skills required. This option can be further developed for those Agri-park farmers who have successfully emerged as commercial farmers.

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ACRONYMS & ABBREVIATIONS

AAMP	Agriculture and Agro-processing Master Plan
AH	Agri-Hub
AIP	Agricultural Innovation Platform
COD	Chemical Oxygen Demand
CoT	City of Tshwane Metropolitan Municipality
CSA	Community Supported Agriculture
DWS	Department of Water and Sanitation
EC	Electrical conductivity
EIA	Environmental Impact Assessment
FAO	Food and Agriculture Organisation
FPSU	Farmer Production Support Unit
GDARDE	Gauteng Department of Agriculture, Rural Development and Environment
GMO	Genetically Modified Organism
GMO	Genetically Modified Organisms
HFIAS	Household Food Insecurity Access Score
HNS	Hydroponic nutrient solution
NAMC	National Agricultural Marketing Council
NGO	Non-Government Organisation
NO_3	Nitrates
PFAS	Per- and polyfluoroalkyl substances
PO_4	Phosphates
RUMC	Rural Urban Market Centre
SAEOPA	South African Essential Oil Producer Association
SDGs	Sustainable Development Goals
SES	Socioecological System
SES	Socio-ecological system
SHFs	Smallholder farmers
STT	Sukuma Transformation Tool
SWE	Sewage water effluent
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
WEF	Water Energy Food nexus
WUE	Water Use Efficiency
WUL	Water Use Licences
WWTW	Wastewater Treatment Works

1 BACKGROUND

1.1 INTRODUCTION

South Africa is a deeply divided nation with a Gini coefficient of 0.63 (World Population Review, 2025). This is one of the highest in the world, indicating the major differences between the rich and the poor in the country. According to the Household Food Insecurity Access Score (HFIAS), which was determined in the National Food and Nutrition Security Survey (Simelane et al., 2023), 63.5% of households in South Africa are food insecure. The economic and social impacts of this reality will reach far into the future, as it affects the development and mental capacity of many children. Research must be done to understand the reasons for this situation, and to find solutions. Even though these problems have persisted over decades, and many initiatives have been launched to overcome them, we are no closer to a solution.

Uplifting emerging farmers in rural areas of the country to practice commercial agriculture is often considered to be a solution to hunger, malnutrition and unemployment (Doyer, 2024), and for this reason, the South African government initiated Agri-parks to uplift emerging farmers and revitalise agriculture. However, the initiative is unable to serve the high numbers of emerging farmers, and the few that are served are seldom able to grow to independence. Government officials are stuck with the problem that, once they start giving support to a farmer, hoping to give him/her some momentum to start growing, the farmer becomes dependent, and they cannot withdraw the support. Farmers do not grow when they receive supplies, whether those supplies are regular provisions of fertilisers and pesticides, or larger infrastructures, trucks, tractors or other capital investments. This formed the main research question that was studied in this project: why does government support often fail to develop independent farmers? The second, but related question was, how can the government provide meaningful support to an emerging farmer?

The emerging smallholder farm is a complex system, meaning that this system is dynamic, with several variables, role-players and interactions between the role-players. Unexpected outcomes emerge that are not predictable and cannot be controlled. A good understanding of these systems is needed to manage them, and problems can emerge if our primary assumptions about the systems are incorrect, leading to interventions that are not suitable for the given context. To manage these problems, it is therefore important to question our most basic assumptions and paradigms with which we typically understand the problem. It is also critical to get various perspectives on the problems, including the perspectives of the farmers themselves, government officials working with the farmers, market agents, non-government organisations, universities, and people from other relevant industries.

Our study was mainly focused on the Rooiwal area up to Hammanskraal, north of Pretoria, South Africa. The Rooiwal area has an Agri-park of about 3 ha on which 3 to 5 cooperatives usually farm, and Rooiwal and Hammanskraal have a mixture of commercial and smallholder private landowning and renting farmers. The Agri-park is managed by the City of Tshwane Metropolitan Municipality (CoT), and the surrounding landowning farmers often get support from the Gauteng Department of Agriculture and Rural Development and Environment (GDARDE).

Smallholder farmers who aim to become commercial farmers deal with a vast number of problems, and in a previous WRC project on Agri-parks, it was found that the lack of water resources and marketing are often the most important (le Roux et al., 2022). In this project, these two problems were addressed. Both water management and marketing have various functions, which must be properly allocated to the correct role-players.

Water management on a farm concerns availability and access to water resources and the water quality, which the government regulates, as well as on-farm irrigation infrastructure, soil water management and irrigation scheduling.

Difficulties in market access are systemic problems, because it cuts through the entire farming operation, including resource supplies, production, storage and processing and finally selling the produce. Marketing is the responsibility of the farmer, but the government provides regulations, for example, SA Gap certification for traceability and product safety. Therefore, solving the marketing problem requires a management plan that integrates the whole farming enterprise.

The report first presents an integrated management plan, which includes the overall vision of the Agri-park initiative, the basic relationship between various role-players in the Agri-park system, roles and responsibilities and marketing strategies. We consider the current way in which Agri-parks are managed and suggest alternatives. The Commission on Growth (2008) correctly noted that there is no set formula to develop an economic growth strategy, as each particular area has different histories, opportunities and constraints. It is therefore important to involve the farmers and other role-players from the industry and government in a conversation on how the solution will look in each context. The concept of working groups which connected various stakeholders was presented and tested with Rooiwal farmers, and lessons learned from this approach are discussed in this report. We have also developed the Sukuma Transformation Tool (STT) to assist farmers and extension officers to profile a farmer and to identify the specific factors that are limiting the farmer to grow. The STT was tested with farmers and government officials, and feedback was very positive. After using the STT, most farmers reflected on their operations and even changed their farming strategies. Officials indicated that the tool addresses a gap in their current operations. We recommend further development and improvement of the STT during future research.

Second, the report presents water management recommendations. Water management includes responsibilities from both users (in our case, the farmers) and the government. Government responsibilities include the development of new water resources, and the management of water uses through Water Use Licences (WUL). Within the Rooiwal Agri-park, where farmers are renting land from the government, stricter control over water abstraction is needed, which will be discussed. When Agri-park farmers reach a large commercial level, water resources often become a major limiting factor. At larger commercial scales, farmers can also make use of technologically more advanced systems, such as hydroponics, which require high capital and operational inputs. To assess the potential of utilising wastewater in large-scale commercial farming, pilot studies on fertigation with wastewater in hydroponic systems were conducted. The impact of applying Kelpak with wastewater in a hydroponics system to grow spinach was also investigated.

Farm-level water management should ensure the efficient use of water. South Africa is a water-scarce country, and most farmers will directly benefit from methods that enable them to manage their water use more efficiently. Methods to achieve efficient water use are often more relevant on the smaller farming levels. We have established a working group of smallholder farmers to test methods of using water more efficiently. Various irrigation methods were presented to the Rooiwal farmers to consider, apply and test. We identified one successful irrigation method that has been tested in similar contexts and presented this method to the Rooiwal farmers. The method was tested on three Rooiwal farms and the outcomes are discussed in this report.

The project followed the broad guidelines of the Agricultural Innovation Platform (AIP) approach, which provides a process in which all stakeholders in the agricultural process can interact and achieve synergy: the farmers, the market, the government officials, other members of the community, service providers, etc.

1.2 PROJECT AIMS

The overall aim of the project was to implement innovative water conservation strategies and agricultural technologies to support Agri-park farmers to become active role-players in the market and to develop the three units of the Agri-park model to support the farmers. This was done through the following sub-aims:

Agri-park level development:

- To strengthen the Rural Urban Marketing Centre by establishing a network of role-players to assist farmers with the appropriate selection, marketing and processing of produce.
- To provide a network of role-players for mentorship support to farmers to enable participation in the value-chain. This includes understanding the business and marketing aspects of the agricultural commodities as well as planning to synchronise production with market requirements

Individual farmer level:

- To use a social learning and co-development approach to ensure technology transfer and adoption of water conservation strategies, and agricultural innovations to support Agri-park farmers to reduce internal competition for resources.
- To enhance farmers' knowledge of sustainable irrigated agricultural techniques and practices, and marketing knowhow
- To co-design, implement and evaluate a successful model of an Agri-park

1.3 SCOPE AND LIMITATIONS

The project scope included the investigation of Agri-parks on two levels: (1) the management of the whole Agri-park and (2) management on a farmer level. As per the original Agri-park model, we have interpreted an Agri-park to include all landowning farmers within a 20 km radius from the hub. We included both vegetable and poultry farmers in the study and although Rooiwal was the main research site, we also included farmers from over Gauteng where possible.

The study mainly focused on the management of water resources and marketing within the Agri-parks. However, due to the complex nature of these components, these were investigated within the context of a whole farm, and in the context of various other role-players involved in the Rooiwal Agri-park. These role-players included government officials, the farmers who farm on the Rooiwal hub and the farmers who farm independently on their own farms in the area around the park.

The following limitations applied to the research:

- Project implementation was dependent on farmer participation
- The pilot study on using wastewater for irrigation focused on macro major cations and anions in the water. Pollutants, like per- and polyfluoroalkyl substances (PFAS), were not included in this research.
- The baseline groundwater quality at Rooiwal is categorised by high salinity and nitrate concentrations. While this water was used as the control, it would have been beneficial to have a better-quality water as a control.
- Indicator biological contaminants (*E.coli*) were used to determine bacterial properties of the water. Individual changes in pathogen populations were not evaluated.
- There was no pre-treatment process in the pilot study.

2 LITERATURE REVIEW

2.1 INTRODUCTION

One of the Sustainable Development Goals (SDGs) is to eradicate hunger and achieve food security while fostering sustainable agriculture and improving nutrition. Given the ability of smallholder farmers (SHFs) to provide food at the household level, SHFs play a key role in attaining food security.

According to the 2017 Agricultural Census conducted by Statistics South Africa (2020), the large-scale agricultural sector comprised 40,122 farms, whereas the small-scale agricultural sector comprised more than 300,000 units. In addition to the 300,000 units, the General Household Survey of 2019 revealed that an additional 2,3 million households were engaged in subsistence-oriented agricultural production activities (Statistics South Africa, 2020). Hawkes et al. (2012) stated that the production of food by SHFs has the greatest potential for either improving or generally influencing the nutrition of their household members directly through consumption or indirectly through the generation of household income, which could enable them to purchase additional food items to satisfy their dietary needs. This demonstrates that the food production of SHFs may be one of the most important factors in enhancing food security on a domestic level.

Subsistence agriculture contributes to food security, poverty reduction, sustainable rural livelihoods, and household food supplementation (Baiphethi and Jacobs, 2009, Mngqawa et al., 2016, Viljoen, 2006).

One of the biggest challenges within the agri-food system is the unequal wealth and power relations across global supply chains, which favour large multinational retailers, industrial producers and patent holders at the expense of small farming enterprises, exploited agricultural workers, and consumers at risk of food insecurity (McMichael, 2009). In response, the South African government is planning to implement 44 Agri-parks, one in each municipal district across the country, aiming to revitalise agriculture, catalyse rural industrialisation and support smaller-scale farmers (Department of Rural Development and Land Reform, 2016). The relevant provincial departments and local municipalities are also involved in the execution and management of the Agri-parks. An Agri-park is defined as '*a networked innovation system of agro-production, processing, logistics, marketing, training and extension services, located in a District Municipality. As a network, it enables a market-driven combination and integration of various agricultural activities and rural transformation services*.' (Department of Rural Development and Land Reform, 2016).

However, the Agri-parks initiative is struggling to develop farmers who can farm successfully and independently. The managers of the Agri-parks are often frustrated by the farmers' poor adoption of technologies that could improve their resource use efficiency and production outcomes. During the previous WRC project on Agri-parks (le Roux et al. 2022), several tools were introduced, but in general, they are not used or maintained. The question is: why are the tools and techniques not working? We agree with van Rooyen et al. (2017), the problems that are faced in the small-scale farming context are not only technological in nature, but they are part of a complex socio-ecological system. The problem can be with the:

- Resources and tools available
- Labour and skill required to use available tools and to farm successfully
- Demand/lack of demand for the products

All of the above are influenced by the social context, culture and the things that motivate the farmer. Motivation can vary from passion for farming, survival, making money etc. Understanding all these aspects and how they interact and combine will form the framework for our approach (le Roux and van Niekerk, 2022).

2.2 DEFINING A SMALLHOLDER FARMER

As a starting point, it is important to define the concept of an SHF within the South African context. Various definitions for an SHF have been published and there is no standard definition. The definition of SHFs varies by country and agro-ecological zone, as does the concept of "small" (Dixon et al., 2003, Machingura, 2007, Nagayets, 2005, Narayanan and Gulati, 2002). This illustrates the frequent and interchangeable nature of "smallholder" with "small-scale," "subsistence," "resource-poor," "small," "low-income," and "low-input," etc (Machingura, 2007, Nagayets, 2005). Moreover, the lack of high-quality data on SHFs exacerbates the problem of defining an SHF (Cousins, 2013).

In South Africa itself, the terminology used to refer to SHFs has been inconsistent and encompasses a variety of general definitions. Diverse authors have utilised a variety of descriptors to classify SHFs, and these terms have been interchanged (Ortmann and Machethe, 2003). For example, subsistence farming and small-scale farming are sometimes used interchangeably (Aliber et al., 2005). The literature has classified SHFs in terms of:

- **Number of farmers/workers:** which makes classification challenging.
- **The size of the farm**: Kirsten and Van Zyl (1998) discredited the attempt to classify SHFs based on the size of the land because a high-value crop can produce commercial yields on a small piece of land, such as one hectare, while five hundred hectares of low-quality land in another region may produce low yields. The authors define an SHF as a farmer who operates at a scale that is too small to attract the services required for increased production. We agree that farm size should not be the only indicator to classify a farmer as an SHF, but in the rural context farm size can be one of several valuable indicators of SHFs. There are many examples of very typical farms in the rural context that are generally low-tech and low energy systems, making intensive farming like hydroponics rather an exception than a rule.
- **Economic variables:** Kirsten (2011) proposed economic variables to define SHFs, including gross farm income below R500,000

Small-scale farmers are said to be primarily seeking to augment food security in agriculture on farms ranging between 1 and 5 ha (Elleboudt, 2012) and selling excess through informal trade (Bureau for Food and Agricultural Policy, 2020, Rusere et al., 2019, Statistics South Africa, 2020, Thamaga-Chitja and Morojele, 2014, Zantsi et al., 2019). Cousins and Chikazunga (2013) proposed a four-part typology of farmers:

- **Category 1** consists of subsistence-oriented SHFs who produce primarily for domestic subsistence and whose agriculture is not significantly linked to markets.
- **Category 2** consists of market-oriented SHFs who are only loosely integrated into value chains; typically, they market a significant portion of what is produced, but agriculture is only one of many household livelihood activities and may not account for the majority of household income.
- **Category 3** SHFs are market-oriented and tightly integrated into value chains. They frequently depend on agriculture for a substantial portion of their household income and are more likely to rely on external financing and non-household labour. Generally, the domestic economy and enterprise economy are intricately intertwined, as is farming.
- **Category 4** consists of capitalist SHFs who consume little or none of their own produce, rely heavily on hired labour, are highly reliant on external sources of capital, and exhibit a relatively clear distinction between the household unit and the business unit.

We agree that the four-part typology is a useful way to classify SHFs. It would also be useful to have a general description of the dynamics on each of these levels, for example, resource use (water, energy, labour etc) and infrastructure requirements, typical markets and a typical budget/business plan. On each level we find different combinations and configurations of these, with its own advantages and difficulties.

2.3 OVERCOMING OBSTACLES IN SMALL-SCALE AGRICULTURE

2.3.1 Typical problems that smallholder farmers face

While the government as a whole has advocated for the ongoing support of SHFs for more than 25 years, information on these farmers, including size of land on which SHFs operate, percentage of income generated from formal and informal trading, market access (including transport, roads and market demand), quality standards and best practice methods and resources used for farming, is still scarce. There are significant differences between groups of agriculturalists who are frequently lumped together, including cultural backgrounds, formal level of education and motivation for farming, as well as commonalities that span across their activities. This is one of the main challenges to assist farmers efficiently (Okunlola et al., 2016).

We agree that small farmers cannot be uplifted through generic support programmes, but that targeted interventions are needed based on the needs of the farmer. Typical problems that SHFs in South Africa face are discussed below.

2.3.1.1 Low productivity

Low agricultural productivity is one of the main problems of SHFs. Globally, production by SHFs is negligible compared to that of large-scale farmers (Cervantes-Godoy, 2015), but they do play a crucial role in local food systems. Mathinya et al. (2022) compared SHFs with profitable large-scale farmers, to understand the causes of low productivity. The study concluded that low productivity of SHFs is not only due to biophysical limitations, but also to the problems that emerge from the context at the farm and regional levels. Therefore, interventions aimed only at the field scale are likely to be unsuccessful in solving the problems. Prospects for SHFs are constrained by the highly competitive commercial-scale agricultural sector, which dominates the markets. More information is needed to better understand the full contribution of SHFs in terms of food security and income generation, etc (Mathinya et al., 2022).

2.3.1.2 Lack of resources

The lack of natural resources hinders the growth and productivity of SHFs and their ability to access formal markets (Mpandeli and Maponya, 2014, Von Loeper et al., 2016). The adoption of technology by SHFs is limited by poor access to necessary resources (Guo et al., 2020). Water scarcity and inefficient water use can result in crop failure (Andersson et al., 2013).

2.3.1.3 Access to land

Rural communities are dependent on the land and resources that are available to them to sustain themselves, and communal farm lands sustain millions of people (Shackleton, 2020). According to Mpandeli and Maponya (2014), Shackleton (2020), Von Loeper et al. (2016) the most disturbing problem for SHFs in the rural communities of South Africa is the lack of access to and ownership of arable land. Some SHFs have access to less than one hectare of land for agricultural production (Tshuma, 2014). The lack of land, together with other obstacles such as a lack of capital and droughts, presents problems for SHFs to farm productively.

Generally speaking, households have exclusive use rights to arable land and communal use rights to grazing land. Small-scale producers lack private property rights because the land is owned by the state and administered by traditional authorities, making long-term investments in agriculture unattractive.

2.3.1.4 Lack of capital to invest

A lack of capital is one of the key differences distinguishing large-scale farmers from SHFs. If SHFs do not have the capital to invest in their farm, they are more exposed to risks and lower productivity. For large-scale farmers, taking a risk to make an investment that does not pay off may result in debt, but for SHFs, such a risk may result in food insecurity. Producers must perceive adequate welfare benefits as a result of an investment, before they would be willing to make it (Senyolo et al., 2018). Fanadzo et al. (2021) found that farmers in the West Coast and Overberg Districts, Western Cape, who had access to livelihood capitals and assets tended to cope and adapt better to drought than those who did not.

While the sustainability standards provide a transparent network, a set of standards and best practice guidelines for sustainable farming, among other advantages, the initial cost may be out of reach for many SHFs without external assistance (Meemken, 2020).

2.3.1.5 Other challenges

Several other problems are often mentioned. These include theft and safety issues, unreliable energy and water pollution.

2.3.2 Possible solutions to problems that smallholder farmers face

Literature sources suggest some solutions to the problems that SHFs in South Africa deal with. These are summarised below.

2.3.2.1 Standards

The adoption and compliance of sustainability standards result in costs and benefits for producers, but despite these costs, certified farmers usually benefit from rising output costs. However, SHFS may be unable to distribute their entire harvest via certified value chains, which could happen when an excessive number of growers in the same region produce certified crops. Certified farmer organisations also offer agricultural training and other services to its members. This is especially significant in areas with restricted access to extensions. Standards can also provide a mechanism for producers to increase output and product quality (Meemken, 2020). It is unlikely, however, that SHFs will invest in these standards if they lack the market access, which they often do not have, to benefit from the higher prices for their produce.

2.3.2.2 Information inputs

Although research on farm-scale interventions that may directly or indirectly contribute to increased productivity is limited, it does exist. To reduce post-harvest losses, interventions such as alternative storage techniques, techniques that improve water use efficiency, succession planting, and the establishment of field nutrient-management zones are implemented. Mixed farming is an example of integrating crop production with livestock (Hosu and Mushunje, 2013). Ecological sanitation and water harvesting can improve crop yield and water productivity (Andersson et al., 2013).

Our approach to empowering SHFs with information is unique. We are mindful that information can be dangerous if it is given without the necessary regard for the complex system in which it will be used. Our approach is to develop better practices on-site with the SHFs, until all agree that such a practice is a solution to their problems and that it is sustainable and beneficial.

2.3.2.3 Network to support farmers

A national survey conducted in South Africa by Okunlola et al. (2016) revealed that the private sector and other non-government actors provide a variety of forms of assistance to SHFs. University research and support groups such as the Agricultural and Rural Development Research Institute at the University of Fort Hare and the Farmer Support Group at the University of KwaZulu-Natal are examples of these actors. Successful outcomes of SHF support programmes have been documented, *albeit* with possibly limited scope and reach. Apleni et al. (2019) report that the Fort Hare Farmer Field School increased farmers' self-assessed knowledge and skills regarding the production, consumption and sale of vegetables in the Eastern Cape Province. We agree that many solutions may emerge if farmers are connected to a network of role-players. This principle was taken up in our methodology.

2.3.2.4 Finding alternative markets

Instead of seeking to compete within the commercial value chain, SHFs could look at other ways of increasing their profitability by means of agro-processing and entering alternative markets where high-value crops are grown, or mixed farming is practiced in sustainable and organic ways, thereby increasing profitability. More research on a regional scale is necessary to assist SHFs with relevant information regarding market accessibility as well as meeting the needs of the local community, ensuring resilience and food security within their feeding area.

Alternative food networks have the potential to assist SHFs and is characterised by a shorter distance between producers and consumers (often eliminating the intermediary), small-scale agriculture and production, an emphasis on local food, and a concentration on sustainable or organic food products (Renting et al., 2003). These networks emerged as a reaction to large-scale industrial agribusiness and a solution to the problems of marginalised rural regions.

2.4 COMPARING MODELS OF COOPERATIVE SMALLHOLDER FARMING

Various models of cooperative smallholder farming have been analysed and compared in this project. These include the original Agri-park model, the various models that have emerged in Rooiwal, Tarlton, and Westonaria Agri-parks, and other models that have emerged in Musina (Mango production and processing), the Community Supported Agriculture (CSA) model and the Agricultural Innovation Platform (AIP), which could be considered as options for best practices.

2.4.1 Agri-park model

The original Agri-park model consists of three components (Department of Rural Development and Land Reform, 2016), namely:

1. A **Farmer Production Support Unit (FPSU)** is the unit that supports rural smaller scale farmers by providing agricultural input supply control, extension support and training, mechanisation support (tractor driving, ploughing, spraying, harvesting etc.), machinery servicing workshop facilities, local logistics support (delivery of farming inputs, transportation postharvest transportation to local markets), processing and packaging etc.

2. An **Agri-Hub (AH)** which supports several FPSUs by providing storage and warehousing facilities; cold storage, dehydrators, silos, weighing facilities, agri-processing facilities (mills, abattoirs), enterprise development areas that lease space to high intensity start-up industries that can benefit from the inputs of outputs of the Agri-hub, i.e. piggeries, tunnel grow crops, bio-gas production, large scale nurseries to supply FPSUs, packaging facilities for national and international markets, logistics hubs for collection of goods from the FPSUs, soil testing laboratories, housing etc.
3. A **Rural Urban Market Centre (RUMC)** is a separate unit in which both the FPSUs and AH provide inputs, to support more than one Agri-park by providing market intelligence, assistance to farmers in managing contracts, warehousing and cold storage facilities, logistics and transport in the collection of produce from FPSUs or AHs.

Figure 2-1 shows the Agri-park model that was presented by the Department of Rural Development and Land Reform (2016). According to this model and map, an Agri-park would be a new management structure that connects and assists a relatively large region of farmers, most of whom probably exist already. According to the Department of Rural Development and Land Reform (2016) the Agri-park initiative is guided by the following principles:

- That one Agri-park per district municipality will be established,
- That Agri-parks be controlled by farmers,
- That Agri-parks must stimulate rural industrialisation,
- That Agri-parks must initially be supported by the government to ensure economic sustainability,
- That agricultural production is supported by providing farmers with services, such as water, energy, transport and training and by developing existing markets and creating new markets,
- That farmers are supported to benefit from existing state land with agricultural potential,
- That access to markets is maximised, with a bias to emerging farmers and rural communities,
- That the use of high-value agricultural land is maximised,
- That existing agro-processing, bulk and logistics infrastructure, roads and available water and energy is utilised to full potential and
- That growing and rural towns are revitalised, by stimulating economic growth and promoting rural urban linkages.

The original Agri-park model was a support system, where resident SHFs are provided with support to improve their productive outcomes. This model is a top-down approach (the government initiates it and there is a hierarchy of control)

The actual Agri-parks, however, are completely different from the model. Instead of being a support system to existing landowners, the Agri-parks now give land at the hub and a certain level of support to a few farmers. Farmers are taken out of the private land farming context, and put into a new context, where they are not landowners, and they often have limited powers. The existing Agri-parks are very similar, but each has developed their own management systems.

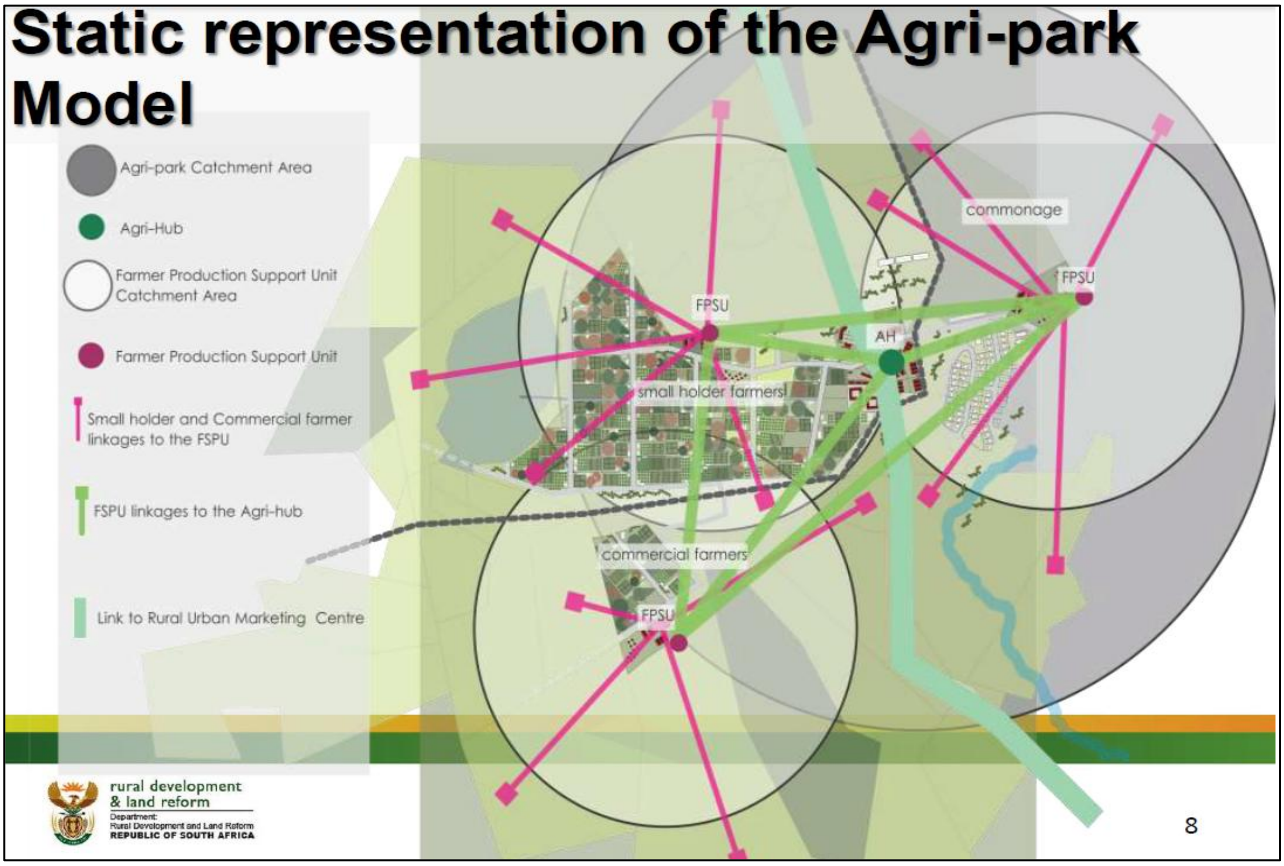


Figure 2-1: The Agri-park model (Department of Rural Development and Land Reform, 2016)

2.4.2 Mango processing in Musina

A tropical fruit processing and drying facility in Limpopo dries large quantities of mango for the local and export markets. Mango fruit is being sourced from commercial as well as black SHFs producing mangos. In 2020, the company was awarded a Jobs Fund grant from the Department of Finance for the development of commercial mango orchards, with black farmers being the beneficiaries. The grant funding from the government made up only 40% of the funds required for the establishment of the orchards. The other 60% had to be match-funded in the form of loans from the private sector. The mango developments are therefore funded with a combination of grant funding and loans. These developments involved all the costs up to the planting of the trees. Additional funding is still required for the maintenance of the orchards until they are in production. When a new farm is established, the funding allows for the support of the SHF until the mango trees start to produce. Once in production the owner harvests the fruit from where it will be collected by the processor (Nel, 2023).

Although the external appearance of the fruit does not need to be perfect, the internal quality must be top grade. For this reason, only certain cultivars are being utilised for drying. An off-take agreement between the producer and the processor ensures a secure market for the farmer. The processor buys fruit directly from the primary producers at market-related prices of fruit for processing. The agreement further stipulates that the supplier is obliged to supply his fruit exclusively to the processor until such time as the development loans are fully redeemed. After that, the farmers will be free to market their fruit wherever they prefer. However, the farmers have indicated that a secure market is important for them and they would prefer to continue selling their fruit to the processor (Nel, 2023).

This model is similar to a commercial farmer, with the main difference that the farm workers become landowners, who can develop agency on their farm, but still have access to the support of the commercial farmer, who now fulfils the role of processor instead of being the landowner.

2.4.3 Community Supported Agriculture (CSA)

The CSA model emphasises the social and communal aspects of the relationship between consumers and producers, although the implementation of this aspect by management may vary from network to network. With a direct partnership between the farmer and a group of consumers or members, all stakeholders share the hazards and responsibilities of farming. The goal of CSA is to produce and distribute food that is environmentally, socially, economically, and nutritionally sustainable (Samoggia et al., 2019).

A CSA employs specific economic, financial, and management practices and ensures a dependable market. A group of consumers who receive weekly deliveries of fresh produce financially supports the farmers for an entire season. Typically, CSA members acquire a share prior to the start of the season. The CSA members and producers share production risks and rewards (Bloom and Hinrichs, 2011, Horst et al., 2011, Kneafsey et al., 2013).

A major advantage of CSA farming is that it eliminates the various food chain stages and interconnections with food chain intermediaries required by conventional food systems to reach the final consumer. This enhances the distribution along the value chain. Farmers are guaranteed a stable and equitable market regardless of seasonal or climatic changes. The CSA members receive a complete share of fresh produce regularly. Long distribution channels in the agro-food chain often result in low producer profits (Bertazzoli et al., 2011, Bregendahl and Flora, 2006, Nie and Zepeda, 2011).

Prior research has established some drawbacks, such as dissatisfaction of CSA members with the inability to choose the share products, the lack of variety, the excessive quantity of products, and the distaste of the delivered product, which results in food waste. Consumers are accustomed to being able to choose the food they want without relying on adverse weather conditions and yield fluctuations. This discontent may discourage members from renewing their CSA membership for the following year. (Lang, 2010, Réthy and Dezsény, 2013). Good communication and constant feedback to members can facilitate their comprehension of agricultural practises and CSA farm dynamics (Chen and Tan, 2019).

2.4.4 Application of the Agricultural Innovation Platform in Zimbabwe, Malawi and Tanzania

The Agricultural Innovation Platform (AIP) was developed and tested by van Rooyen et al. (2017) in six small-scale irrigation schemes in Zimbabwe, Malawi and Tanzania. The method is based on the complex systems theory, arguing that an SHF is a complex socio-ecological system. The typical problems experienced by SHFs, of which there are often many, such as a lack of water and markets, poor access to infrastructure and equipment etc, are most often, incorrectly, treated as technical problems, because the technical issues are the most visible and easiest to correct (van Rooyen et al., 2017). He argues that the root cause of the problem is that, when SHFs transform from subsistence-based agriculture to production systems that are market-oriented, the institutional structure in which they operate has not adapted to this new situation. In order to address this problem, it is important to involve all relevant stakeholders, including government, private sector, scientists etc. The key to the success of this cooperative farming model is the strong interactions between the farmers and the stakeholders, where a relationship of trust is established and all the necessary roles are identified (van Rooyen et al., 2017).

2.5 AGRI-PARKS AS A COMPLEX SYSTEM

We consider SHFs in an Agri-park context to be a complex socio-ecological system, with many actors that interact on various levels and produce unexpected outcomes. According to Preiser (2019), complex systems have certain characteristics which should influence the way we engage with them, for example:

- Complex systems are not only driven by the components within the system, but also by the interactions between the components
- Interactions within complex systems are dynamic and nonlinear, making them unpredictable, so that they cannot be controlled
- The context is important, because complex systems evolve and organise themselves according to changes in the environment. The boundaries between the complex system and its environment are not clear
- Solutions to problems that may occur in complex systems must emerge from within the system, or at least must be integrated into the system, it can usually not be produced outside the context and then merely imported into the system

The problem that government support to emerging farmers leads to dependence is just another example of complex systems that respond in unexpected ways to inputs or changes from outside. The reason for these failures is that the offered solutions do not address the fundamental problems, which are often very poorly understood.

Complex systems must be able to adapt to changing circumstances to remain resilient. Therefore, rules and regulations must be applied in such a way that they do not limit the role-players from responding to problems. Suitable responses to changes are also subject to the availability of feedback mechanisms and leverage points in the system. For example, Stirzaker et al. (2017) found that the chameleon sensor and the wetting front detector provided emerging farmers in Tanzania with the necessary feedback to know when to stop irrigation and why. The chameleon sensor indicated over-irrigation, while the wetting front detector indicated when nitrates were washed past the root zone. Using these tools together, farmers understood that over-irrigation caused leaching of very expensive fertilisers, and that resulted in the necessary behavioural changes. Water use efficiency and scarcity did not inspire farmers to change their irrigation practices, but the loss of expensive fertilisers did. Thus, saving fertilisers is the leverage point in that system, as opposed to water scarcity. We find similar unresponsiveness to water use efficiency among emerging farmers at Rooiwal, despite water scarcity.

The Fadama project in Nigeria successfully empowered and developed emerging farmers in a community-driven way (Hima et al., 2016). The success of the project was ascribed to the fact that communities were responsible for decision-making, and to the continuous process of learning and adaptation. Through this process, the project managed to exceed its targets in terms of the number of direct and indirect beneficiaries, supporting marginalised people and creating jobs. Local government was empowered, conflict resolution became more successful and effective response to emergencies were improved.

2.6 CHALLENGES OF UPLIFTING INFANT INDUSTRIES

There are different schools of thought regarding how emerging industries become independent. There is a spectrum of opinions: on the one hand, some argue that there will be no development without government support, on the other hand, some argue that free markets and access to resources will naturally lead to new economies arising (Coutinho et al., 2012).

The concept of "infant industry" refers to new or emerging industries that are not yet able to compete effectively with established foreign competitors (Melitz, 2005). The infant industry concept is concerned with export, but the same principles will apply to emerging farmers who are not competitive in the local commercial context. Much research has been done globally to find ways of protecting infant industries, but generally, the problem arises that the support leads to dependency, and that there are very few examples of successful infant industries in developing countries despite investments and policies to protect them (Bell et al., 1984). Typical strategies employed to ensure that support for infant industries leads to sustainable growth without fostering long-term dependency include:

- **Set Clear Objectives and Timelines and Gradual Reduction of Support**: Define specific goals and timelines for the support measures. Ensure that there is a clear plan for how and when industries are expected to become self-sufficient and competitive. Implement a gradual phase-out of protectionist measures. According to Ray (1998), the success of temporary support for infant industries depends on the government's commitment to end support. Only when the receivers of the support know that it will come to an end, will they make the effort to reduce costs and become competitive.
- **Focus on Competitiveness**: Provide support that enhances the competitiveness of infant industries. This could include investments in technology, research and development, and workforce training to help these industries innovate and improve efficiency.
- **Encourage Innovation**: Promote innovation within supported industries. This can be achieved through incentives for research and development, partnerships with academic institutions, and fostering a culture of innovation. According to Aubert (2005) innovation does not only refer to technology, but can also include new ways of marketing, of management, etc. This is often a difficult task in developing countries where resources are generally limited.
- **Performance-Based Support**: Link support measures to performance benchmarks. For instance, subsidies or other forms of assistance could be contingent on achieving specific milestones related to production efficiency, market share, or export performance. According to Mumssen et al. (2010), output based aid is considered successful in, among others, enhancing transparency, private sector engagement, innovation and efficiency.
- **Monitor and Evaluate**: Regularly assess the effectiveness of protection measures and the progress of supported industries. Use these evaluations to make data-driven adjustments to policies and support mechanisms.
- **Encourage Private Sector Investment**: Reduce reliance on government support by encouraging private sector investment. This can be done through tax incentives, public-private partnerships, and creating a favourable business environment.
- **Develop Supporting Infrastructure**: Invest in infrastructure that supports industry growth, such as transportation, energy, and technology. Strong infrastructure can enhance the efficiency and competitiveness of emerging industries.

The measures above form part of a top-down approach, and it is worth considering each when establishing an Agri-park. Output-based aid is better than providing input support, because it encourages farmers to produce before receiving support, but it does not ensure that farmers will continue production when support is no longer provided. Private sector involvement is also important, as this creates a more diverse system for farmers, from where they can access markets and get support. However, many of the above measures have already been proven unsuccessful in current Agri-parks. For example:

- Enhancing competitiveness through training is unlikely to improve the success of farmers, especially when training is given outside the context where technologies will be applied, and by a person who is unfamiliar with that context. We believe that mentorship and co-design will be more suitable forms for information sharing.
- Government officials say that farmers gradually reduce production according to the reduction in support. If government exits, the farmers cease operations.
- Developing infrastructure on the farm is not always suitable, because many farmers do not maintain the infrastructure, some even sell it for cash.

Top-down interventions are important, but there is a clear need for a positive response from the bottom up. Kandachar and Halme (2008) discuss the way in which the bottom of the pyramid concept was applied by various industries. The bottom of the pyramid refers to the vast number of poor people in the world, who are seen as a potential market for businesses, compared to the small number of rich people. Some companies aim to produce cheap products for the poor, however, these products are often still out of reach of the poorest segment. In response to these problems, it was argued that the poor can only be supported if they become producers, rather than mere consumers of cheap products. Kandachar and Halme (2008) further argued that we should move beyond turning the poor into 'consumers' or 'producers' and start to consider them as 'partners' to co-create new businesses that will produce mutual benefit. This way of thinking is more focused on the relationship between the emerging farmers and the developing agents, which could be the government.

2.7 WATER RESOURCES

The Rooiwal Agri-park lies within the Apies River quaternary catchment, A23E, of the Crocodile West Catchment (A23E), which is characterised by flat to gently undulating topography (BKS, 2008). Farmers in the broader Agri-park area have access to direct pumping from the Apies River and groundwater. Farmers inside the Agri-park have access to groundwater only. Should it be viable, it may be possible to access treated effluent from the Rooiwal Wastewater Treatment Works (WWTW) which is located adjacent to the Agri-park.

2.7.1 Apies River flow

The surface area of the Apies River catchment is 490 km^2. The mean annual precipitation is 674 mm and the mean annual runoff in the Apies River is 14.34 million m^3. The Rooiwal WWTW discharges its treated effluent into the river, increasing the total cumulative mean annual runoff to 31 million m^3 (BKS, 2008). Abstraction is possible from this river, but a Water Use Licence (WUL) would be required from the Department of Water and Sanitation (DWS). Through these licenses, DWS allocates volumes of water that may be abstracted by users.

2.7.2 Apies River Water Quality

Tau et al. (2021) undertook an assessment of sewage pollution on the Apies River. The pollution index of the river (concentration at the end/concentration at beginning) shows notable increases in concentrations of all pollutants downstream of the WWTW effluent discharge (**Table 2-1**). There are some natural sources of pollution in the Apies River such as the weathering of geological formations; whereas the anthropogenic sources are agriculture; municipal WWTW and direct deposit of waste into the river. The natural sources of pollution contributed towards chemical pollution, whereas the anthropogenic sources contributed to both chemical and microbiological pollution. The Apies River becomes hypertrophic downstream of the Rooiwal WWTW; however, the current physiochemical state of the river does mean it may be used for safe irrigation in agricultural practices. The current microbiological state of the river does make it harmful for human consumption, especially as drinking water.

Table 2-1: Water quality up- and downstream of Rooiwal WWTW (Tau et al., 2021)

Parameters in water	Upstream average	Downstream average	Pollution index
E Coli	364	2420	6.6
Total Dissolved Solids (mg / ℓ)	308	432	1.4
Suspended Solids (mg / ℓ)	4.6	46.6	10.1
Conductivity (mS / m)	55.2	85.7	1.6

Parameters in water	Upstream average	Downstream average	Pollution index
Absorbed oxygen (mg / ℓ)	3.4	13.9	4.1
Chemical Oxygen Demand (mg/ℓ)	16.9	97	6.1
Nitrate (NO_3) (mg / ℓ)	0.9	1.3	1.5
Nitrite (NO_2) (mg / ℓ)	0.1	0.8	12.8
Ortho-phosphate (PO_4) (mg / ℓ)	0.1	1.9	34.5

2.7.2.1 Apies river pollution upstream of the WWTWs

The presence of *E. coli* upstream shows that there is *E. coli* pollution that is not only contributed by the Rooiwal WWTW but other sources as well (**Table 2-1)**. Chemical Oxygen Demand (COD) is a measure of organic pollution intensity and the levels of COD range between 12 and 20 mg / ℓ. These levels are low and therefore correlate with the levels of *E. coli* at the site. There are no minimum standards for levels of *E. coli* in aquatic ecosystems, as it is not pathogenic to fish; however, the presence of *E. coli* serves as an indication of human and animal waste in the river. There is a South African Water Quality Guidelines for Recreational use (Department of Water Affairs and Forestry, 1996) and based on the full-contact recreational guideline, the water upstream of the WWTWs is unsuitable for swimming and poses a risk of gastrointestinal illnesses. The river is suitable for intermediate contact recreation such as canoeing and water skiing. Total Dissolved Solids (TDS) of the Apies River upstream of Rooiwal ranges between 284 and 332 mg / ℓ; with chloride, calcium, magnesium and sodium being the most dominant elements in the water. The average orthophosphates (PO_4) concentration of the river ranges between 0 and 0.11 mg / ℓ at the upstream site. The values are below the hypertrophic threshold value of 0.13 mg / ℓ; therefore, the Apies River upstream from the Rooiwal WWTW fluctuates between the states of oligotrophic and eutrophic. The fluctuations may be as a result of variation in the flow of agricultural run-off towards the river. Nitrates (NO_3) range between 0.75 and 0.98 mg / ℓ. Nitrates follow a similar trend to the COD with higher concentrations downstream

Per- and polyfluoroalkyl substances (PFAS) are persistent environmental contaminants widely detected in water and sediment worldwide. These chemicals are man-made and known for their heat and water-resistant properties, but they are also extremely persistent and can accumulate in the environment and living organisms. These "forever chemicals" are used in many everyday products, such as non-stick cookware, stain-resistant fabrics, and firefighting foam, and can enter the environment through manufacturing and waste. Exposure to certain PFAS has been linked to serious health impacts, and regulatory efforts are underway to reduce their presence in the environment and food chain.

A study by Okwuosa et al. (2025) aimed to address the knowledge gap in PFAS contamination by analysing the spatial and temporal distribution of 18 PFAS in the Apies River water and sediment in Pretoria, South Africa. Surface water and sediment samples were collected upstream and downstream of the Rooiwal WWTW on the Apies River during dry seasons. The study revealed significant spatial variations in PFAS contamination, with upstream locations consistently exhibiting higher concentrations than downstream. Perfluorocarboxylic acids were the dominant PFAS class in surface water (50.47–57.15 %), whereas perfluorosulfonic acids were more prevalent in sediments. The PFAS concentrations observed in this study exceeded several established regulatory guidelines for both water and sediment. While international thresholds for PFAS in sediment remain limited, the European Union's proposed environmental quality standard for PFOS in sediment is 13.5 ng / g, a value that was significantly surpassed by some chemicals measured in this study. Similarly, for water, PFAS concentrations in surface water reported in this study exceeded the European Commission's recommended limit of 4.4 ng / ℓ. (Okwuosa et al., 2025).

2.7.2.2 Apies river pollution downstream of the WWTWs

The average concentration of *E. coli* downstream of Rooiwal is 2420 mg / ℓ (**Table 2-1**). This value is significantly higher than upstream. The elevated levels of *E. coli* can be attributed to the direct input of Rooiwal WWTW effluent into the river. The PO_4^- concentration of the river downstream ranges between 1.28 and 2.51 mg / ℓ. The values are significantly higher than the hypertrophic threshold value of 0.13 mg / ℓ; therefore, the Apies River downstream is hypertrophic as a result of effluent input from the Rooiwal WWTW. The PO_4 concentration of the effluent ranges between 4.12 and 4.68 mg / ℓ. The NO_3 concentrations ranged between 1.1 and 1.55 mg / ℓ. According to Ekwanzala et al. (2017), NO_3 levels in the effluent from the Rooiwal WWTW are also very high, with an average concentration of 18.3 mg / ℓ as a result of the presence of nitric acid from poor pH control at the Rooiwal WWTW.

A study by Abia et al. (2018) evaluated the bacterial diversity in water and sediments in the Apies River to find out how the different land uses influenced the bacterial diversity and to verify the functional classes of human diseases in the bacterial populations. The study confirmed the anthropogenic impact on water quality. Samples were collected on river stretches influenced by an informal, peri-urban and rural settlements. Genomic DNA was extracted from water and sediment samples and sequenced. Metagenomic data analysis revealed that there was a great diversity in the microbial populations associated with the different land uses, with the informal settlement having the most considerable influence on the bacterial diversity in the water and sediments of the Apies River. The *Proteobacteria* (69.8%), *Cyanobacteria* (4.3%), *Bacteroidetes* (2.7%), and *Actinobacteria* (2.7%) were the most abundant phyla; the *Alphaproteo* bacteria, *Betaproteobacteria* and *Anaerolineae* were the most recorded classes. Also, the sediments had a greater diversity and abundance of bacterial population than the water column. The functional profiles of the bacterial populations revealed an association with many human diseases including cancer pathways (Abia et al., 2018). While the study did not specifically determine the impact of the Rooiwal WWTW, it does show that human influence on rivers can be significant.

2.7.3 Groundwater aquifer

Granite underlies a considerable portion of the Quaternary catchment, A23E. In general, groundwater occurrence is controlled by weathering and structure. Groundwater occurrence is widespread but generally low, borehole yields are usually below 0.5 ℓ / s, although sustainable yields up to 2 ℓ / s are locally available (Department of Water Affairs and Forestry, 2004).

Most of the area is Bushveld with ranching and some agriculture. Groundwater occurrence tends to be between 40 and 100 m deep. Groundwater quality is generally good. However, zones of elevated TDS (conductivity >150mS / m) and NO_3 are present in the catchment (Department of Water Affairs and Forestry, 2004).

There is no detailed analysis of the sustainable yield of the groundwater resources at Rooiwal. The Revision of General Authorisation for the Taking and Storing of Water, Notice 538 of 2016, states that a general authorisation does not apply and that no abstraction can take place without a WUL. The notice also stipulates that a maximum allowable abstraction of 45 m^3 per hectare per annum can be abstracted, and any abstractions below 45 m^3 are subject to a WUL. At Rooiwal (42 ha), this would amount to an annual abstraction of less than 5 m^3 per day if a WUL is in place.

The groundwater quality at Rooiwal can be described as poor with elevated EC (>150 mS / m), and high concentrations of NO_3 (>500 mg/l). This poses a health threat to consumers of the water as it is an order of magnitude higher than the SANS241 drinking water standards. Heavy metal concentrations are below detection and health limits. Orthophosphate concentrations are very low for use as a source of water without fertiliser. Phosphate will probably need to be added. In the absence of good quality groundwater data for the whole area, the initial evaluation indicated that the groundwater contamination is coming from various operations at the Rooiwal WWTW (seepages from the maturation ponds, sludge management etc).

2.7.4 Using wastewater for fertigation in hydroponics systems

2.7.4.1 Literature studies on irrigation with wastewater

Wastewater reuse for agriculture has developed into a strategic option to improve water use-efficiency, promote sustainable management of freshwater resources, and recycle nutrients in food production systems. Wastewater reuse shows potential as both a water resource and a source of nutrients for crop growth. In regions with issues of water scarcity, such as South Africa, where SHFs face this resource constraints, integrating recycled treated sewage wastewater effluent (SWE) will align with sustainable growing strategies (Mpandeli and Maponya, 2014).

Empirical evidence indicates the potential for SWE to boost agricultural productivity in the short-term. Jiménez (2006), Kharub (2020), and Ngasoh et al. (2020) showed SWE irrigation can improve soil physicochemical properties, and fertility, provided sodium contamination is kept below acceptable thresholds. SWE includes macro-elements such as nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and sulphur (S), and trace micro-elements such as iron (Fe), boron (B), manganese (Mn), zinc (Zn), and copper (Cu) (Mai et al., 2023). The nutrients represented in SWE are critical to plant metabolic processes, but levels in SWE vary from source to source and by treatment (Hofmann et al., 2024). Such variability requires strong water quality monitoring and nutrient replenishment programmes to avoid inconsistent crop performance. However, research gaps in the literature include comprehensive investigations on the seasonal variability of SWE nutrient profiles, and the potential influence of SWE nutrient profiles on hydroponic crop performance, using sustainability as the metric, in typical conditions in which crops are grown.

The advantages of fertigation with SWE are acknowledged and documented. Jiménez (2006), and Ngasoh et al. (2020), reported increases in crop yields, reductions in chemical fertiliser reliance, the conservation of freshwater resources, and recycling of organic matter. For smallholder farmers, SWE can provide an offset to significant fertiliser costs. However, the use of SWE can present chemical and biological risks. Ndunda and Mungatana (2013) noted increased incidence of gastrointestinal illnesses and skin irritation in farmers using SWE in Kenya, although there were confounding factors with sanitation that limited the ability to draw a causal relationship. Risks in the form of chemicals may involve heavy metal bioaccumulation. Kharub (2020), noted metallic cation accumulation in soils and crops following extended exposure to SWE irrigation and found instances of levels above permissible limits.

Kreuzig et al. (2021) looked at lettuce cultivation in a hydroponic system with reclaimed water, focusing on food safety risks posed by micropollutants, specifically pharmaceutical and personal care product residues. The study indicated that while conventional tertiary treatment eliminated microbial contamination, it did little to remove a number of persistent micropollutants that accumulated in the recirculating nutrient solution. This point reinforces a fundamental weakness in SWE use: conventional treatment processes cannot remove all contaminants, even if pathogens are eliminated, and other advanced treatment technologies (e.g., activated carbon filtration, advanced oxidation processes) may be critical for crops that are consumed raw and of high value.

However, monitoring and analysis of SWE typically focus on conventional water quality monitoring (pH, EC, N, P, K, and heavy metals concentrations) and does not include micropollutants. For crops like lettuce that are consumed with minimal processing, lack of monitoring for micropollutants represents a consumer safety risk.

According to FAO, SWE treatment should depend on the type of crop and the method of irrigation, to reduce the potential for risk. As indicated, the drip irrigation used in this study drip bag hydroponic system limits leaf contact and any pathogen transfer compared to a sprinkler system where there is an increased risk of exposure (Jiménez 2006).

From a feasibility standpoint, Schrammel (2015) conducted an economic analysis of hydroponics with SWE treatment in Sweden that demonstrated the feasibility of using favourable nutrients valuation, but financial losses if the environmental benefits were not valued. This is significant for South Africa, where policy frameworks need to consider the full value of nutrient recycling and possible reduced eutrophication. The gap is in the economic modelling specifically for Africa, relating to SWE hydroponics being limited while the acute water stress is still unresolved.

2.7.4.2 The use of wastewater in hydroponics

Hydroponics is the soilless growing of plants in nutrient-rich water solutions that allow for accurate nutrient use and water use efficiency (Dos Santos et al., 2013). Two hydroponic systems were evaluated, namely the drip bag and flood & drain systems.

These systems differ significantly in SWE management. The drip bag systems apply nutrient solution directly into a root zone, which minimises leaf contact with the nutrient solution and reduces the risk of pathogens (Hasan et al., 2018). Flood & drain systems allow the roots to be flooded periodically, promotes oxygen access and nutrient uptake, but it requires more rigorous pathogen monitoring (Chauhan & Sharma, 2017).

The HypoWave project in Germany (Winker et al., 2020) has demonstrated that reclaimed water (SWE) hydroponics is technically practical alongside multilayered treatment and coordination of involved stakeholders. Cifuentes-Torres et al. (2021) also noted that hydroponics with reclaimed water is appropriate for controlled environments, for high-value crops production, but adoption remains limited due to public perception and operational complexity.

Hydroponic cultivation can be used both as a food production technology and as a component of a wastewater treatment process. A study by Mai et al. (2023) demonstrate pollutant reduction efficiencies of greater than 70% for COD, 60% for total nitrogen and over 80% for total phosphates, as well as reductions of copper by 64.2% and zinc by 49.5% via a hydroponic system. Kaushal and Mahajan (2021) demonstrate that hydroponics systems can be an example of a tertiary treatment system and Kumar and Cho (2014) highlight the importance of a closed-loop design to ensure nutrient-rich effluent is not discharged. Closed hydroponic systems are systems in which nutrient solution is recirculated and reused, reducing waste and improving efficiency of resources (Dankwa, 2019). The risk of nutrient-laden runoff and environmental contamination is a concern when open systems are integrated with SWE.

Public acceptance remains a key challenge. The public being hesitant to consume wastewater-grown produce highlights the importance of transparent monitoring, third-party safety certification and public awareness campaigns all of which play a role in improving public acceptance of urban agriculture. Literature addressing consumer acceptance in the African market is notably limited, creating a lack of evidence in understanding socio-cultural barriers to the adoption of SWE hydroponics.

2.7.4.3 Nutrient Management in SWE Hydroponics

Nutrient management is a key issue in SWE hydroponics, as SWE exhibits large variations in nutrient compositions. Hofmann et al. (2024) found that existing nutrient-recovery technologies from wastewater can meet only a small portion of hydroponic nutrient requirements without additional fertilisation; supplying just 11.5% of the sector's total nutrient demand. Even with the most advanced treatment processes, recovered nutrient levels reached only 56%. This highlights the need for careful nutrient management to ensure adequate nutrient supply in systems using wastewater-derived inputs.

Crop-specific studies provide empirical evidence for this requirement. Carvalho et al. (2018) reported a controlled study conducted on lettuce comparing three nutrient regimes; conventional nutrient solution;

supplementary fertiliser with SWE; and SWE without fertiliser. The results indicated that SWE plus fertiliser was similar in growth and nutrient uptake to conventional, while SWE alone resulted in much lower biomass and nutrient concentrations. In particular, potassium and magnesium were limiting, again showing that the nutrient balance of effluents was limiting hydroponic performance unless mitigating supplied nutrients were applied.

Baiyin et al. (2021) elaborated this concept by demonstrating that nutrient uptake and nutrient use efficiency of hydroponic crops are also significantly impacted by the nutrient solution flow rate. This was demonstrated in their Swiss chard experiment whereby moderate flow rates (~4 ℓ / min) allowed higher leaf area, root length, and biomass due to improved nutrient exchange; However, too high of a flow rate compacted roots and reduced nutrient uptake. Hence, this highlights the need to balance nutrient concentrations and hydrodynamic conditions when using SWE in hydroponic systems.

Together, these studies emphasise that the success of SWE hydroponic production relies on a dual optimisation strategy, one that combines nutrient addition to balance chemical composition with the regulation of physical flow parameters to maximise uptake efficiency.

2.7.4.4 Crop-Specific Responses to SWE in Hydroponics

- **Lettuce**

Lettuce (*Lactuca sativa*) is one of the most researched leafy vegetables in hydroponics due to its fast-growing cycle and to its sensitivity to nutrient variations. This makes it a reliable indicator crop to test new sources of nutrients. Xavier et al. (2019) showed that nutrient-optimised SWE can support lettuce growth comparable to conventional nutrients. However, high sodium and heavy metal concentrations in effluents have been reported to reduce leaf expansions and cause physiological stress, leading to lower yields (Xavier et al., 2019). But also, studies by Baslam et al. (2011) and Kim et al. (2016) showed that lettuce can maintain nutritional quality in terms of vitamins and mineral levels if deficiencies are corrected by supplementation.

Kreuzig et al. (2021) have explored the food safety aspect of SWE fertigation of lettuce in hydroponics. While the reclaimed water provided sufficient macro- and micronutrients and met standard microbiological food safety test, the hydroponic solution still accumulated persistent micropollutants, which could present risks to consumers. This also fits with previous evidence that contaminants within different classes behave differently in plants. For example, heavy metals, like cadmium, lead and zinc, can be taken up by the roots through transport proteins that also take up essential nutrients (i.e., calcium and iron), and after uptake, they tend to accumulate in vacuoles and cell walls of leaf tissue, which can remain in place until harvest (Luo et al., 2019). Sodium and chloride salts also accumulate in the leaves, causing osmotic stress and tip burn that reduces lettuce quality (Flowers and Colmer, 2015).

Pathogen dynamics create other potential obstacles for safe and consistent crop production. Bacteria like *E coli* and Salmonella can attach to the surface of roots, enter the lettuce through natural openings or micro-injuries, and then move up to the leaves through the xylem (Kumar et al. 2015). Since leaves of lettuce are edible organs, surface washing cannot fully eliminate risk, and the food safety issue would remain. Viruses and protozoan cysts are less likely to internalise but can survive on leaves if irrigation water contacts the canopy in an open system. Micropollutants, including pharmaceuticals and endocrine disruptors, demonstrate crop and compound-specific behaviour. Hydrophobic compounds tend to stay in root tissues, but more mobile polar compounds can move to the edible leaves (Malchi et al., 2014).

Overall, these studies indicate that lettuce has the potential to be a food safety-sensitive crop in SWE-fed hydroponics. Yields can be optimised to levels equivalent to those in conventional nutrient solutions with supplement feed, however the accumulation of contaminants in edible leaves is a large research gap. Most studies completed to date are short-term, focus only on nutrient provision, and do not carefully monitor or measure contaminants in relation to crop performance. This study will directly connect monitored water quality with the effect of SWE hydroponics water on quantitative assessment of lettuce growth and nutrient quality in a flood & drain SWE hydroponics system.

- **Swiss chard (*Beta vulgaris L.*)**

Research shows that SWE, depending upon its origin and treatment, can provide enough nutrients for hydroponic vegetable growth (Hofmann et al., 2024, Mai et al., 2023)(Jiménez, 2006; Ngasoh et al., 2020;. Swiss chard can tolerate a wide range of growing conditions, which makes SWE hydroponics feasible if salinity levels are managed properly (Musazura, 2014; Bulgari et al., 2017). The crop's ability to accumulate nitrates and heavy metals means that SWE composition needs to be carefully monitored for food safety reasons.

- **Green pepper (*Capsicum annuum*)**

Green pepper is a fruiting crop that requires moderate amounts of nutrients and responds to nutrient shortages, particularly calcium and potassium. Research has shown that maintaining a consistent nutrient supply in hydroponics will increase the fruit setting and quality (Sambo et al., 2019). However, SWE is inconsistent in its nutrient content and there is a risk for blossom-end rot due to a calcium deficiency. Nutrient supplementation is likely necessary when using SWE due to its nutrient variable composition. There is limited research directly examining the use of SWE in hydroponic green pepper.

Magwaza et al. (2020) investigated the potential of partially treated domestic wastewaters as a nutrient source through an anaerobic baffled reactor for hydroponic tomato crop production. Their study compared tomato plants grown with different blends of effluent and a commercial nutrient solution to determine whether nutrient uptake could be enhanced by supplementing, or even replacing, conventional nutrients with the effluent. The results showed that blending effluent with the commercial nutrient solution improved the uptake of nitrogen, potassium, calcium, and zinc, leading to higher yields and better fruit quality than using the nutrient solution alone. These findings indicate that partially treated wastewater can provide meaningful nutrient contributions, although supplementation may still be necessary to prevent deficiencies. This conclusion is directly relevant to supporting the use of SWE in hydroponically grown green pepper crops, where similar nutrient uptake dynamics are expected.

While research by Magwaza et al. (2020) was specific to tomato, their findings allow us to transfer this understanding to investigate SWE as a nutrient source for other fruit crops such as green pepper. Both vegetable crops need sufficient calcium and potassium for fruit set and quality to be achieved, and therefore, if the tomato had a significant improvement in yield and nutrient uptake from the supplementation of effluent, SWE could have the same potential effect on nutrient uptake as long as the nutrient supplementation is optimised.

- **Basil (*Ocimum basilicum*)**

Basil is a high-value herb that is valued for its aromatic oils and tender leaves. Hydroponically, it can be grown under moderate EC and pH conditions, with SWE possibly supplying most of its nitrogen (N) and potassium (K) requirements (Putra & Yuliando, 2015). As basil is primarily a leafy herb consumed raw, food safety risks associated with SWE is higher, therefore, more microbial monitoring is recommended. To the authors' knowledge, there has been little published literature available on SWE-fed hydroponic basil, suggesting that the present study is among the first to examine this application.

2.7.4.5 Economic, Social, and Institutional Considerations

The analysis from Schrammel (2015) has demonstrated the potential viability of SWE hydroponics using an economic modelling approach, comparing SWE hydroponics to other food production systems, and underlining the potential for stable level profitability as long as the environmental benefits are acknowledged. The social acceptance of SWE hydroponics remains limited because of perceptions of risk (Cifuentes-Torres et al., 2021). Institutional capacity and collaboration for quality control and product extension support and alignment of policy frameworks will be of utmost importance for the safe adoption of SWE hydroponics. Aspects of economic feasibility studies and research on social perceptions of SWE hydroponics adopted in the African contexts are not yet combined into published literature and there is not much indication of how national water and agricultural policy provisions have practically enabled or limited the use of SWE in controlled-environment systems like hydroponics.

Policies continue to shape the use of effluent in agriculture. The Department of Water Affairs and Forestry in South Africa (1996) established effluent discharge requirements and monitoring protocols. These policies show that SWE can only be used for food production under regulated circumstances and with proper institutional coordination.

The studies on SWE in hydroponics will contribute to the water management plan for Agri-parks and will be particularly relevant to Agri-parks that have sewage pollution in their groundwater. The effluent from South African WWTWs varies depending on the process, operators and budget. The latest Green Drop report reveals wastewater compliance has plummeted since 2013 (Department of Water and Sanitation, 2022). Of 850 municipal WWTWs, 334 (39%) are in a critical state. The average Green Drop score across all provinces in 2013 was 61%. In 2022, the average score was 50%, indicating that about half of raw sewage and industrial waste is not being treated to South African standards (Kretzmann, 2022).

Several research projects have already been undertaken globally on the use of effluent from WWTWs. These studies have typically focused on used effluent in field-based drip irrigation systems (Swartz et al, 2022). Cifuentes-Torres et al. (2021) reported on many examples of successful experiments, however, full-scale examples are still limited. In South Africa, published literature on using treated sewage effluent in hydroponics is scarce. Studies undertaken in KwaZulu-Natal investigated the use of hydroponics using effluent, but the effluent was from a de-centralised water treatment system, not a large-scale treatment facility (Musazura, 2015). There is thus a gap in knowledge on using hydroponics as a post-treatment option, which is scalable, and which is applicable to South Africa.

3 RESEARCH METHODOLOGY

3.1 THE IMPACT OF AGRI-PARKS AND WEF NEXUS INTERACTIONS ON AGRI-PARKS

The project kicked off with a scoping study during which several Gauteng Agri-parks, including Tarlton, Westonaria and Rooiwal were visited. During the scoping study, the project team did an assessment of the current conditions and problems that the government and farmers experience and their success in uplifting emerging farmers. This was done to determine if the Rooiwal Agri-park is a good representation of Agri-parks in general.

To determine the effects of Gauteng Agri-park services and Water-Energy-Food nexus interactions on (1) farmers within the Agri-parks, (2) landowning farmers within 30 km who use Agri-park services and (3) farmers within 30 km who do not use Agri-park services. Research was conducted across multiple Agri-park sites in Gauteng, representing diverse farming systems. Agri-parks included in the surveys are Rooiwal, Soshanguve, Tarlton, Westonaria, Sebokeng, Eikenhof, Sokhulumi, Camel Estate, Rethabiseng, Tshwane Food and Energy Centre (**Figure 3-1**). The target population included smallholder farmers within and around Agri-parks, as well as governance stakeholders involved in WEF-related functions.

Figure 3-1: Gauteng Agri-parks included in study

The study used a mixed-methods design, combining qualitative stakeholder interviews with a quantitative farmer survey. Both qualitative and quantitative data sets were integrated through a convergence model to develop WEF developmental pathways, sustainability strategies, and policy recommendations.

Qualitative data came from 40 purposively selected stakeholders, including managers, extension officers, specialists, and policy actors. Qualitative data were collected through semi-structured interviews exploring governance, resource challenges, sustainability practices, market integration, and policy alignment. Qualitative data underwent thematic analysis, identifying patterns aligned with WEF Nexus pillars and Agri-park functions. Data validity was strengthened through member-checking and triangulation, while transferability was supported through thick descriptions. Dependability was maintained via detailed audit trails, and confirmability was ensured by actively minimising researcher bias.

Quantitative data were collected from 148 farmers across three groups (Agri-park farmers, participating and non-participating landowners) selected through stratified random sampling. Quantitative data were gathered through structured, face-to-face questionnaires covering demographics, water and energy use, sustainable practices, productivity, market access, and waste management (**Appendix 2**). Quantitative analysis used SPSS/Stata to generate descriptive statistics and inferential analysis, such as regression models (logistic and multinomial), technical efficiency analyses (DEA/SFA), chi-square tests, and correlations. Data validity was ensured through pre-testing of the questionnaire, assessing internal consistency of scales using Cronbach's alpha and ensuring representativeness of samples across locations.

3.2 COMPLEX SYSTEMS THEORY

The complex systems theory provides useful principles according to which a system, such as an Agri-park, can be approached. These principles guided the project as it unfolded through various phases. According to Bjornlund et al. (2020) the multitude of problems faced by emerging farmers cannot each be solved on their own, but can only be overcome if addressed within the full complexity of the entire system. Farmers need a functional rural economy integrated with market, transportation, information systems and the availability of affordable local input supplies.

Reductionism is an approach where a system is broken up into its components, which are then solved separately, and brought together again (van Rooyen et al., 2017). Researchers often analyse a complex system using reductionism, which is criticised by specialists of the complex systems theory (Haider et al., 2021, Reyers et al., 2018, van Rooyen et al., 2017). Although reductionism works in a mechanical system (e.g. a computer), it fails in a complex living system, as the components interact in such a way that they function differently together than on their own. An example of reductionism in the Agri-park context is the isolation of farmers from the network of role-players in the farming community, such as other farmers and market agents who can work with them. Another example is the focus on giving money or supplies, while ignoring the bigger context of the farmers' needs, which is more complex. Reductionism does not consider the context of the whole system and interactions between the various components, which are often unpredictable and dynamic. A complex system is composed of various components interacting with each other, and there are resources and information flowing through the system. Unpredictable outcomes emerge through interactions, and the results cannot be dictated. A learning attitude on the side of the research team should ensure the participation of, and interaction between, the SHFs and other role-players to form a common vision between them.

A socio-ecological system (SES) is typically a dynamic cross-scale complex system, where global decisions impact local conditions and emergence on local scales in turn impact global conditions (Reyers et al., 2018). This creates difficulty to implement sustainable solutions. Developing effective interventions is dependent on selecting the most appropriate scale at which to focus, without neglecting the interactions between the chosen scale and the scales above and below it.

Characteristics of an SES that are relevant for our project include: multiple perspectives; inter-relationships and communication; feedback loops and information flows; ideas emerging from the interactions; continuous adaptation to change. Relationships are very important in complex systems, and linear processes, i.e., predictable cause-and-effect outcomes, should not be expected (Preiser, 2019). Development is done through an iterative process until a suitable solution emerges.

A good understanding of the problems, opportunities and behaviours of all the role-players within the Agri-park is imperative. We initiated a deep analysis of the Agri-park system, together with the current role-players. The stakeholder engagement process has been initiated through successive focus group meetings, training sessions and through individual interviews with the major role-players, namely Agri-park farmers, surrounding landowner farmers, market agents and government officials from GDARDE and CoT. The stakeholder engagement process aimed to qualitatively characterise the group of SHFs inside and outside the Rooiwal Agri-park and to build a relationship with them as part of a transdisciplinary research team that will work together to develop a model of a sustainable Agri-park system.

3.3 CO-DESIGN AS A HOLISTIC APPROACH

Our approach is to work with farmers to develop solutions which are suitable for them. Co-design is an approach that tries to address complex contexts. Farming is a good example of a complex process: there are natural forces such as the weather, water resources, soil types and pests; there are human factors such as the history of the area, the social interactions, crime, and skill sets; there are economic factors such as the market and the national and international events; all these different factors interact and combine in that context, there are tensions and synergies in the flowing nature of an unfinished process. To solve complex problems, the focus must be on the interactions between components within a given context, which needs the combination of insights from different disciplines as well as people living within the context (end-users: farmers and other stakeholders such as the local authorities). Available resources and technologies must be applied in such a way that it will function within the local context, facilitating technology transfer.

A given problem within a system can sometimes be solved by attention to the problem itself, for example, a water pipe that leaks can be fixed. But some problems cannot be solved on their own: a lack of capital to build a facility for chickens can often not be solved by providing capital, because the other factors come into play and the money can be used to buy a luxury car, as we had observed in Rooiwal. Such problems must be solved by considering all the factors involved, and their interaction with each other, and that mostly requires a process in which the knowledge that different people have of the process is combined – that is what we call co-design.

3.3.1 Co-design versus the contextual engineering approach

What Hayes (2017) wrote about air pollution applies to many projects that aim to solve some or other problem where people are involved, not least in Africa:

> .... around the world... 'people' are absent in the models and scenarios used to estimate and predict air pollution concentrations. The modelling of emissions sources, not the human activities that result in them, leads to a bias in policy that focuses on mitigating emissions through technological change rather than through changing individual and societal behaviour. In turn, this leads to a consequent reliance on technological innovation not social innovation. We need to bring citizen's daily practices, activities and behaviours into this debate.

The *way* in which the emerging farmers and their daily practices can be brought into the process to improve the systems that aim to support them is important. The way we did this in the project is through cooperation that is not the same as the contextual engineering way. A common practice in the contextual engineering approach is that information is obtained about the target group's "user requirements," and that this is then considered when the solution is designed by the experts. We argue that such information is insufficient for the goal of finding a solution. The information from the farmers must not be brought into the debate of the experts and officials, but the other way round: the information from the experts and officials must be brought into the debate of the farmers, or rather, it must be a debate where there is synergy between all, from which fitting solutions can emerge – that is, fitting within that specific context.

3.3.2 Multidisciplinary research

Research that adopts a multidisciplinary approach to farming systems can incorporate the broader socio-economic context of SHFs. This multi-disciplinary research approach to SHFs has been implemented in other African countries, such as Malawi (Franke et al., 2014), Ethiopia (Josephson et al., 2014), Uganda (Van Campenhout and Bizimungu, 2018), Mali (Falconnier et al., 2016), Rwanda (Rosa et al., 2017), Mozambique (Roxburgh and Rodriguez, 2016), and Kenya (Willy et al., 2019). In South Africa, this type of research has been conducted sparingly, with only one study (Rusere et al., 2019) utilising the DEED cycle (Describe, Explain, Explore, and Design), intended to limit the researcher's assumptions while encouraging co-learning among stakeholders.

Transdisciplinary research is a form of multidisciplinary research that explicitly includes the practitioners and intended end-users as co-researchers and not merely people who are consulted by the researchers. Over the past few decades, we have developed a transdisciplinary approach to co-develop sustainable practices with end-users within complex socio-ecological systems. Our approach is to work with end-users within their context, and instead of trying to present our own ideas and solutions to the end-users, for example, through training, we look out for practices that have emerged spontaneously from individuals among them, or co-create possible solutions with them, in a process where the sharing of information from both sides takes place freely and spontaneously. We then work with a small number of members of these communities to further refine these emerging practices (Van Niekerk, 2023).

3.4 AGRICULTURAL INNOVATION PLATFORM

In any management plan, there are both top-down and bottom-up approaches. Some problems have to be addressed through top-down approaches, such as policies, management of international trade, public infrastructure, which includes the provision of water and electricity etc. Most governments focus on the top-down approaches, but in many cases, such solutions are neither enough nor suitable. For example, government officials who are responsible for the management of the Agri-parks indicated that the support they give to emerging farmers is not effective to help the farmer grow towards independence.

Our focus is on the development of bottom-up solutions. The AIP was developed by van Rooyen et al. (2017) is based on the complex systems theory and provides a way of working with all role-players in an agricultural community, in particular with emerging farmers, in such a way that new models or solutions to daily problems can emerge from the interactions of role-players. Such solutions are more likely to be implemented sustainably. The networks of role-players within the community can provide emerging farmers with the resources, opportunities and mentorship which they need to grow. For example, by developing the relationships between farmers and market agents, farmers can take responsibility for selling their own products.

In a personal communication with van Rooyen, he explained the process. At the beginning of the project, the project team enters the community and forms relationships with all relevant role-players in the system. In time, the team connects the role-players to each other, until the community forms a network of role-players, each offering different functions. At this point, the community can support itself independently and the project team can exit (Van Rooyen, 2019). This differs from the current Agri-park model where government is a central role-player that controls the system.

The AIP follows four steps:

- Identify all relevant role-players in the system and invite them to participate.
- Discuss the problems that the various role-players experience. This is done by dividing the role-players into groups to provide them with the freedom to share their perspectives without judgement from other role-players, especially in cases where conflict is possible.
- Talk about a shared vision with all the role-players. Too often in development projects, the vision is formulated by the project team that is contracted from outside to provide solutions in a context that they have no experience with. In the AIP approach, the role-players in the system formulate a shared vision.
- Undertake an innovation process of testing various options with the different role-players. Ideas that emerge from regular interactions are tested and evaluated. This is done over several months and new ideas are included throughout the process.

3.5 WORKING GROUPS

During the initial meetings, the complex problems that farmers face were noted. The best form of learning is to discover something for yourself. Empowering a person requires that they work their way out of their current situation and that they are connected to a diverse support network. The SHFs at Rooiwal must see the solutions that are available to them as a possibility for themselves. Once the farmers reach that point, they can be assisted to grow. Our approach was to establish working groups with SHFs that can address the problems which they are facing. Every community can establish different groups, depending on their opportunities, problems and aspirations.

The working groups were launched on 18 January 2024 at the Rooiwal community hall. It was explained that the research team does not bring solutions to the farmers, but instead work with all the role-players until everybody agrees that the solutions are good. The solutions emerge from the interactions between all role-players. Farmers, market agents and government officials were invited to join the working groups and contribute to solving different challenges. Based on our initial interactions with farmers and feedback from all stakeholders, the following working groups were established:

- Water use efficiency (WUE)
- Seed saving
- Market access and agro-processing
- Essential oils
- Farmer graduation program
- Poultry

The working groups kicked off by forming a WhatsApp group for each. The farmers suggested that if someone is interested in more than one group, he or she could be a follower of some of the groups and just be actively involved in one. As a general guideline, the groups were told that they could start their planning by deciding what problems to address, forming a shared vision, and getting all the relevant role-players together to work with them.

It was suggested that the formal meetings will be discontinued, and that the project will continue through the working groups, because there was a concern that farmers might have a problem with the amount of time spent in long meetings, rather than to work on the problems. The farmers, however, did not agree. They wanted the formal meetings to continue, because these meetings are a good place for the groups to give feedback to each other. They saw it as a way to put some pressure on a group that had not made much progress, by seeing the progress of other groups. Also, the farmers will attend the meetings to hear what is happening in the other groups, because they are all interested in the various topics. Quarterly feedback meetings were therefore agreed upon.

3.6 DEVELOPMENT AND TESTING OF A FARMER SUPPORT TOOL

A tool was developed for the use of both SHFs and extension officers who support them. The tool is based on an important insight that was gained through this project, i.e., that there are various farming levels between subsistence/food garden farmers and large-scale commercial farmers, and that farmers should only move up one level at a time and only when they are farming efficiently at the level they are currently on. It follows that farmers should know at which level they are currently farming on and how efficient they are at that level. However, other than the important work done by Cousins and Chikazunga (2013), we found gaps in the available information on these levels; what they look like, what is required for a farmer to be successful and how much a farmer can expect to earn when farming efficiently on each level. GDARDE officials confirmed that current support programmes only recognise the food garden farmers and larger commercial farmers who work on more than 1 hectare. The actions undertaken to develop the farmer support tool, called the Sukuma Transformation Tool (STT), is described in the following sections.

3.6.1 Characterise the different farming levels

Actual farms in Rooiwal and Hammanskraal that are currently operating profitably at various small-scale levels were identified. Each farm was characterised in terms of size, daily practices of the farmer, and various requirements. Potential incomes were calculated for each farm using cabbage as a reference crop, because it is both a very common crop in the area and it represents an average income per m^2. Expenses were recorded for the existing small farms, and the Enterprise budget for cabbage (Western Cape Government, 2023) was used to calculate the expenses of a commercial farm.

3.6.2 Identify farming level indicators

It was discovered that different sizes of these profitable small-scale farms had different characteristics that made it possible to identify indicators for different farming levels. These indicators were divided into farm indicators (i.e., at what farming level the development of the farm is) and farmer indicators (i.e., at what farming level the ambitions and skills of the farmer are).

The selected farm indicators included:

1. Field size
2. Water management systems
3. Labour requirements
4. Potential markets and market requirements
5. Farm equipment and infrastructure

The selected farmer indicators included:

1. Farmer's vision
2. Experience and knowledge
3. Planning skills
4. Marketing skills
5. Financial management skills
6. Farmer habits

3.6.3 Development of a tool for farm and farmer-level categorisation

Two questionnaires were developed to determine at which farming level a farmer currently is in terms of each of the above indicators. One questionnaire shows the current farm level, and the other identifies the current farmer level. Relevant questions were formulated for each indicator, and the typical responses of different farming levels are presented as options to select. Specific aspects that a farmer lacks at a certain level can clearly be identified after completion of the questionnaires.

3.6.4 Development of the cabbage calculator

The calculator has five categories, one for each of the farming levels. Production potential is determined according to **Equation 3-1**, using the field size (m^2) of the farm multiplied by 4 cabbages per m^2.

$$Production\ potential\ (number\ of\ cabbages) = Field\ size\ (m^2) \times 4$$

Equation 3-1

Potential income is calculated according to **Equation 3-3** using the typical price per cabbage head that farmers at different levels typically receive. There are differences between the prices of produce in the formal market versus the informal market, for example, farmers who sell directly to their local community maximise their own income by avoiding the costs of agents and hawkers. These prices were obtained directly from the communities where we worked and are current prices in the formal market. Monthly production and income are calculated based on the assumption that a farmer will plant three crop cycles per year. The number of cabbage plants per m^2 is harvested every four months, and the monthly average is calculated using **Equation 3-2**. Three scenarios for crop success are included: 75% success, where three of the four cabbage / m^2 survived; 50% success, where two of the four cabbage / m^2 survived and 25% success, where one of the four cabbage / m^2 survived.

$$Average\ monthly\ crop\ yield\ (nr\ of\ cabbages\ harvested) = Production\ potential\ (nr\ of\ cabbages\ planted) \times crop\ success\ (\%) \div 4\ (months)$$

Equation 3-2

$$Average\ monthly\ income = Average\ monthly\ crop\ yield\ (nr\ of\ cabbages\ harvested) \times Price\ per\ cabbage\ (R)$$

Equation 3-3

3.6.5 Verification of the tool

The tool, which consists of the questionnaires and the cabbage calculation, was verified during a workshop with farmers and officials on 29 October 2025. Farmers and officials completed the questionnaire for their own or another farm to see if the outcomes are realistic and useful. Once the questionnaire is completed, the farmers can identify their current farming level and aspects that they lack, which are limiting their current success. The results were discussed and feedback was noted.

3.7 USE OF SEWAGE IN HYDROPONICS PILOT STUDY

A pilot study was designed and built at Rooiwal Agri-park, which aimed to evaluate the growth performance of crops by comparing plants grown with treated sewage water effluent (SWE) with plants grown with groundwater enriched with hydroponic nutrient solution (HNS).

3.7.1 Experimental design

An experiment was designed to test the use of SWE and HNS in two seasons, namely summer and winter. Four plant types were used in the trials:

- Lettuce (*Lactuca sativa)* and Swiss chard (*Beta vulgaris var. cicla*) during winter; and
- Green peppers (*Capsicum annuum*) and basil (*Ocimum basilicum*) in summer

Experiments were done in two kinds of hydroponic systems:

- Recirculating flood & drain hydroponics for lettuce and basil, where water quality could potentially be improved for subsequent discharge to a water resource
- Drip bag hydroponic system for the green peppers and Swiss chard which is a consumptive use of water with no recirculation.

Figure 3-2: AB Farms pots for flood & drain of lettuce

The two hydroponic systems were fed from a series of four tanks. Two tanks were dedicated for each system, one for effluent and one for groundwater. The entire water volume in the circuits was replaced weekly with new water. In the flood & drain system (**Figure 3-2** and **Figure 3-3**), water from an 800 ℓ tank was pumped into banks of six connected AB Farms pot columns. The water enters the top of the growing pot and overflow is channelled to the drainpipe back to the tank. The water in the pot remains in situ for 24 hours, and then the filling process begins again. The water in the pot is flushed out and replaced by water from the tank. The flushed water drains back to the feed tank. The pumps ran on solar power. The system consists of two identical stands with a total of 120 plants, 60 on each stand.

Blocks of 20 plants alternated between the SWE and HNS-fed crops. Therefore, there was a distribution of alternating blocks of plants providing a degree of randomisation.

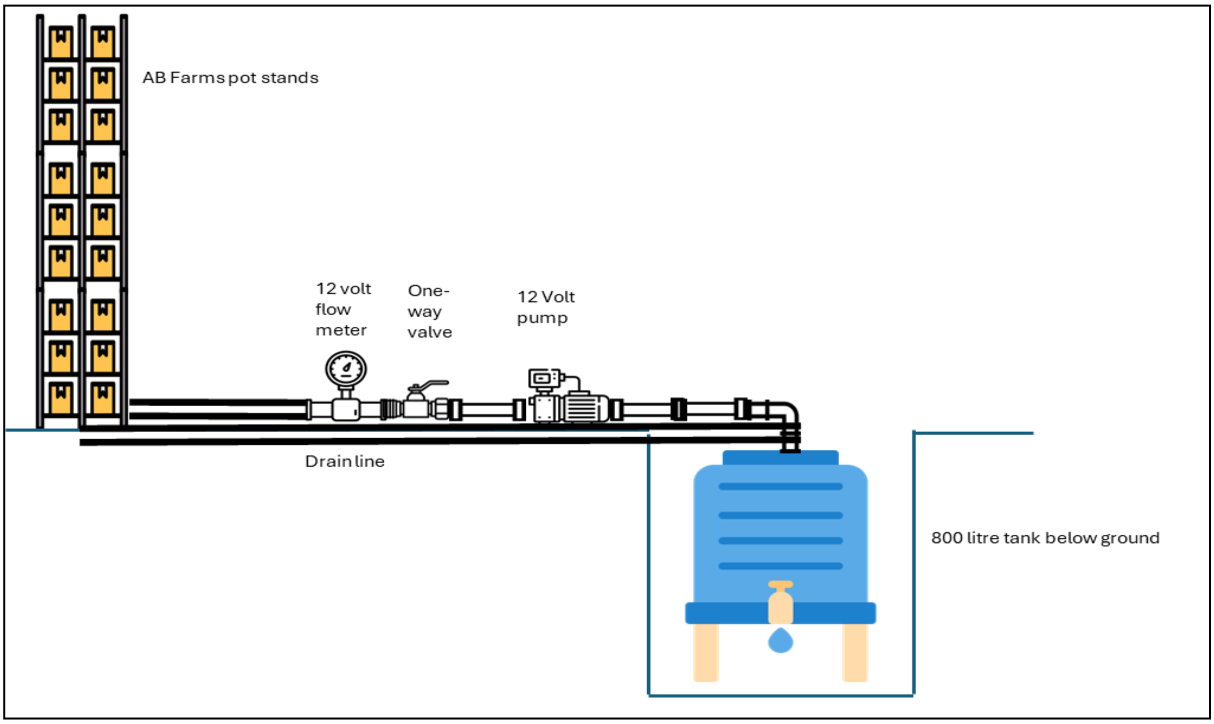


Figure 3-3: Water recirculation layout for flood and drain hydroponic systems

Figure 3-4: Drip bag hydroponic system layout

In the drip bag system (**Figure 3-4**), water from the 800 ℓ tank was fed via gravity directly to each plant through drip irrigation (**Figure 3-5**). Once the system is in balance, there is minimal surplus water. Any occasional surplus was discharged to the fields. Eighty plants were grown in the drip bag system, with forty plants allocated to each treatment.

The design only allowed for 1 water feed into a stand, which restricted randomisation of water supply to the crops. Two stands were used, one for HNS and one for SWE fertigation. To optimise the result each stand was aligned along a north-south axis, 1 m apart and were more than 1 m from the shade cloth wall.

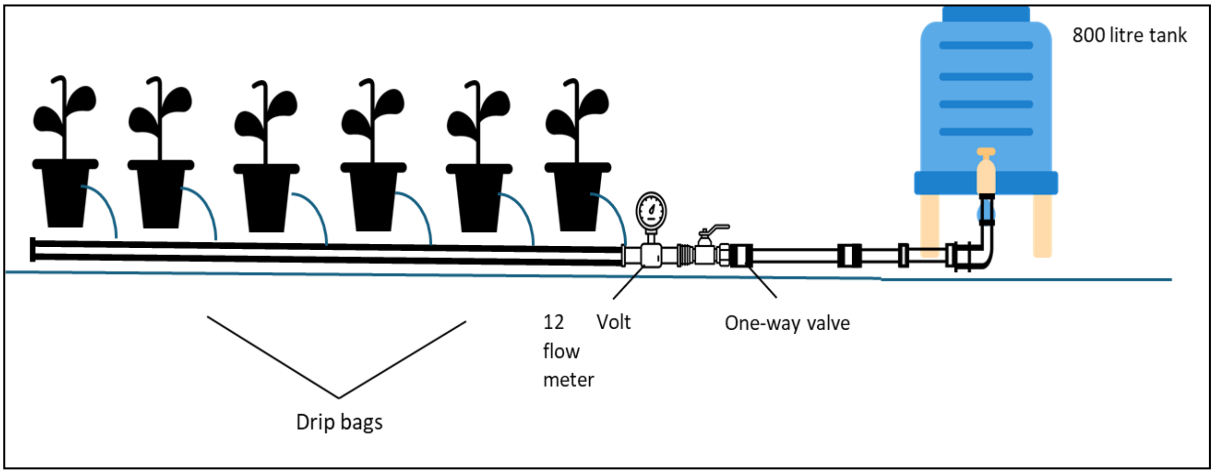


Figure 3-5: Components of the drip bag hydroponics system

3.7.2 Water Sources

3.7.2.1 Groundwater

Groundwater was sourced from an existing borehole on site, which supplies all farmers on the Rooiwal Agri-park. A supply pipeline already existed to two storage tanks used by the adjacent farmers, approximately 50 m from the pilot plant site. A 20 mm HDPE pipe was used to fill the groundwater test tanks.

3.7.2.2 Effluent

Effluent was collected from Rooiwal wastewater treatment works (WWTW). The effluent was pumped from the final effluent dam through a UV steriliser and filter cartridge system into a 1 000 ℓ water bowser. The water was transported back to the experimental site and pumped into the effluent test tanks (**Figure 3-6**).

Figure 3-6: Locations of the Rooiwal Agri-park, experimental site and the Wastewater Treatment Works

3.7.3 Water quality monitoring

A water quality monitoring programme was followed to test the chemical, physical, and microbiological quality of the HNS and SWE, to determine the suitability of the water for fertigation, to monitor for potential chemical deficiencies, and to provide a baseline to assess outcomes. Some water quality parameters were measured daily on-site, while other parameters were tested through sampling on a weekly basis.

3.7.3.1 Daily data collection and analysis

Water from the tanks was measured daily for electrical conductivity (EC), pH, and temperature in the mornings and afternoons during the pilot study. A portable handheld EC meter was used to record values. Daily values were averaged for the week. The minimum, maximum and average values were used to determine overall transits between the morning and afternoon values.

3.7.3.2 Weekly data collection and analysis

Weekly water samples were collected from the incoming supply tanks before emptying and after refilling. The water samples were sent to X-Lab (PTY) Ltd for analysis. The following constituents were analysed:

- Microbiological parameters: *E. Coli*
- pH in water at 25°C
- Conductivity in mS / m 25ºC
- Dissolved Metals: Aluminium (Al), Antimony (Sb), Arsenic (As), Barium (Ba), Boron (B), Cadmium (Cd), Calcium (Ca), Chromium (Cr), Cobalt (Co), Copper (Cu), Iron (Fe), Lead (Pb), Magnesium (Mg), Manganese (Mn), Nickel (Ni), Phosphorus (P), Potassium (K), Selenium (Se), Sodium (Na), Strontium (Sr), Uranium (U), Vanadium (V), Zinc (Zn), Mercury (Hg)
- Hardness: Calcium hardness as $CaCO_3$, Magnesium hardness, Total hardness as $CaCO_3$
- Inorganic ions: Chloride as Cl, Nitrite as NO_2, Nitrate as NO_3, Sulphate as SO_4, Phosphate as PO_4
- Ammonia: Ammonia as NH_3, Ammonia as N
- Total suspended solids (TSS) (0.7µm) @ 105°C

Weekly changes in chemical water quality were calculated based on the percentage change of the constituents from the beginning of the week to the end of the week. Change in element concentrations was calculated using **Equation 3-4**.

$$Change\ in\ element\ concentrations\ (\%) = \frac{Final\ value\ - Initial\ value}{Initial\ value} \times 100$$

Equation 3-4

3.7.4 Vegetative sampling and analyses

From each treatment group, twenty plants were randomly selected for weekly data collection. Growth parameters measured included the number of leaves per plant, plant height, leaf length, and leaf width over six weeks.

Entire plants were harvested at the end of the study to allow full biomass evaluation. Fresh weight of whole plants was measured immediately after harvest to estimate marketable yield and growth performance. Plant material was dried using different methods depending on crop characteristics and laboratory facilities available.

- During the winter studies, harvested plants were air-dried at room temperature for seven weeks until completely dehydrated.
- During the summer studies, basil was oven-dried at 60–70 °C at the UNISA Florida Campus, while green pepper fruit samples were freeze-dried to protect heat-sensitive compounds.

Dried samples were ground into a homogeneous powder using a household blender to prepare them for chemical laboratory analysis. Ground samples were packaged and labelled in airtight zipper bags with unique sample codes to ensure traceability, prevent contamination, and avoid moisture absorption before laboratory submission.

3.7.5 Statistical analyses

Descriptive statistics such as minimum, maximum, mean, and standard deviation were used to summarise water quality and growth performance trends. Inferential testing was done using Two-Way ANOVA ($p < 0.05$) to determine whether treatment type (SWE vs. HNS) had statistically significant effects on growth performance and nutrient composition. Post-hoc comparison were conducted using Tukey’s HSD test to separate treatment means and identify which groups differed significantly when ANOVA showed significance. A regression analysis was done to examine relationships and trends over time in parameters such as nutrient concentrations, EC, pH, and microbial activity in the water. Water quality results were compared with SANS 241, DWS agricultural standards, and FAO irrigation guidelines for safety and suitability interpretation.

3.7.6 System optimisation and risk management

To optimise nutrient use, mitigate risks and ensure consistent system performance, the following interventions were applied.

- Regular pH and EC monitoring and correction to maintain parameters within optimal hydroponic ranges.
- Adjustment of pH using phosphoric acid, where necessary, to enhance nutrient solubility and uptake
- Addition of hydroponics solution to the borehole water to provide phosphorus for the plants
- Weekly draining and refilling of treatment tanks to prevent accumulation of salts and organic matter.

3.7.7 Cost assessment for using sewage water in hydroponics

A cost comparison was prepared for each treatment to estimate the cost efficiency of using effluent water versus nutrient solutions for irrigation in the two hydroponic systems. Data used in the comparison is summarised in **Table 3-1**.

Table 3-1: Data for cost comparisons

Data input	Data sources
Seeds	Price of seedlings purchased
Fertiliser	Price of hydroponic nutrient solution purchased for use in HNS treatments
pH correction	Price of phosphoric acid used for pH corrections (all treatments)

Data input	Data sources
Borehole pumping cost	Projected energy to pump water for the growing season = 2.8 kW, based on estimate that the currently installed borehole can pump 3.2 ℓ / second and 2000 ℓ per week was required for the pilot studies. The Eskom rural rate of R5.4 per kWh.
Fuel	Estimated R38.88 per study, based on 18km travelled for weekly transport of SWE and 10 km / ℓ average fuel consumption
Yield per plant	Fresh weight biomass at the end of the trial
Number of plants	Fixed
Total yield (kg)	Fresh weight per plant x number of plants
Price/kg	Average price at the Johannesburg Fresh Produce Market

Total expenses and total income for each treatment were calculated and used to determine the cost efficiency of each treatment. The cost efficiency was calculated using **Equation 3-5.**

$$Cost\ efficiency = \frac{Total\ costs\ of\ production}{Total\ income}$$

Equation 3-5

3.7.8 Growth of spinach in a floating pond with Kelpak supplement

Kelpak is a natural plant bio-stimulant extracted from *Ecklonia maxima,* a brown seaweed harvested along the South African coast. It is used in agriculture and horticulture to improve plant growth, yield, and stress tolerance as it contains plant hormones that stimulate root development, vegetative growth, and overall plant health. A trial was undertaken to examine the effects of treated wastewater effluent and Kelpak bio-stimulant strengths (100% and 50%) on the growth and yield performance of spinach (*Spinacia Oleracea*) grown in a deep-water culture.

4 RESULTS: INTEGRATED MANAGEMENT PLAN

4.1 OUTCOMES OF STAKEHOLDER ENGAGEMENT

4.1.1 The effect of Agri-park services and WEF interactions on farmers

4.1.1.1 Irrigation Practices

Farmers within the Agri-park as well as nearby farmers who make use of Agri-park services, have greater access to efficient drip irrigation systems, while non-participants depend more on sprinkler systems (**Table 4-1**). This suggests that Agri-park involvement improves access to advanced irrigation infrastructure, supporting higher productivity and climate resilience. Those who make use of Agri-park services rely more on diesel-powered irrigation systems, while the farmers who do not use the services use more electric-powered irrigation systems (**Table 4-2**).

Table 4-1: Type of irrigation system by participant type

Type of irrigation used	Agri-park non-participant	Agri-park participant	Overall
No irrigation used	4%	5%	5%
Manual from tube well	2%	0	1%
Manual from tank/lake	7%	16%	11%
Sprinkler	30%	12%	20%
Drip	56%	65%	61%
Others (specify)	1%	3%	2%

Table 4-2: Irrigation energy source by participant type

	Agri-park non-participant	Agri-park participant	Overall
Solar powered	7%	5%	6%
Hydro-powered	1%	2%	2%
Electric powered	70%	49%	60%
Diesel-powered	4%	39%	20%
Petrol-powered	0%	2%	1%

4.1.1.2 Determinants of Agricultural Income

Table 4-3 shows that farmers within 30 km from an Agri-park, who actively uses Agri-park services, earns about R230,000 per annum more than those inside the Agri-park, while nearby farmers who do not make use of the services earn a similar income to those within the Agri-parks. Through the qualitative research, two reasons for the success of landowning farmers who use Agri-park services above those within the Agri-parks were identified; one was that the land within the Agri-parks were limited, and the other was that the farmers within the Agri-parks are more dependent and less driven to achieve success, compared to surrounding landowning farmers. This result shows that both the farmers who are completely dependent on government and those who get no support are equally disadvantaged. The most successful group are those who farm independently but make use of government services as and when required.

This was also confirmed through the intensive work done at the Rooiwal Agri-park. Throughout the study it was observed that independent landowning farmers were much more motivated and driven compared to those working within the Agri-parks. However, many of the landowning farmers were unable to access the use of the Agri-parks for various reasons, like not having the transport to get to the Agri-parks for renting tractors.

Table 4-3: Regression results estimating determinants of livestock, crop, and total agricultural income among farmers

VARIABLES	Livestock annual income	Crop annual income	Agricultural annual income
Ref: Farmers inside the Agri-park			
Farmers within 30km and using the Agri-park	-988.736	183,604.453	230,643.366**
	(17,263.558)	(120,442.425)	(113,046.612)
Farmers within 30km but not using the Agri-park	5,169.394	-64,126.479	-46,204.396
	(11,385.371)	(80,211.100)	(74,554.598)
Ref: Female			
Gender: Male	10,196.342	15,988.805	11,611.084
	(10,157.174)	(72,842.609)	(66,512.021)
Ref: No formal education			
Education: Less than Grade 12	4,049.484	123,753.496	141,021.500
	(19,581.162)	(136,302.779)	(128,222.932)
Education: Grade 12 (Matric)	12,376.265	404,928.211***	376,334.779***
	(20,984.016)	(145,467.482)	(137,409.215)
Education: Certificate +	6,575.574	293,758.378*	303,330.930**
	(21,837.488)	(151,005.280)	(142,997.984)
Ref: Livestock			
Livelihood: Crop	-59,604.723***	-487,214.728*	-17,542.271
	(15,776.629)	(287,930.127)	(103,309.785)
Age	504.221	9,068.374***	9,092.841***
	(468.704)	(3,342.416)	(3,069.206)
Constant	23,976.120	-59,566.170	-542,934.094**
	(39,619.441)	(395,751.690)	(259,439.194)
Observations	143	128	143
R-squared	13.5%	14.5%	12%

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Other determinants that notably influenced agricultural incomes included education and age (**Table 4-3**). Education positively influences earnings: farmers with matric or higher qualifications earned substantially more than those with no education. Age positively affects crop and total income, indicating that experience contributes to better performance, though this does not significantly influence livestock income.

4.1.1.3 Constraints Affecting Farmer*s*

The study indicated that landowning farmers who do not make use of Agri-park services face greater constraints than those who do make use of the services, for example having constraints to access markets (51% vs 28%), to suffer from higher post-harvest losses (48% vs 34%), having limited access to credit (27% vs 17%) and lower technical skills in energy and water management. Some problems were experienced by both groups, including the lack of value-added equipment (57–62%) and high electricity costs (25–32%). These constraints indicate underlying structural issues not fully addressed by Agri-parks.

4.1.2 Involving all relevant stakeholders

Throughout the project, new role-players had been identified and added to the team. The following role-players became involved:

- Various SHFs from Rooiwal and surrounding areas (about 100 attended meetings)
- Role-players in food marketing: (i) the National Agricultural Marketing Council, (ii) Simply Garlic, a food processor within 25km from Rooiwal Agri-park, (iii) white farmers with marketing connections in the Rooiwal area, (iv) an essential oils processor.
- Commodity support groups, including the South African Essential Oil Producers' Association
- Academics who could support the team and/or farmers with water resource challenges, including (i) the University of Applied Science in Zurich, (ii) the Agricultural Research Council at Glen, which is interested in finding future projects together to continue the research on water use efficiency methods with emerging farmers at the farm level. (iii) engineers with experience in wastewater treatment at Rooiwal.
- Leaders of the Rooiwal Farmer Production Support Unit, an initiative that is managed by emerging farmers around Rooiwal.
- Officials from the City of Tshwane (CoT) and Gauteng Department of Agriculture, Rural Development and Environment (GDARDE).
- People from other industries, i.e., incubation units for suppliers to the automotive industry
- Local churches and Non-Government Organisations (NGO's)

In the following sections, we discuss the various relationships between the farmers in the Rooiwal area and other role-players according to the views that the government officials and the farmers expressed in our frequent discussions.

4.1.2.1 Farmer: Government relationship

The officials were concerned about the trend that farmers who receive government support become dependent on the government, instead of using the opportunity to become independent. Many Agri-park farmers prefer to be given supplies of seeds, seedlings, fertilisers, etc., over information and training. The supplies that are given to the farmers, even in some cases, larger equipment like tractors, are sometimes sold by farmers for cash. Even farmers who are trying to be successful are frustrated by their inability to become independent despite many efforts on both the side of the government and these farmers. The relationship between emerging farmers and government is key to address this problem. But this relationship needs to be well understood.

The government also assists farmers with a business plan, based on their ambitions to be either subsistence or commercial farmers. However, there is a problem in the system, because the government is pushing for larger numbers of commercial farmers, and often classifies subsistence farmers as commercial, due to the size of their property. When these farmers are then evaluated, they are not successful on a commercial level.

At the operational level, the nature of the government/emerging farmer relationship is complex and therefore has similarities with other mentoring and coaching or guiding relationships, such as the mentor/mentee relationship. There is one important benefit of understanding the similarities between the government/farmer relationship and other complex relationships: we can make use of the abundance of literature on these relationships to learn how to deal with the government/farmer relationship. Some basic principles of a coaching or developing relationship are the same as for developing an emerging farmer, for example:

- The mentor has the task of guiding the mentee to become an independent professional. The government has the task of developing emerging farmers to become independent farmers.
- The nature of both the government/farmer and mentor/mentee interfaces is relational and interactive, not linear and prescriptive. The skills needed to deal with these relationships develop over time.
- Each particular relationship is different, and it is not possible to formulate specific rules. Rather, general guidelines should be tried and tested in each particular case.
- The mentor cannot force the mentee to develop in a certain way. The mentee must make decisions about the goals he/she wants to achieve. Such decisions must be respected and supported by the mentor. This is also the case in the government/farmer relationship.
- Biddulph (2013) said that when children grow up, they do not become independent, they just become dependent on a larger community. We would add that when growing up, children have to make a contribution and become an active role-player in the larger community. In the same way, farmers can never successfully operate in isolation, they have to be taken up in a community that includes other farmers and all other role-players that support the industry.

4.1.2.2 Farmer: Farmer relationship

One of the farmers who participated in our market access working group used the support from the NAMC and GDARDE to apply for SA-Gap. She noted the importance of having a mentor throughout the project. Her mentor was another farmer who previously applied for SA-Gap. Our working groups provided the right platform for her to connect with NAMC, GDARDE and other farmers.

Through our conversations with farmers, we noticed a clear tension between farmers. Some farmers who joined our group are passionate about working with other farmers, but they find their fellow farmers to be competitive and not willing to share information that could be of benefit to their neighbours. There is little that can be done to change the attitudes of people, and those farmers who seek cooperation with neighbours will have to work with other like-minded people.

The poultry working group has four active members who work hard to develop the forum, but many who attend the meetings do not contribute to the success of the group. The four who are active are starting to realise that they will be more successful with a model based on principles of the free market, where they focus on finding markets and buying from fellow farmers, rather than trying to create a large complex forum in a communal approach where all farmers are needed to stay committed and to contribute. An important vision of the poultry working group, which could be applied to all commodities, is to develop the full value chain within the community.

Commercial farmers often have the goodwill to support emerging farmers, but they do not have the resources to become involved in projects that may require a lot of their time. If there is some form of incentive for commercial farmers to give their time for mentorship, it may be very beneficial to the overall success of the Agri-park. Sometimes the commercial farmer could directly benefit from co-operating with the emerging farmer, e.g. if the emerging farmer becomes a supplier of products to the commercial farmer. Commercial farmers also have access to markets, with which they can connect SHFs.

4.1.2.3 Farmer: Industry relationship

Industries such as Simply Garlic are a promising way to support emerging farmers. These industries have the knowledge to support farmers with production, and they provide the farmers with a market. Even more importantly, the industries can benefit from this relationship by sourcing produce locally. That constitutes a win-win relationship.

The importance of industries is highlighted in an example of an incubation programme in the automotive industry. In this model, the mentee (prospective supplier), mentor (motor manufacturer) and government cooperate to develop new supplier companies. In our context, the emerging farmer is the mentee, and Simply Garlic is the mentor.

The first and important step in the incubation programme of the automotive industry is the selection of suitable candidates based on qualifications or experience. This step is important to exclude those who do not aim to grow to independence. The promising candidates are incubated in an on-site facility provided by the motor manufacturer, from where they start a business and sell supplies to the manufacturer. The manufacturer provides support to the participants, but also puts pressure on them, because their products are needed for the continuous operations of the automotive plants.

The programme is run over five years:

- **Year 1:** The motor manufacturer supports the supplier with a business plan, financial management and general support, and buys supplies from it.
- **Year 2 – 4:** The participant should continuously strive to become independent. His financial records are regularly reviewed, and regular visits to his facilities are made. If a participant fails to deliver, the programme will end prematurely.
- **Year 5:** At the end the participant qualifies and support ceases. The participant can then apply for a contract to continue supplying the manufacturer, and will typically look for other contracts with other manufacturers

This example illustrates the important role that industry can play. In the automotive industry the manufacturer provides most of the support and mentorship. The mentee is operating at the manufacturer's facilities. In our case, Simply Garlic which represents the industry is not completely incentivised to provide this support, because they are able to import crops at low prices. Other ways of providing the industry with incentives to support local farmers may include tax benefits for products that are purchased from local farmers.

4.1.3 Problems in the system

The Rooiwal agricultural community provides an interesting place to study agriculture in South Africa. There is a diversity of commodities and farmers operating in the area, with a mixture of commercial and emerging farmers. Our conversations with farmers and government officials provide good insight into the problems and opportunities that emerging farmers in the Rooiwal community face. In this section, we discuss the insights we obtained through a focus group meeting in the early stages of the project, during which the problems within the Rooiwal Agri-park and surrounding landowning farmers were discussed.

4.1.3.1 Government officials' perspective

There were more than 20 officials from CoT and GDARDE present at the meeting where these concerns were discussed. As was mentioned before, officials' main concern was the inability of farmers to become independent from support. Farmers should only use the Agri-park as an incubation facility and move to their own farm once they have grown independent, but the exit process is not defined, and these farmers generally stay on indefinitely. They also mentioned that Agri-park farmers do not always pay the required rent to use Agri-park, and it seems as if there is uncertainty about the roles and responsibilities of farmers and the government regarding Agri-park. Several other key challenges emerged from the conversation, and are shortly discussed below and summarised in **Figure 4-1**.

Government processes

- Government processes and supply chain management are slow and there is a lot of financial red tape. If farmers request supplies, for example, seedlings of a certain kind of crop, it may take up to 8 months for the government to supply, at which time the supplies are too late. Farmers need a system where they can source their own supplies much more quickly.
- Certain bylaws cause conflict between CoT and GDARD, and the two entities operate in silos, instead of working together. Management in government often changes, and promises made to farmers under one management are often not fulfilled under the new management.
- Officials complained of corruption at higher levels of government. They are sometimes instructed to provide more support to certain farmers with government connections.

Market-related problems

- The initial idea of the Agri-parks was to connect farmers to the market. However, the officials were very clear that they avoid any sort of facilitation for marketing. Once the government gets involved, the farmers hold them responsible for selling the produce. If the farmers do not receive the price they were hoping to receive, they blame the government for stealing it from them.
- Currently, the government only supports farmers by giving them advice and contacts of marketing agents. Often, they find that farmers do not follow up those contacts.
- The officials admitted that the Agri-parks do not include market-planning from the start. This creates the situation where crops are produced for which there are no market. Government assists farmers with SA Gap certification, but farmers do not renew it.

Extension services

- Officials complained that language is often a barrier to effectively supporting farmers.
- Some of the young extension officers do not have experience with, for example, particular soil conditions in new environments and then give the wrong advice.

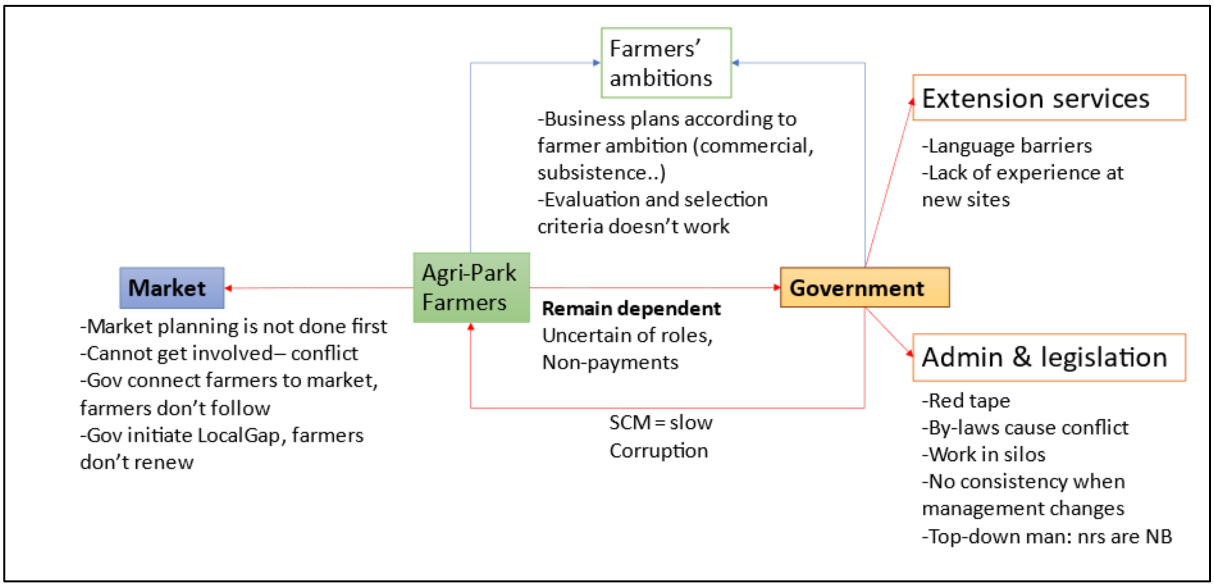


Figure 4-1: Current situation and problems in Agri-parks from the Government perspective

4.1.3.2 Agri-park farmers' perspective

There were 5 Agri-park farmers present at the discussion. The current situation and problems in the Agri-parks, as described by Agri-park farmers at the first meeting are summarised in **Figure 4-2.** The farmers indicated that they expect supplies to be given to them by the government. Government provides some supplies to the farmers, including tractors with drivers, fuel and maintenance, pipes and fittings for irrigation systems and seeds or seedlings of high-quality crops. If farmers require anything else, they have to buy it for themselves, but they complain that supplies are expensive, and seedlings are sometimes unavailable and of poor quality.

There is no agreement between the farmers and the government regarding roles and responsibilities, and the farmers expect all maintenance of infrastructure to be done by the government. This often results in maintenance not being done. Farmers have a lack of water, electricity, storage and security, which are problems that the government should deal with.

Currently, the Rooiwal Agri-park farmers have a stable market, as they are selling all their produce to a company called Double fresh, which has GlobalGap certification. However, this farmers' exiting from the Agri-park is long overdue and if that happens the farmers will need to find their own markets again.

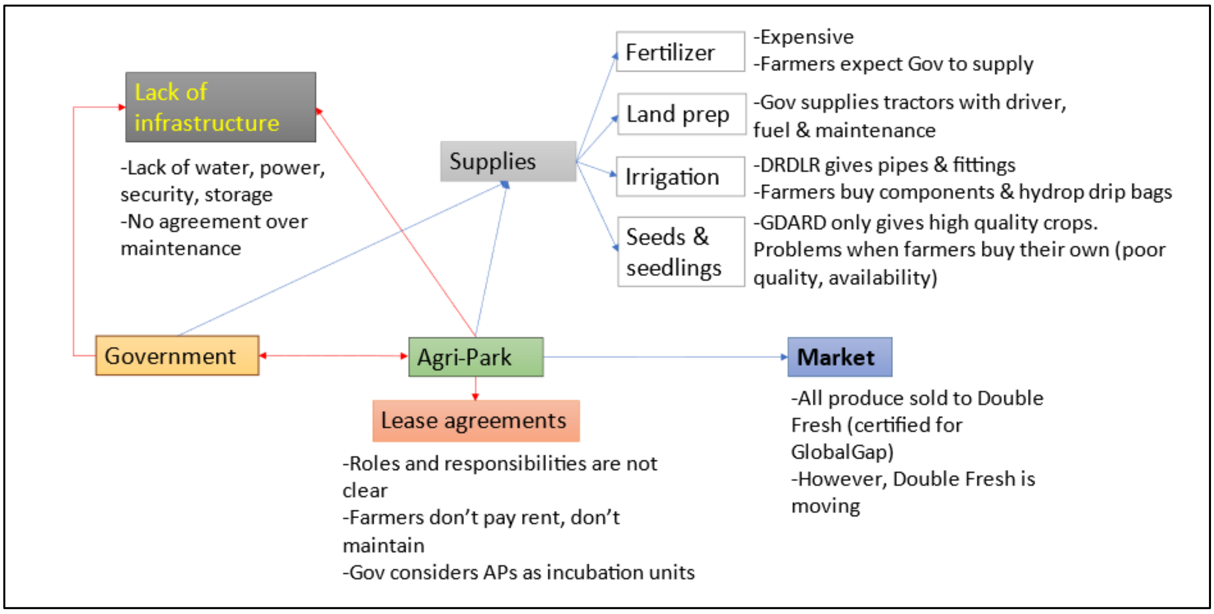


Figure 4-2: Current situation and problems in Agri-parks from the Agri-park farmers' perspective

4.1.3.3 Surrounding landowning farmers' perspective

There were 15-20 landowning farmers from the areas surrounding the Rooiwal and Soshanguve Agri-parks at the exploratory meeting, and most participants were actively involved in the discussions. Key outcomes emerged from the workshop, as discussed below and summarised in **Figure 4-3**.

The landowning farmers can be divided into commercial and subsistence farmers. It was indicated that the commercial farmers get more government support than subsistence farmers. The landowning farmers discussed their relationships with various role-players as follows:

- **Farmer Production Support Unit:** Among the independent landowning farmers, a farmers' support organisation has emerged, where they support each other. They are having some problems with competition and jealousy, and people not wanting to share information, but they have made good progress with this network and are hopeful that these problems will be overcome. Such a network can be a very important support system within an Agri-park.

- **Commodity organisations:** The landowning farmers work through commodity organisations to provide them with specialist information. Farmers are also hopeful that the commodity organisations will help them get government support.
- **Relationship with government:** The landowning farmers were very negative about the government, claiming that the government is 'incompetent, inconsistent and corrupt'. They are also unhappy that the government favours Agri-park farmers.

In terms of marketing, the landowning farmers complained of a lack of information on buyers and crop choice, and they need support in quality assurance of their produce. Difficulties with transport and prices for produce were also mentioned.

The landowning farmers complained of a lack of services, including:

- Electricity, which impacts irrigation, cold storage and security. They have considered various alternatives, but all of those are expensive.
- The lack of water, land and infrastructure was also mentioned.

Communication and a lack of information were considered to be important problems within the current system. Despite the current support structures the government has in place, many smallholder farmers are still either not aware or properly informed of where to access information such as when training takes place or application requirements when funding becomes available.

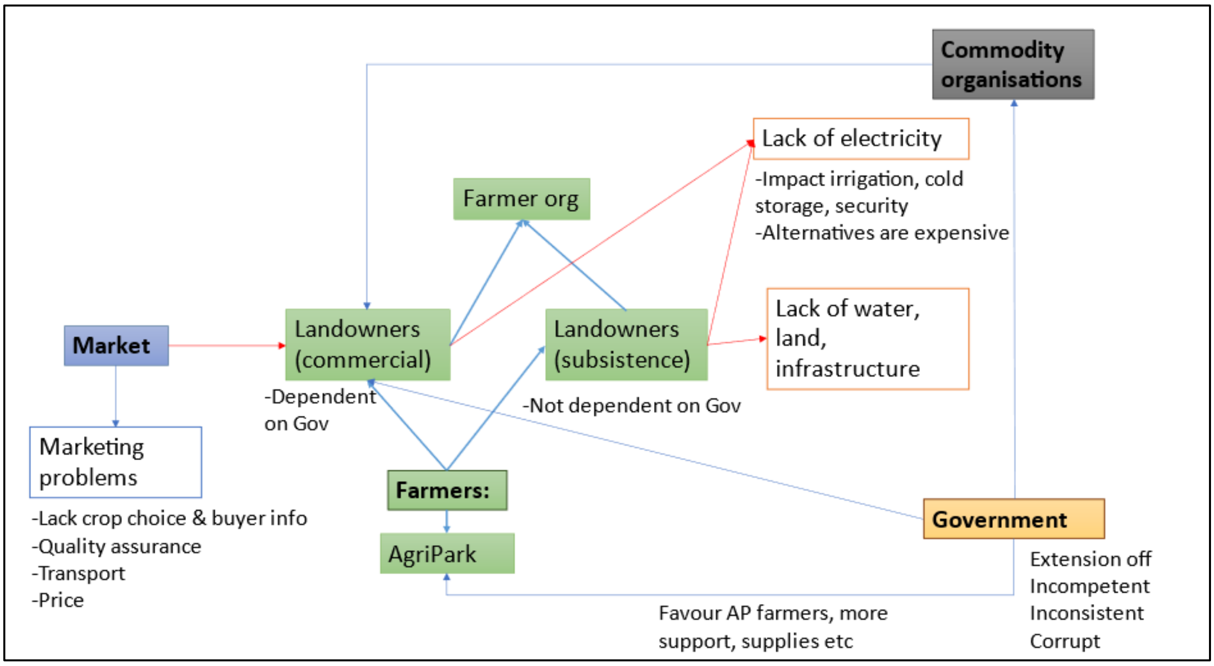


Figure 4-3: Current situation and problems in landowners' farmers from the farmers' perspective

4.1.3.4 Problems with information flow

The flow of information is a crucial part of a complex SES. Information flows enable a system to adapt and learn and to create feedback loops that people can respond to. This allows the role-players to recover from shocks and become more resilient (van Rooyen et al., 2017). Good communication requires good relationships between the various role-players. Communication was one thing that had to be improved in the current system, which all three groups, government officials, Agri-park farmers and landowning farmers, have mentioned.

From the various discussions the project team was able to determine the current flow of information through the Agri-parks as a system. There are some strong communication lines in the current system, for example:

- The commodity organisations and the ARC provide specialist information to farmers.
- The surrounding landowners share information via WhatsApp groups
- Through a steering committee, the government provides information to the Agri-park farmers and surrounding commercial SHFs through extension services, support with business plans and give marketing information.

In other cases, communication is insufficient, for example:

- Extension services are considered poor for various reasons, including different languages causing difficulty in communication.
- Information for marketing support before production commences is also considered inadequate, because the government acknowledged that this matter is only considered after production.
- Surrounding landowning farmers are not always aware of the support that they can get from the government

Improving communication can, therefore, improve the current system, but information can also be shared in a destructive way. For example, there can be an unconscious assumption in the minds of government or experts that they have more knowledge than the farmers they work with. It is not an unfounded assumption; they are, after all, experts in their field. The farmers for whom these technical solutions are meant often share this assumption. The problem with such an assumption is that these technical solutions may do more harm than good within the particular context where it is implemented, as Witmer (2022) clearly shows with various case studies. This would happen, in this case, if the knowledge of the experts influences the eventual result to such an extent that the farmers' knowledge of their context does not play a sufficiently strong role in the process.

4.1.3.5 Problems with the flow of resources

The project team determined the current flow of resources through the Agri-parks system. Local and provincial government provides input supplies and support to the Agri-park farmers. These inputs include infrastructure, seeds and seedlings, fertilisers and pesticides. The government provides electricity, water resources and water infrastructure, but this supply is inconsistent and often lacking. At the marketing level, the government supplies trucks to Agri-park farmers for transporting their produce. There are plans to extend the provision of resources to all SHFs within a 20 km radius of the Agri-parks, which is in line with the original Agri-parks model.

Sometimes the provision of resources can be destructive, for example, where the government supplies a farmer with farming inputs and equipment, but the farmer does not learn to farm profitably and does not grow to independence. The government's supporting role in the flow of resources must be well understood and resources given should be appropriate for the specific needs of a farmer and should be in line with the requirement of his/her current farming level.

4.1.3.6 Market-related problems

The farmers mentioned several problems, which seem to indicate that the food markets are highly competitive and that current supplies exceed demand, at least for certain markets and products. The NAMC agreed that the commercial markets are highly competitive and often saturated. The problems mentioned include that small farmers cannot sell at the Tshwane market, because they get low prices for their produce, costs of packaging and transport are high and often their *produce is not sold*, and they must collect it again at own cost. Producers of poultry and essential oils are struggling to get markets because cheap imported products are *flooding the markets*.

4.1.4 Current visions in Rooiwal Agri-park

The third step in the AIP is for a farmer to formulate a vision for his farm. Together with our stakeholders, we tried to formulate a vision for the Rooiwal Agri-park. From the beginning, this was more difficult than formulating the problems. It was, for example, difficult to develop a shared vision for Agri-park, because every farmer had a different vision that was incompatible with each other. The goals of the government are sometimes also in conflict with the vision of the farmers. The government wants to develop a large number of emerging farmers into large-scale commercial farmers, even if some farmers do not have the commitment to achieve this goal. The outcomes always seem like failures when high percentages of the farmers who received benefits did not become commercial. Government officials said during our meetings that it is important to help a farmer to reach his/her own vision, rather than trying to get them to achieve the government's goals.

From the problem identification process, it was clear that various stakeholders have tried to make the current Agri-parks model work in a variety of ways, without succeeding. However, when government officials had to formulate a new vision for the model, they persisted in working harder to make the current model work. They were unable to formulate a new vision for the model, one that is outside the current paradigm. For example, they indicated that marketing support creates a lot of conflict between them and the farmers. Their vision was to become more involved with marketing by buying the food from the farmers and giving it to feeding schemes and correctional services. Theoretically, this vision is not a bad idea, but the conflict over prices and market opportunities will not be resolved when the government becomes the consumer, instead of playing the role of the market agent. Officials also complained that farmers do not do what they should and they resist all kinds of micro-management over budgets and finances. Their new vision was to get greater control over the farming businesses, which will unlikely be more effective than the current system. To get a new vision requires new experiences and insights, and this is best achieved through interactions with people from different backgrounds and industries.

Each farmer also has a vision for his/her own farm. Farmers' success is also determined by the *kind* of vision they have. Sometimes a farmer does not grow because he/she never had the vision to grow. For example, many farmers join the meetings with the expectation that they might access financial support; they usually do not return. Other times, farmers' visions were too ambitious. The most frustrating part of this stage was to learn that not all visions are realistic. For example, farmers who had a vision to start a cooperative at production level was unable to get equal or even sufficient contributions from all members, which caused the initiative to fail.

From the various farms that we have visited, we saw that there are many different levels of farming below the large commercial level, which is currently not well understood. We discuss these levels in **Section 4.3.3**. A farmer may have a long-term vision to become a successful large commercial farmer, but he/she should be realistic about the process of getting there. Just like a student who cannot go to Grade 12 directly after passing Grade 1, a small farmer should not attempt to jump any of these farmer levels. Some farmers may go through these levels quicker than others, but they should first succeed in one level before going to the next.

We came to the understanding that different visions are suitable for different farming levels. For example, the most important vision for a commercial farm is to make money and there is little room for any other aspirations. Food security of one's own household is the main vision of a food garden. If a farmer has aspirations besides making money, he/she may make certain decisions that will limit his/her growth into the commercial level, for example, by choosing less lucrative crops because his/her community prefers it. Some farmers who aspired to become large commercial farmers had a vision to grow food for their neighbours. We also found that some of them have a desire to form cooperatives with their neighbours. Some farmers have goals such as 'to empower women' through agriculture. These kinds of visions could be very valuable in solving many problems in their communities, but are not typical of a large commercial farmer.

Finally, a farmer's vision is greatly influenced by expectations, which are very often not well-informed. We have provided many opportunities for farmers to attend training to obtain the SA Gap certification. This certificate is needed for any farmer who wants to sell to retail markets, for record-keeping purposes and food safety. The government subsidises this application process and provides mentoring and support to all who want to do it; farmers merely have to undertake the process with the support of the assigned official. More than a hundred farmers were invited to join the group and about 30 attended the various meetings. Only one made use of the opportunity and got her SA Gap certificate through this project. Most farmers who attended the training on SA Gap indicated that record-keeping is too much work. The administrative work did not appeal to most farmers, who are passionate about food production and not so passionate about working in an office. Large commercial farmers, however, have a lot more administrative work to take care of, including finance and tax management, human resource management, contracts and litigation and environmental authorisations. A farmer who is not keen on doing SA Gap, but still has the vision of growing into a large commercial farmer probably has unrealistic expectations of what it would be like to farm on a large scale.

Therefore, farmers must aim to become excellent on their current level, before moving to the next level, this is a realistic vision. But the levels should be well described, and farmers need to know at which level they are currently at. For this reason, we have developed the STT tool that can help farmers to characterise themselves and to identify their shortcomings. Please refer to **Section 4.3** for more information on this tool.

4.2 FARMER WORKING GROUPS

Our project established six working groups in the Rooiwal Agri-park and surrounding communities. The purpose of the working groups was to create a platform for farmers to connect with a network of role-players where they can get support and market opportunities. The working groups provided very useful information and we are reporting on these findings.

4.2.1 Water Use Efficiency (WUE)

Several farmers indicated that they had problems with water. Some had water quality issues, others did not have access to enough water, and yet others did not have the irrigation infrastructure to get the water to the crops. Most farmers did not practice efficient irrigation, which made the problems worse.

The WUE group was initiated with two training sessions and farm visits. Farmers were taken to successful farmers in Hammanskraal, who gave them training on irrigation and water use efficiency. Alternative irrigation methods were presented and some farmers tested these on their farms. The soils around Rooiwal are sandy, meaning that the water-holding capacity is low. It eliminates rainwater harvesting as a possibility for water saving and requires shorter and more regular irrigation sessions. Some farmers are irrigating with hosepipes and watering cans, which is inefficient and the time required to irrigate is already a limitation to their farm size.

There are different aspects to irrigating efficiently; 1) the quality and quantity of the water, 2) the irrigation system, 3) the management of soil moisture and 4) irrigation scheduling. If a farmer complains about water, their problems could be with one or more of the above aspects. They need to know which aspects have a problem to develop the correct response.

4.2.1.1 Water resource

The quality and quantity of the resource are generally the responsibility of the government. If there is not enough water available, it can lead to conflict between farmers, as observed in the Agri-park, where farmers are using a borehole according to a schedule. Apart from the conflict between farmers, it increases the water scarcity, because all farmers are using their maximum time to pump, even if they can work with less water. The development of new water resources from wastewater was investigated and reported on in **Section 5**.

Farmers need to know how much water they can access daily; with proper management of water application this can help them to calculate the potential production, which in turn is necessary for financial management and budgeting purposes. Few farmers know how much water they have access to and how much they use. There is a concern that some of the farmers on the Agri-park, who have access to free water, knowingly increase their water use by planting water thirsty summer crops during the dry winter season in tunnels. Although farmers may benefit financially from this by producing out-of-season crops, the amount of water used to produce those crops remains an issue in a country where water is a scarce resource. By giving water, and other supplies for free obscures the fact that the farmer is not profitable, which is not helpful to develop a farmer towards independence.

4.2.1.2 Irrigation system

The irrigation system is important because some systems are more time-consuming and labour-intensive than others and a system can be more efficient (like drip systems) or less efficient (like overhead irrigation). The irrigation system determines the size of the farm, the amount of labour needed, and the amount of water used. Different systems are appropriate for different farming levels, for example, a hosepipe may work for a food garden, but it will not be suitable for a larger farm. A pivot system is suitable for a large commercial farm but will not be appropriate for a smallholder farm. Farmers do not in general realise the importance of this.

4.2.1.3 Soil moisture management

Soil moisture management is particularly important where water is limited, but it becomes too labour intensive for larger farms. Mulching is an important way to keep the soil moist, but we see that farmers who work alone struggle to maintain mulching on more than 200 m^2 of crop fields. The physical labour of collecting and applying mulch is a problem, and the availability of mulch material is another problem. Adding manure and organic material are more ways of increasing the water holding capacity of the soil, but labour and access to these present the same problems.

4.2.1.4 Irrigation scheduling

Irrigation scheduling is another very important aspect of WUE, to know when to start irrigation and when to stop. According to the complex systems theory, there must be feedback mechanisms within a system, but there are no feedback mechanisms in the soil for a farmer to know when irrigation is needed. Soil water sensors provide this feedback, but we find that these are generally poorly adopted by small farmers.

We have encountered a very simple solution to irrigation scheduling, which was developed by Sukuma Community Transformation (**Figure 4-4**). A drip system is connected to a slightly elevated bucket or Jojo tank. The size of the bucket or tank is calculated using approximately 3 ℓ of water per m^2 of land. The bucket or tank is filled once or twice daily, and the drip system is fed from the bucket through gravity. This physical volume of water that a farmer can observe and, over time, the degree of success of the crops, serve as feedback mechanisms. The system is cost-effective; the whole system costs approximately R100 – R200 for a 10 m bed. Filling the bucket/tank takes less time than a hosepipe, but when a farm reaches about 200 m^2 a solar pump may be needed to reduce labour requirements to fill the tanks. This solution has been validated with 40 farmers. The Sukuma drip irrigation system was also presented to the WUE working group.

Figure 4-4: Sukuma drip irrigation system

More than 35 farmers have attended at least one of the meetings and workshops presented for WUE. Farmers implemented and tested some WUE solutions that were suggested, for example, mulching, increasing soil organic matter, manure, drip systems, intercropping and the Sukuma drip irrigation system. The smaller farmers who tested the Sukuma drip system soon purchased more of the system to use it on all their fields. But there was a problem with the continued use of all the above solutions: even though some farmers are currently farming on land that is small enough to justify these solutions, they aspire to be large commercial farmers and are instead trying to install systems that are more suitable for that level. The problem is that these farmers are not yet big enough to afford and maintain these systems. An example of this is seen on a Rooiwal farm, where a small farmer bought a second-hand pivot system that he intends to repair and use once he has grown to a large commercial size (**Figure 4-5**). However, he does not have the time or money to repair it. Even if he does repair it, he also does not have enough water for it, and he lacks a number of requirements that are needed for large commercial farming, such as SA Gap certification and market agreements, Environmental Authorisations, facilities and vehicles to pack, store and transport large volumes of produce. Instead of growing the farm, it seems as if he is giving it up because he is watering his crops with a hosepipe, which is labour intensive and his crops are always dry, and his yields are poor. If this farmer invested his time and resources to develop his farm at the appropriate level before moving to a large commercial level, he was much more likely to succeed.

Figure 4-5: Rooiwal farmer's irrigation systems: Left: a broken pivot, representing his aspirations to farm on a large commercial level; Right: showing the current system, a labourer watering the fields with a hosepipe

Extension officers can assist farmers with WUE by being realistic about the short-term goals of a farmer and providing suitable solutions for the level a farmer is currently on. They can further assist a farmer by determining the volume of water that is available daily and determining what size crop fields can be irrigated with that volume. This is necessary data to start with when a business plan is developed. Where farmers are utilising government land, such as the Agri-parks, the government needs to monitor and charge them for their water use, because many farmers are using water, together with various other sponsored supplies, without paying for it, and unknowingly, they are not actually making a profit. This way, they are not learning how to be profitable, meaning that they will continue to be dependent on the government.

4.2.2 Agro-processing and market access

The market access and agro-processing groups merged soon after being established, because of the need for traceability and SA Gap requirements for all food products, even when they are processed. We first discuss agro-processing and marketing separately for background. Then we discuss the work that was done in the working group.

4.2.2.1 Agro-processing

Agro-processing is considered to be a good opportunity for SHFs to cooperate at the market level. If different farmers produce crops that are physically very diverse, the produce can be combined in a processed form, second or third-grade or slightly older produce can still be processed and sold and processing could add value and increase the shelf life of the product.

The working group started by visiting farmers who have already started with agro-processing. Some farmers follow traditional ways to process food in the African culture, by cooking Swiss chard leaves and then dry it during times of excess. Some farmers produce and dry *Moringa olifera* leaves. One farmer said that she processes and sells various kinds of vegetables, and after processing, she earns up to R80 for one head of cabbage. When selling fresh cabbage directly to the consumers in the community, farmers get about R20 per head, and at retail markets, farmers often get much less than that. We have also visited a farmer who is interested in essential oils, because his brother has a soap-making facility on the farm.

There are drawbacks to agro-processing, for example, it is labour-intensive, processing can reduce the actual size of the crop, in which case it is not perceived as a product of higher value, and it may require expensive equipment, which increases pressure to generate an income. If the equipment can process various kinds of produce, then it may become easier to find enough crops for processing.

4.2.2.2 Marketing

Addressing the lack of market access was one of the main aims of this project and marketing is a fundamental part of the farming business. But there are many problems with marketing that are causing emerging farmers to fail. One problem is the competition in retail markets. Farmers at Rooiwal do not consider the Tshwane market to be suitable for them. The farmers do not have enough resources to deliver their produce to the market. Once delivered, they have no control over the prices they can get and if their products are not sold, they must remove them at their own cost. The produce remains the property and responsibility of the farmer until it is sold at the market. These conditions are too expensive and too risky, with very poor remuneration for an SHF.

Government officials said that they cannot sell the produce on behalf of the farmers or even arrange for markets for any particular harvest. When they did this in the past, it caused conflict if the farmer felt that the price was not good, and the officials did not have the capacity to take that responsibility. The government can only support farmers to develop a good relationship with various role-players in the markets, so that they can deal directly with each other.

It is therefore concluded that marketing should be the responsibility of the farmers themselves. One way of getting into the market is to find other role-players that can provide access to specific niche markets. We have identified several niche markets that can provide opportunities for emerging farmers.

- Subsistence farming promotes freedom from the market

Subsistence farming is an alternative way of solving food security outside the cash economy. A sustainable subsistence farmer is less affected by large retail industries that are controlling the food system or the competitive market. Rural households previously produced most of their own food, but many have converted to a cash economy, buying 90% of their food and spending between 60% and 80% of their income on food. According to Temple and Steyn (2009) low income households are pressured to buy low cost foods with high energy values, which are low in nutrients. Thus, the cash economy has resulted in poor people becoming malnourished, while subsistence farming can still provide the necessary nutrition.

- Rural and peri-urban communities

Rural and peri-urban communities where emerging farmers often reside are an important niche market that can support many smallholder farmers. For example, supplying food to neighbours and local markets within walking distance where fresh produce is not available is an option for emerging and smallholder farmers. We have visited several farmers in the Rooiwal/Hammanskraal area who successfully farm in this way. Their competitive advantage is that they are close to their market and food can be harvested (either by the farmer or consumer) and consumed on the same day, cutting out the costs of packaging, transport and cold storage. Farmers who sell directly to consumers in their communities indicated that they get higher prices for their produce, and in the communities, the prices do not fluctuate as they do in the formal market.

According to Devereux et al. (2019) about 25% of children in South Africa are stunted, even though there is enough food on the national level, meaning that food is unequally distributed. One of the main drivers of malnutrition is poor access to food. This can be due to food supply problems, for example, food is not locally available, or problems on the demand side, for example, people are unable to afford food (Devereux et al., 2019). According to the FAO (2023) 4.7 million people in South Africa were undernourished in 2021. According to Ritchie et al., (2023) 56.6% of South Africans were unable to afford a nutritionally adequate diet in 2021. The average income of small-scale food producers in South Africa was $784.63 (expressed in 2017 prices) in 2015 (Ritchie et al., 2023). It is a paradox of emerging farmers who are struggling to find markets, and hungry people who cannot buy food. At the roots of this paradox is the culture of dependence on government in South Africa and conversion to the cash economy.

In 2020, the ETH University in Zürich undertook a study to determine the impact that COVID-19 and the measures to curb the spread of the virus had on people living in poor urban areas in the greater Johannesburg (South Africa) and Accra (Ghana). A total of 409 surveys were completed in Johannesburg and 1 034 in Accra. There is a huge contrast between the two: in Accra, the majority (58%) of respondents had their own business and only 5% depended on grants, and in Johannesburg, the majority (64%) depended on grants and only 5% had their own business; 57% of respondents in Johannesburg indicated that they were unemployed compared to only 4% in Accra (Durizzo et al., 2020). The challenge in South Africa should be to develop small businesses and farms for food security.

- Supporting emerging farmers to utilise retail market opportunities

Farmers who cooperate at the market level have proven to be successful. This is illustrated by the farmer on the Rooiwal Agri-park with Global GAP certification, who contracts several other farmers to buy their produce. This way he ensures consistent supply of products to his market and supports several small farmers in the area.

Local agro-processors, such as Simply Garlic, provide a niche market for SHFs who are emerging into commercial farming. An agro-processing company often has retail contracts, which provide stability for the demand and price. But these industries require SA Gap certification. Not many farmers are interested in doing the SA Gap, but those who are should continue to receive the necessary support from government to complete the application process. Simply Garlic buys second grade quality for processing, thereby reducing food wastage. Farmers indicated that it is a beneficial alternative, because they are close and the farmers can cut out the costs of packaging.

- Summary of the market problem

The government always advises farmers to do market planning before they start to produce. In the retail markets, this could be difficult. For example, it is not practical for a farmer to get offtake agreements before they produce, because a buyer typically does not commit to prices before they have seen the product, unless the farmer has proven credibility. There are, however, at the lower farming levels, many decisions that a farmer can and has to make before planting, including which crops to plant and how much. The farmers must have a plan to transport their produce, and for that, it is relevant to know how far the market is and how much they can transport with the means at their disposal. If the local community is the market, the farm size should fit the size of the market. Selling in the local community has advantages over the retail market, in that the crops that are in demand, as well as their prices, are relatively stable. The kind of crops that are produced affects how much of the immediate and local market a farmer can utilise. For example, if a farmer produces five different kinds of vegetables and chicken, he can sell six products to each household in his street every week. If the farmer only produces one crop, he can only sell that one product to each household per week. By diversifying the products on a small farm, a farmer can make the most of the local markets. Larger farms typically specialise in a small number of crops.

In summary, we can say that the market problems are closely linked to the level of farming. A food garden essentially makes use of the household's own need, which is a market of sorts. At the next level, a farmer may still produce for their own consumption, but also sell a percentage of his/her produce to neighbours. As the farm grows, the immediate neighbours do not present enough market to the farmer and the produce must be transported to the wider community. At first, a wheelbarrow is sufficient to transport produce, but as the farm grows even more, reaching 1 200 m^2, a small truck becomes necessary. At larger commercial levels, one or several big trucks are needed. In reality, we observe many farmers producing on less than 200 m^2, serving their local communities, who own trucks. These farmers typically struggle, and the money spent on the trucks might have been utilised better to help them grow to the desired level.

Government officials indicated that their programmes work with two levels of farmers, the food garden level and the commercial level. The size of a farm at the commercial level is based on the minimum viable unit for each crop and usually starts above 1 hectare. To calculate the profitability of the minimum viable unit, the opportunities of utilising local resources and markets that are currently wasted are disregarded. There are many examples of profitable farms working below the minimum viable unit, because they can minimise expenses and maximise income. The niche markets within the rural and peri-urban communities discussed above can best be utilised by smaller farms below 1 hectare. It is also clear that the farm levels between food garden and commercial farms are very different in terms of the market that should best be utilised, with storage and transport requirements. For marketing purposes, it is therefore important that a farmer knows at what level he /she currently farm, and the appropriate investments at that level. Please refer to **Section 4.3.3** for a discussion on these levels.

4.2.2.3 Working group activities

We introduced the market working group to the National Agricultural Marketing Council (NAMC), GDARDE officials and a local food processor, Simply Garlic, for marketing support. Together with the farmers and

NAMC, the group kicked off with a meeting with Simply Garlic to discuss which crops they are in the market for, specifications for each of these crops, prices and other requirements. General requirements of Simply Garlic include that crops are second grade and SA Gap certified. Even though Simply Garlic wishes to buy second-grade produce only, their prices are very reasonable, and the farmers mentioned that the money they save from not having to buy packaging materials makes this agreement very beneficial to them.

Regular meetings were held to support farmers in registering with SA Gap, and follow-up support was provided by NAMC and GDARDE. The intention was to have two groups:

- SA Gap-certified farmers who are ready to supply the Simply Garlic market. In addition to the SA Gap training, we have identified 21 farmers who are already SA Gap certified, and
- Farmers who still need support and workshops to apply for the SA Gap certification.

Farmers in these groups were located in various municipalities in Gauteng, namely City of Tshwane, City of Ekurhuleni, Sedibeng and West Rand. Through the working group, these farmers were registered on the Simply Garlic database and started to deliver to them.

From the various workshops on SA Gap, only one farmer from Rooiwal successfully obtained her SA Gap certificate and is now also being registered with Simply Garlic. Other participants did not like the amount of work required for the SA Gap. Some of the problems that participants with SA Gap raised were having difficulty getting the pesticides that are acceptable for SA Gap in their local stores, and difficulty in measuring the volumes of pesticides that should be applied in the fields.

A meeting was then held with Boxer, who indicated that their vision is to support small farmers with market access. The recent focus on the dangers of poor management of food outlets, which resulted in the deaths of 20 children and the hospitalisation of hundreds (The Conversation, 2025), highlighted the need for record-keeping, traceability and food safety. Boxer is now investigating easier ways for small farmers to do record-keeping. If a community can organise itself to sell in bulk to Boxer, they would be interested in supporting them, but they cannot buy small volumes of produce from single small farmers.

If the matter of record-keeping can be solved, this can be an opportunity for farmers to cooperate at the market level. The matter of food safety in informal markets is not currently managed; it is assumed that people know the local farmers well enough to trust them with the safety of the food, and to be able to trace any sickness back to them. Traceability and recordkeeping for food safety purposes in the informal market are important topics for future research.

4.2.3 Seed saving

The seed saving group generated a lot of energy and enthusiasm. The reason for this is that seeds are generally difficult to access. Poor financial management causes many farmers to spend their profits from the previous season, with no savings to invest in the next crop. Genetically Modified Organisms (GMOs) have also changed the system, and farmers are struggling to adapt to these changes. First, GMO seeds are expensive, and they do not yield viable seeds. These seeds must be bought at a high cost at the beginning of each season. These GMO crops often need particular care and can be more difficult to grow organically, again increasing costs. And despite these drawbacks, farmers are under more pressure to convert to GMO crops because the market prefers these varieties.

The government officials particularly highlighted a problem with the provision of seeds and seedlings to Agri-park farmers. Farmers would apply for seedlings of a certain crop, and in response, the official would start the slow bureaucratic process of getting permission. After about 6 months, the seedlings are delivered to the farmer, but at that point, it is too late. Farmers need better access to seeds and the current bureaucratic systems are not suitable for that.

These problems and the interesting varieties of heirloom seeds probably explain the enthusiasm with which the seed saving group was started. Some farmers are already saving seeds informally, and other farmers joined the programme. Seed saving is, however, not completely straightforward. Some varieties of crops can cross-pollinate and therefore these varieties should not be planted on the same farm if seeds are to be harvested. Harvested seeds must be stored in a cool and dry container and marked with the name of the crop, and location and date of harvest. Seed viability must be tested and diseases that spread through seeds must be controlled. Finally, the farmer must get a market for the seeds, because some of the seed savers collect storerooms full of seeds and are unable to use all seeds before they expire.

Various training sessions dealt with topics including summer and winter crop selection, pest and disease control, crop-specific requirements for seed saving and business opportunities for the seed producer. Winter and summer crop seeds were given to the farmers during two different workshops at the beginning of each respective season, giving them the task to grow the crops and multiply the seeds. At the end of the season farmers returned with the seeds. Some of the farmers produced almost 2 kg of seeds for future use. Farmers have shared their experience and thoughts on the challenges and benefits of seed saving, which was met with a positive response and sparked a great interest in farmers who were not participating in the seedbank initiative.

Figure 4-6: A field of squash (*Cucurbita sp.*) planted from seeds that a Rooiwal farmer on the seed saving group harvested and saved.

There were some reported drawbacks regarding seed saving. One of the farmers mentioned that it is difficult to find a market for his produce, because it looks different from the usual produce. However, he is committed to the cause and still manages to find a market. He was growing elephant garlic to harvest the seed for his own future production. Simply Garlic was very interested in his elephant garlic, because they currently import the large garlic they need. Another farmer is now growing a large field of squash (*Cucurbit species*) with seeds that she has saved (**Figure 4-6**).

If a community does not have a shared seedbank, there are opportunities to satisfy the need for seeds. Seeds are small and many seeds can easily be transported, even by using public transport. Small entrepreneurs in a community can take advantage of such an opportunity to supply seeds to farmers. The current expectation that the government would supply seeds may hinder the development of such small businesses, which would be more effective.

4.2.4 Essential oils working group

The essential oils working group was initiated in response to farmers' interest in it. Farmers are currently growing *Moringa oleifera* and castor beans (*Ricinus communis*). Some of the commercial farmers in the area have the equipment and markets to extract and sell the oil.

Two formal training sessions on essential oils were given, one by the South African Essential Oil Producers' Association (SAEOPA) and another by an oil processor. The processor visited the farmers in the group to advise them on particular crops that they can plant, based on their farms, i.e. land size, soil conditions, water availability and market opportunities. A commercial farmer from Rooiwal attended a meeting to discuss cooperation with the emerging farmers, small farmers in our groups were surprised to realise that even the commercial farmers are struggling.

There was a lot of interest in the group, with more than 15 people attending each of the training sessions. Participants came from as far as Mahikeng and Brits to attend one of the sessions. It was indicated that a farmer should ideally start with 10 ha and grow towards 40 ha to be commercially viable. The expensive part of the business is the oil processing equipment. Most farmers are living on less than 5 ha of land, in which case the business can only work if they have a good market and easy access to a local seed press or distiller. Benefits of producing essential oils include that it can be grown in denser communities, because the crops are not stolen like food crops, leaves can be dried and stored until enough is collected to take to the distiller, and there seems to be a good market for many of the oils. Problems with the oil industry are that farmers are competing with oils that are imported at low cost and often these oils are mixed with cheap oils, but sold as expensive oils. The local market for *Moringa,* for example, is very difficult to get into, because the retail shops have contracts with larger farms.

There was also a group of farmers who formed a cooperative at the market level to supply castor beans to the same buyer. These farmers organised themselves efficiently and one of the farmers collected and delivered all the beans to the buyer. However, early in 2025, the buyer was no longer available, and the farmers had seeds to sell. Through the working group, these farmers were connected to SAEOPA instead and managed to find a new market. This success was mentioned by one of the farmers at a quarterly meeting, but it was not reported to the project team. This indicated that the farmers' communication with the project team is not always good, and there may be more successes in the working groups that we are unaware of. It is also a good sign that the farmers are not dependent on the team members anymore, but that they are now relying on the connections they formed during the project.

4.2.5 Farmer graduation programme

Landowning farmers in the Rooiwal area felt like they were not getting the support from the government that they needed, while farmers within the Agri-parks are getting all the support. This is partly true, as the government cannot provide time and supplies to every SHF, and those that do receive support need to be supported indefinitely. The landowning farmers suggested the idea of a farmer graduation programme, where support is given to a farmer for a limited time and then the government withdraws its support and moves to another farmer. The farmer graduation programme working group was established to discuss this idea with government officials.

4.2.5.1 Defining the Problem

Experience has shown that if different parties cannot agree on what a problem is, they cannot solve it. In that respect, we have a firm foundation in the Rooiwal network: both government officials and farmers agree that emerging farmers who receive continuous government support often become dependent on it and seldom continue farming independently. As a result, some farmers remain permanently dependent, while others receive no support at all.

Officials also observed that the current policy framework focuses more on the number of beneficiaries than on the impact of support. Inputs such as free supplies may satisfy government performance indicators, but rarely lead to independence. Training sessions often become social events rather than practical learning opportunities.

The landowning farmers' suggestion to gradually reduced government support over three to five years before final exit, after which the support is transferred to another farmer, was discussed. Government acknowledged this as their goal but noted that, in practice, when support is reduced, production levels drop accordingly. When support stops, many farmers stop producing altogether.

Through these discussions, we have refined the problem definition:

1. **Farmers are not all the same.**
   - Some are genuinely motivated to become independent commercial farmers ("real farmers").
   - Others see government support mainly as a source of benefits ("opportunists").
   - The opportunists often occupy resources permanently, blocking access for motivated farmers.
   - *Conclusion*: Aspiring farmers must first prove themselves before receiving support — but the question remains how this should be done.
2. **Types of support that do not yield good results:**
   - Once-off capital funding (e.g., growing tunnels or abattoirs) often fails because infrastructure falls into disrepair.
   - Support for running expenses (e.g., fertiliser) creates dependency.
   - Provision of tangible goods (e.g., seeds) is slowed by bureaucracy.
   - Market support by officials creates conflict when prices differ from farmer expectations.
   - Advisory support by extension officers is undermined by market changes or a lack of practical experience.
3. **Types of support that may be more successful:**
   - Removing obstacles to growth, e.g., funding for SA-GAP certification or Environmental Impact Assessments (EIA), which enables farmers to access formal markets.
   - Partnerships with commercial farmers, where experienced farmers support emerging ones financially and technically, while providing a ready market. There are examples of such mentorship models working without government intervention.
4. **Roles and responsibilities**
   - It became clear that roles and responsibilities are incorrectly allocated within the current Agri-parks system.
   - Government's proper role: Develop and manage the quantity and quality of water resources, providing electricity, managing crime etc;
   - Farmers' proper role: Sourcing production inputs, running a profitable farm, improving own skills, increase water use efficiency.
   - The system fails if government is taking responsibility for things that farmers should do, for example supplying farming inputs, and neglecting the functions that farmers are unable to take care of, such as crime and provision of water resources

4.2.5.2 Possible Solutions

To find practical ways forward, we consulted incubation units in other industries, since challenges of dependence and growth are not unique to agriculture. The key insight is that entrepreneurship skills—especially financial discipline—cannot be taught in a classroom; they must be learned through experience. A farmer who receives free inputs does not learn to manage costs, chase markets, or plan for profit. Without profit or free supplies, production ceases. In contrast, a farmer who receives mentorship without free inputs is forced to build real business skills.

It highlights the importance of mentorship and extension services. However, extension officers often have too many farmers to support, and there is a communication gap between the theoretical knowledge of the extension officer and the experiential knowledge of the farmer. Farmers, in turn, tend to value physical inputs more than advice.

To bridge this gap:

- Mentorship networks should be expanded to include NGOs, market agents, and commercial farmers. These mentors should be incentivised to support emerging farmers.
- A structured apprenticeship model could combine hands-on learning with mentorship, similar to the automotive industry's supplier development programmes.
- The incubation units of the automotive industry can be used as a model, because they have some success stories. Their selection process is key to their success, but they warn that you can never predict who will succeed in business.

4.2.5.3 Linking Government Support with Farming Levels

Field studies show that farmers require different kinds of support depending on the level they are farming at. Support that is appropriate for a small farmer may be counterproductive for one at a more advanced level and the other way around. For example, after expanding her plot to 200 m², a Hammanskraal farmer needed a solar pump to irrigate effectively. A small, targeted loan improved her efficiency and sustainability. Another farmer had 1 200 m² of land and required tractor services for seasonal soil preparation. Renting equipment instead of purchasing it was the most efficient solution. These examples demonstrate that government support should be tailored to the specific growth stage of each farmer, not provided as a one-size-fits-all package.

Since the current support is very generic, the project team developed the Sukuma Farmer Support Tool (**Section 4.3**) to help government officials to classify farmers according to their current level, and to identify the specific constraints preventing progress to the next stage.

Once a farmer reaches the commercial stage—having secured SA-GAP certification and market access—a performance-based support model can apply. In this model:

- Government collaborates with an industrial partner (e.g., Simply Garlic).
- The industrial partner mentors the farmer and purchases the produce.
- Government subsidises a percentage of the product price to reward production rather than inputs.

This ensures that:

- Support is earned through measurable output,
- Farmers stay motivated to produce, and
- Government funds contribute to long-term independence instead of dependency.

4.2.6 Poultry working group

The poultry group was initiated on 11 April 2024 at a quarterly meeting held by the project team. The poultry farmers identified two primary issues that are limiting them from growing into successful commercial farmers:

difficulty accessing markets, which are typically flooded by cheap imported products and the prohibitive costs of Environmental Impact Assessments (EIAs) required to expand production beyond 5 000 chickens. The EIA process, which typically costs around R200 000, is unaffordable for most small-scale farmers. As a result, they remain locked into a scale of operation that is financially unsustainable. For example, the cost of chicken feed when bought in the quantities that small farmers require is not cost-efficient.

The Forum invited the Small Enterprise Development Agency (SEDA) and the National Agricultural Marketing Council (NAMC) to their meetings. Farmers were also linked with the South African Poultry Association (SAPA), which offers training and assistance with EIAs for qualifying members. NAMC encouraged the farmers to formalise as a group to benefit from production scheme models and the delivery model under the Agriculture and Agro-processing Master Plan (AAMP). Through collective action, the farmers can be linked directly to larger markets.

Throughout the project, this group has tried many ways to succeed in their goal of becoming successful commercial farmers, because they do not 'want to remain emerging farmers forever':

1. The Forum's first objective was to work together to get support from GDARDE with EIA applications, which they cannot afford. GDARDE appreciated their initiative but said that they are not allowed to provide any support because they must evaluate these applications as independent parties and such support would create a conflict of interest.

2. The second objective of the group was to establish the full chicken value chain, consisting of producers of parent stock, hatcheries, growers / layers and abattoirs / markets, within the Rooiwal community. However, the Forum faced challenges related to declining participation and leadership fatigue. The core members temporarily lost momentum, and the group leader expressed frustration about the lack of contribution from others.

3. At the final meeting in June 2025 a new objective was formulated, to establish the chicken feed value chain within the Rooiwal community. By growing the various grains and soya beans to produce chicken feed locally, they can reduce their input costs. It was agreed by all to pursue this plan of action. However, the group still struggles with cooperation among all members.

Looking back at the efforts that were invested into this initiative and the failures they experienced, it seems obvious that there is a fundamental problem with the aim. The government often encourages cooperation at the production level because its support can reach multiple beneficiaries, but it has mostly proven to be unsuccessful. It is a general trend that a small group will work hard, while the rest will do very little. This is not the same as cooperation at the marketing level, which is successful, as mentioned in **Section 4.2.2**

The NAMC suggested the following steps to strengthen the Forum's operations:

- Conduct a baseline assessment to evaluate each farmer's production capacity, identify gaps, and map opportunities in the value chain.
- Support the registration of members with the South African Poultry Association, providing access to information, training, and EIA-related assistance.
- Encourage the development of local market systems within the community to promote intra-group trade.
- Strengthen and expand existing market relationships.
- Discuss group dynamics and leadership

The importing of cheap chicken products in South Africa presents another fundamental problem with the poultry industry. This situation makes it more difficult to get a market, but even when markets are found, the prices are generally low, making the business less profitable. Government policies should address the import of products that are competing with local businesses.

4.3 FARMER SUPPORT TOOL

4.3.1 Background

The idea of developing a farmer support tool emerged from various impressions that we got during this project. Our first impression was that farmers and government officials are stuck in a situation in which both groups feel powerless to overcome, namely that farmers are unable to grow to independence, despite all the support that the government can give them. A GDARDE official pointed out that the selection of farmers for support is not done correctly. Certain Key Performance Indicators for the officials drive the government to develop a maximum number of large commercial farmers. This leads to classifying farmers as emerging commercial farmers based on farm size, even when the farmer only wishes to farm for their own consumption.

Second, we got the impression that many farmers aspire to become large-scale commercial farmers, but do not understand what it entails. For example, most of the farmers who have attended our SA Gap training said that the requirements are too much for them to do. Even though SA Gap certification requires a lot of record keeping and paperwork, this is still a fraction of what is required from a larger-scale commercial farmer. Large-scale commercial farming is very challenging compared to other industries, with high start-up costs, high risks and high competition in the formal retail market. Farmers can develop towards such farming levels by gradually moving from one farming level to the next. Farmers who are profitable at a certain level often prefer not to move to the next level. Small farmers can still produce profitably, as proven by successful smallholder farmers in Hammanskraal and Rooiwal areas. These small farmers play a vital role in providing food security and nutrition to their communities. While retail markets are often saturated and mostly highly competitive, hunger and malnutrition in the country is an indication that we need more local farmers. But those who are hungry and malnourished are unable to afford the prices on the formal market. In many cases, they live too far away from these markets and have to spend money on transport to access the fresh produce that they need. The government, therefore, must decide how much attention it wants to give to developing more large-scale commercial farmers, or how much attention it wants to give to addressing food security. To address food security and to empower more people to farm, we need SHFs that produce food for their own communities. And we need a tool to help us select and support those farmers who are in a position to grow all the way to large-scale commercial farming.

We have identified profitable small farms at various levels in Rooiwal and Hammanskraal, and we found that there are fundamental differences between these levels. We have also found that a person can only move up one farming level at a time. We believe that many of the failures in Agri-parks are due to the government supporting a farmer who is currently at the lower farming levels to achieve large-scale commercial farming, meaning that this farmer would have to skip one or more farming levels. This could explain many of the failures that we see in the Agri-parks system. The Sukuma Transformation Tool (STT) that we have developed for farmers and extension officers, therefore, aims to determine which level a farmer is currently operating on, and his/her potential to grow towards the next level. The tool also highlights the shortcomings that a farmer must address to be efficient on the current level or to grow to the next level.

In this section, we describe the various farming levels, based on the actual farms that fit these categories in Rooiwal and Hammanskraal. Second, we discuss the parameters that we use to identify the farming level of the farmer, the questions that should be completed by each farmer and the outputs of the tool. Finally, we discuss the testing and verification of the STT in Rooiwal and whether it was able to provide farmers with information that they needed to grow.

4.3.2 Assumptions and limitations

It is assumed that the farms use little technology, and systems such as hydroponics and vertical farming are excluded from this classification. This is because the management of such systems requires a high level of management, high input costs, constant electricity and advanced skills. All the farmers that we work with currently plant in soil, and some have shade nets to cover their crops. Electricity is unreliable and the farmers do not have access to funds for hydroponic systems yet. We therefore consider such vertical systems as characteristic of commercial farmers, which could be considered by those who are at the large commercial level.

We developed a calculator to estimate potential income, based on cabbage as a reference crop. Cabbage is a crop that is commonly produced in the study area, and it represents a good average of income per m^2. The implication is not that a farmer should plant only cabbage, but the calculator can be used for general planning. The tool should be expanded in future research to include other typical crops like Swiss chard, beetroot, tomatoes, onions etc.

The tool also made the following assumptions, which can be changed by the user if needed:

- Assume 3 ℓ of irrigation water per m^2 per day.
- Assume 4 cabbages per m^2, three planting cycles per year.
- Assume a maximum of 75% crop success
- Assume the farmer resides in a rural community that is not densely populated, and that the competition in the community is not limiting the market.
- Data for Levels 1 to 4 were based on actual farms in Rooiwal and Hammanskraal. Data on Level 5 was based on the enterprise budgets for cabbage published by Western Cape Government (2023)
- The tool is based on irrigated vegetable production systems and should be adapted for grazing or dry land production.

4.3.3 Characterisation of the farming levels

Figure 4-7 shows the opportunities and challenges that are related to different levels of farming (note that not all levels are presented in this figure). It shows that challenges increase significantly as a farmer moves towards larger-scale commercial farming. At the commercial level a farmer spends most of his/her time in the office running a business. Together with a team, the farmer typically handles legal requirements, contracts, agreements, budgets and finances, marketing and business management, together with production. The subsistence farmer is only concerned with crop production aspects. The kinds of skills required are also changing. Therefore, if government is pushing for more commercial farmers, they assume the farmer will have the opportunity, skills and motivation to deal with many complex challenges. The two levels represent two widely different undertakings, and it does not follow that all successful farmers with experience in food production can or want to be promoted to large commercial farmers.

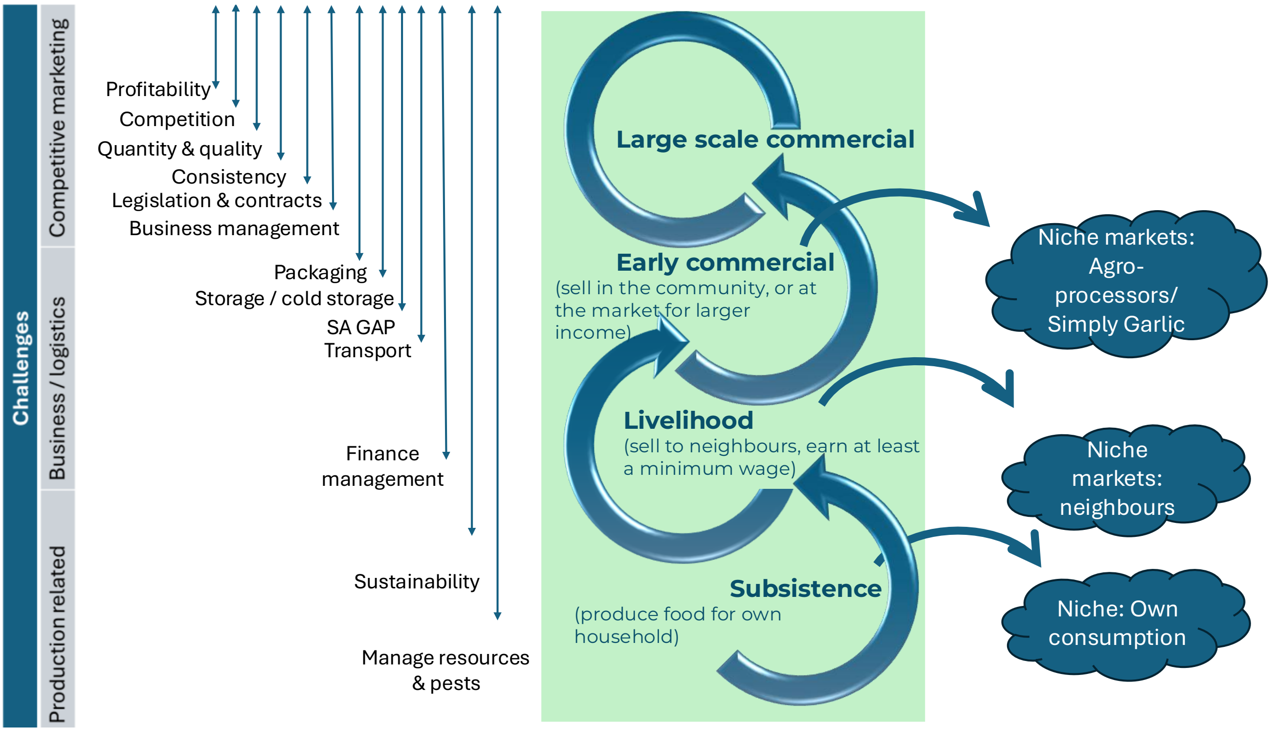


Figure 4-7: Challenges and opportunities related to selected farming levels

Cousins and Chikazunga (2013) identified similar farming levels; their focus was on the clear categorisation of farmers, for which quantity is important, e.g., how much farmers in each category earn. We focus on providing farmers with a tool to plan their farming. We build on the current research by describing a combination of a few key factors: size of land, how much water, the available market, what technology is needed (e.g. solar pump, truck), how much labour is needed, cost of input, the weather. These key factors must fit into each other and combine well. To go to the next level, you must be able to manage a whole new combination of such key factors.

4.3.3.1 Bridging the gap

To bridge the gap between food garden farmers and large commercial farmers, the levels in between must be characterised. These levels can help us in two ways: (1) to provide the pathway for small farmers to grow incrementally towards commercial farming, and (2) to improve the support given to those farmers who prefer to stay on one of these levels. Based on actual farms in Rooiwal and Hammanskraal, we have classified five farming levels ranging from food garden farming to emerging commercial farming. We discuss each of these levels below by describing the actual farms and farmers, the typical challenges, markets, and resources, tools and infrastructure that are needed at each level. For each farming level, we describe the potential expenses and income based on crop success of 75%, 50% and 25%, respectively. We use pseudonyms to protect the identity of our participants.

4.3.3.2 Food garden (Level 1 on the cabbage calculator)

This category ranges from the subsistence farmer to a small farmer who sells excess produce. The farmer needs up to 50 m^2 of land for crop production and 150 ℓ of water per day. Labour requirements are about 2 hours per day for 5 days per week. These farms typically have a variety of crops, which the household consumes, and sometimes combine this with animals like chickens or goats. The food garden farmer is mainly concerned with issues regarding crop production. At this level, local resources that are freely available can be used to grow seedlings, apply mulch and produce fertilisers and certain pest controls, which greatly lowers the costs of production. Issues of marketing, packaging, transporting crops, hiring labour, administration and legal requirements are not applicable. Customers reside in the same neighbourhood and often come to the farm to buy what they need. Crops can be sold at a high profit percentage (for example R20 per cabbage), because it is sold directly to the consumer with no need for agents, hawkers or even packaging and storage. The prices in the communities are consistent, as opposed to the fluctuations in retail markets. We characterise this level based on an actual farm in Hammanskraal, belonging to Simone[1].

Simone's vegetable garden is 50 m^2 (5 x 10 m beds) in size, on which she produces enough vegetables for her family of three adults and two children, with some left to sell to her neighbours (**Figure 4-8**). She plants a variety of crops which they typically eat, including carrots, cabbage, beetroot, Swiss chard, beans and onions. Irrigation is done with the Sukuma bucket drip system combined with mulching. Simone produces her own liquid fertiliser and seedlings. She manages pests with a set spray programme using organic pest control. Water resources used include municipal water, if available and borehole water. Two boreholes have been manually drilled up to 6 m depth using soil augers and fitted with a self-constructed manual pump. Simone is part of the Sukuma agriculture group and receives weekly visits from Mr Dawid du Plessis for agricultural support. This farm, with all infrastructure, was established with the Sukuma community transformation agricultural support.

Figure 4-8 Garden in Hammanskraal which characterises an early livelihood farm

The vegetable garden supplies them with a nutritious diet as well as income. Apart from selling vegetables, the family gets their income from a variety of sources. Simone operates a small shop in her yard, and she sells perfumes in the community. Her mother works as a domestic worker in Pretoria.

4.3.3.3 Early livelihood (Level 2 on the cabbage calculator)

The early livelihood farm is larger than the food garden, requiring about 200 m^2 of crop fields and 600 ℓ of water each day. Labour typically involves 4 hours per day for 5 days per week. At this level, local resources that are freely available can be used to grow seedlings, apply mulch and produce fertilisers and certain pest controls, which greatly lowers the costs of production. According to our cabbage calculator, a farm that operates well at this level could potentially produce up to 150 cabbage heads per month. If all these cabbages are harvested at once (600 cabbages every four months), finding a local market could be difficult, and transport may become necessary. However, transport is usually not an issue, because of stagger planting and these farmers typically produce a variety of crops that are consumed in the community, meaning that they make the most of the market in the vicinity. Also, neighbours often buy at the farm gate. At this level crops can typically be sold at a relatively good price, because it is sold directly to the consumer with no need for agents, hawkers or even packaging and storage. If all the cabbage is sold at the current price of R20 per head, the farmer could potentially get R3 000 / month income. With relatively few expenses, this level of farming can be very rewarding, compared to being without income, granted that crop success and selling price are both high.

[1] Pseudonym

We characterise this level based on an actual farm in Hammanskraal, belonging to Lina[2]. Lina is one of Simone's neighbours and part of the Sukuma agriculture group (**Figure 4-9**). She farms with a variety of vegetables on approximately 200 m² (10 x 20 m beds). A shallow borehole was constructed manually using a spade and by connecting a self-constructed pump. However, the amount of water that must be pumped manually for this size of crop field requires so much time, that a solar pump had to be installed. Her irrigation system is a scaled-up version of the bucket system, with 4 x 20 m drip lines connected to 200 ℓ water tanks. The irrigation is also combined with mulching for soil-water preservation. Lina produces her own liquid fertiliser and seedlings. She manages pests with a spray programme using organic pest control. This farm with all infrastructure was established with the Sukuma community transformation agricultural support.

Figure 4-9: Farm in Hammanskraal that characterises the livelihood scale

4.3.3.4 Livelihood farmer (Level 3 on the cabbage calculator)

We classify a farm of more than 400 m² (20 x 20 m beds) as 'livelihood farmer'. This size of farm requires approximately 1 200 ℓ of water per day and the farmer must work fulltime. At this level local resources that are freely available can be used to grow seedlings, apply mulch and to produce fertilisers and certain pest controls, which greatly lowers the costs of production, although the availability of these resources in close proximity may become limited at this point. A successful farmer at this level can produce up to 300 cabbage heads per month. This farming level is a critical point before a farmer can move into commercial farming and fundamental changes are needed beyond this point. As a farm expands, the labour requirements increase. When the farm reaches a point at which a full-time labourer is required, the production must theoretically double to support another household. A percentage of the produce can still be sold at the farm gate and distributed with a cartwheel. Once production reaches a certain quantity the farmer needs markets that are further away, and both the distance and the volumes will necessitate a truck for transport. The livelihood level reaches the ceiling for both labour and transport. Once the farmer expands from the livelihood level, a full-time labourer and a small truck (1 000 kg loading capacity) is needed. At this level, a hawker might be used from time to time, because of the larger quantity of crops to be sold, meaning that crops are sold at a lower price (R15 per cabbage head). To be very successful at this level, it is important to do record keeping for budgeting purposes, to work on a plant schedule and to keep a nursery for germinating seedlings for 12 months per year.

We characterise the livelihood of the farmer level based on an actual farm in Hammanskraal, which belonged to Sonny[3]. Sonny used to work in Pretoria for a minimum wage, but he was unhappy with the long hours, the traveling and being away from home all the time. He met another farmer in Hammanskraal who became his mentor and he decided to start farming himself. Today, he earns a wage that is similar to the salary he got previously. The difference is that he is at home, he produces nutritious food for his family, and he is doing something that he is passionate about. Sonny uses the Sukuma drip system, which is connected to a JoJo tank to irrigate approximately 1200 ℓ of water on 400 m² of crop fields. He produces a variety of crops, including Swiss card, cabbage and onions. Sonny does well, and he works hard, but he still needs to improve his record keeping, planting schedule and financial management, otherwise he often ends up earning a similar income to Lina. But despite these improvements that are needed, farming has empowered Sonny and given him fulfilment and purpose.

[2] Pseudonym
[3] Pseudonym

4.3.3.5 Early commercial; local market (Level 4 on the cabbage calculator)

We classify a farm of more than 1 200 m^2 (60 x 20 m beds) as an 'early commercial' farm. This size of farm requires approximately 3 600 ℓ of water per day. At this level freely available local resources can be used to grow seedlings, apply mulch and produce fertilisers and certain pest controls, lowering the costs of production, but sometimes these will have to be supplemented through purchasing. A successful farmer at this level can produce up to 900 cabbage heads per month. At this level, a truck is needed for the distribution of produce to the market and street hawkers will be used, meaning that the price per cabbage head that the farmer gets drops to R10 to R15 (R20 at farm gate, R15 with transport at street hawkers, R10 at the formal market). At this point, a full-time labourer and seasonal workers (1 000 kg loading capacity) are needed. Market agreements, record keeping, plant schedule and financial management become critical at this level for 12 months per year.

We characterise the early commercial farmer level based on an actual farm in Hammanskraal, which belongs to Jim[4]. Jim received support from Sukuma Community Transformation to establish the farm, and he uses the Sukuma drip system, which is connected to a JoJo tank to irrigate. He produces a variety of crops, including Swiss card, cabbage and onions.

4.3.3.6 Emerging commercial; formal market (Level 5 on the cabbage calculator)

At the emerging commercial phase, a farmer should at least produce on 5 000 m^2 or more. These fields can be irrigated with at least 15 Kℓ of water per day, provided that good irrigation practices are used. This size of farm will require 4 full-time labourers, which means that production should notably increase to maintain profits, and administrative work increases. At a 75% success rate, this farmer can produce 15 000 cabbage heads in a growing season, which equates to 3 750 heads per month. These volumes are likely to exceed the local demand, and trucks are needed to transport the produce. Prices obtained at this level are often lower because a large percentage of the produce cannot be sold directly to the consumer. Agents and hawkers become necessary and packaging and storage also add costs to the produce. At this farming level, a farmer usually plants only one or two crops, and need market contracts. This farmer can likely benefit from niche markets such as Simply Garlic and Boxer and requires SA Gap certification.

4.3.3.7 Summary of farming level data

Table 4-4 shows the ranges in field sizes and the irrigation water required for each farming level. The early livelihood and livelihood farmers who sell directly to their neighbours typically get R20 per cabbage head. This price is relatively stable, as opposed to the major price fluctuations of the retail markets. Emerging and early commercial farmers typically use agents and hawkers to sell their produce, and they can realistically expect between R10 and R15 per cabbage head. During times when the formal markets are flooded, cabbage heads can even drop below R10. **Table 4-5** shows the potential production and income for each farming level.

Table 4-4: Land area and water requirements for the five farm levels classified below large-scale commercial, as used in the cabbage calculator

Farm level	Farm size range (m^2)	Irrigation water required (ℓ);
Food garden	50	150
Early Livelihood	200	600
Livelihood	400	1 200
Early commercial	1 200	3 600
Emerging commercial	5 000 – 10 000	15 000 – 30 000

[4] Pseudonym

Table 4-5: Potential production and income for the farm levels classified below large-scale commercial, as used in the cabbage calculator

Farm level	Price per cabbage	Crop success	Potential Production (Cabbage heads/month)	Potential monthly Income (not profit)
Food garden	R20	75%	37	R740
		50%	25	R500
		25%	12	R240
Early livelihood (200 m²)	R20	75%	150	R3 000
		50%	100	R2 000
		25%	50	R1 000
Livelihood (400 m²)	R20	75%	300	R6 000
		50%	200	R4 000
		25%	100	R2 000
Early commercial (1200 m²)	R15	75%	900	R13 500
		50%	600	R9 000
		25%	400	R6 000
Emerging commercial	R10	75%	3 750	R37 500
		50%	2 500	R25 000
		25%	1 250	R12 500

Farmers in food gardens generally have minimal capital and running expenses. The farmers in the Sukuma agricultural group produce their own liquid fertiliser and pesticides, and it works well. Some organic sprays are used, which they buy from the money they earn. The major support given to these farmers by the Sukuma agriculture group is the provision of loans and supplies (at cost) that are not available locally. Typically, seeds and organic pest controls are not locally available.

4.3.4 Questionnaire to determine the current farmer and farming level

Table 4-6 and **Table 4-7** shows the questionnaires for farm and farmer level categorisation, respectively. Farmers complete these questionnaires and count the marks in the different columns at the end to see in which category they predominantly fall. The questions where they marked below their current level indicate those areas where they are currently lacking, and where they need to grow.

Table 4-6: Questionnaire for farm level categorisation

			Food garden	x	Early livelihood	x	Livelihood	x	Early commercial	x	Emerging commercial	x
1. Land	1	How much land do you have available for farming?	50 m² - 100 m²		200 m²- 400 m²		400 m² - 600 m²		1200 m² - 1500 m²		>5000 m²	
2. Water	2	How much water do you have available per day?	100 ℓ / day		600 ℓ / day		1200 ℓ / day		3600 ℓ / day		15 000 ℓ / day	
	3	What water source do you use?	Rain		Rain / municipality		Borehole		Borehole / rain		Borehole / rain	
	4	What irrigation method do you use?	Bucket / hosepipe						Overhead		Drip /Overhead	

Section	No.	Question	Food garden	Early livelihood	Livelihood	Early commercial	Emerging commercial
	5	Do you have an irrigation scheduling programme?	No	I irrigate for a while when the crops are dry,	I water my crops every day	I know more or less how much water I give per crop	I have an irrigation scheduling programme
3. Labour	6	How much time do you spend working in your garden? (Labour)	1-4 hours per week	2 hours every day	Full day every day	Half day with a worker	I employ more than 2 workers
3. Labour	7	How many people do you employ to work on the farm?	None, I work alone	None, me & one family member work alone	1 Seasonal worker	1 Permanent worker and seasonal workers	More than 2 permanent workers + seasonal workers
3. Labour	8	How would you describe your normal day/week on the farm?	Most of my time goes to physical labour in the garden.	Most of my work goes to physical labour and some to marketing	50% on physical labour; 50 % to market and sell	50% on farm. 50% to plan, market, sell & manage farm workers	Almost 100% of the time to plan, market, sell & manage the farm workers
5. Market	9	Where do you prefer to sell your produce?	Neighbours	Local community. Selling from the farm	Local community and food market on weekends	Local food markets and formal market	Formal market
5. Market	10	How much time do you spend to market and sell?	1 hour per week	1 hour per day	2 hours per day	Half of my time	Supplying weekly to formal market
5. Market	11	How many households do you sell to monthly?	1- 5 households	5-30 households	30-100 households	30-100 households and local food markets	N/A
5. Market	12	Do you have agreements delivering goods to neighbours on a weekly basis?	No, the neighbours come when they need food.	No, I take the produce around in a wheelbarrow.	Yes	N/A	N/A
5. Market	13	Do you have agreements delivering goods to formal markets (retail shops)	No, I mostly don't sell	No, I don't sell to retail markets	No, I am trying to get agreements	On and off	Yes, I plant according to my supply agreements
6. Farm equipment and inputs	14	Do you use/have access to the following equipment?	Spade and fork	Hand planter	Tractor with harvester	Tractor with plough	Tractor with plough
6. Farm equipment and inputs	15	Do you have access to transport to take your produce to market and to get farming supplies?	No	I have a wheelbarrow	I have my own car	I make use of a local contractor to move my produce	I have a truck with 5000kg loading capacity.
6. Farm equipment and inputs	16	Where do you buy inputs (seed, fertiliser, pesticides)?	Wait for donations	Keep seeds from last year		Local Agri store	Order direct from suppliers

		Food garden		Early livelihood		Livelihood		Early commercial		Emerging commercial	
17	Do you make use of contractors for soil preparation, planting and harvesting?	No						I use a tractor contractor once or twice a year.		I use my own tractor and implements	
		Total		Total		Total		Total		Total	

Table 4-7: Questionnaire for farmer level categorisation

			Food gardens		Early livelihood		Livelihood		Early commercial		Emerging commercial	
				x		x		x		x		x
1. Vision	1	What is your vision for your farm? I want to ..	... farm to produce healthy food for my family		... produce healthy food for my family and give it to needy people		... feed my household and community and also make some money		... make money and sell to local food markets		... be a large-scale commercial farmer	
2. Farming experience and knowledge	2	How many times per year do you plant? (Planting cycles)	Once or twice per year		3 times per year		Every 2 month		Almost every month		I have a planting schedule for 12 months of the year	
	3	How did you learn to farm?	Self-taught		Mentor		Mentor plus training		Mostly training		Training and / or studies	
	4	How many years' experience do you have in farming?	No experience		1 year		2 years		3-4 years		5 and more	
3. Production and planning	5	Do you have a planting schedule?	No, not really		I have one, but don't stick to it		I have a rough planting schedule for the next 3 months.		I plan 6 months ahead.		I have a detailed planting schedule for the next 12 months	
	6	Do you enjoy managing other people (e.g. Assigning tasks to workers)?	No, not at all		No, not really		Yes, for certain tasks		Yes, but I don't want to do that all the time		Yes, I can do that all the time	
	7	How do you provide nutrition to your crops?	I do not concentrate on it		I give fertiliser when the government gives me supplies		I put manure and fertiliser when I have time and money		I invest regularly in my soil		I have a set programme to make sure I provide the nutrients the specific crop needs	

			Food gardens	Early livelihood	Livelihood	Early commercial	Emerging commercial
	8	How do you manage pests and disease?	No idea	I give pesticides when the government gives me supplies	I spray with pesticides when I have time and money	I address the problem when I see it	I have a good idea of which pests I can expect on my crops and I have a spray programme.
4. Selling	9	Do you have a plan to enlarge your market access?	No need	No	Yes, I want to expand in the local market	Yes, I am thinking of expanding into the formal market	I am SA Gap certified and am looking at formal market opportunities
4. Selling	10	Do you notice when markets move?	No need	No	Yes, sometimes	Yes, most of the time	Yes, I have good connections in the markets
5. Financial management	11	How much income do you want to generate on your farm?	R100-R300 per month	R1000-R3000per month	R3000-R7000 per month	R7000 - R10000 per month	R30 000-more
5. Financial management	12	How much do you currently make per month on your farm?	I have no idea	R1000-R3000per month	R3000-R7000 per month	R7000 - R10000 per month	R30 000-more
5. Financial management	13	Do you have a budget and a financial management system?	No need for it.	No	I know more or less how much money I spend & how much I get.	I track my income & expenses and allocate them.	I have a full bookkeeping system
5. Financial management	14	How much money do you save?	I have no savings plan.	I save 10% per month.	I save 10% of my profit per month.	I save 20 % of my profit to reinvest in the farm.	I save 30 % of my profit to reinvest in the farm.
5. Financial management	15	Are you keeping records of the input cost of every crop?	I have very little input costs	Do not keep records	Yes, I keep record and I know my crop success %.	Yes, I keep record and I know my crop success %.	Yes, I keep record and I know my crop success %.
13. Habits of the farmer		**Would you describe yourself as someone who....**					
13. Habits of the farmer	16	.. saves money from profits every month	No	Sometimes	Mostly	Yes	Definitely
13. Habits of the farmer	17	.. has weekly planning schedule	No	Sometimes	Mostly	Yes	Definitely
13. Habits of the farmer	18	.. who does everything to the best of your ability	No	Sometimes	Mostly	Yes	Definitely

			Food gardens		Early livelihood		Livelihood		Early commercial		Emerging commercial	
	19	.. reinvest capital back into their business	No		Sometimes		Mostly		Yes		Definitely	
	20	.. invest in yourself (training)	No		Sometimes		Mostly		Yes		Definitely	
	21	.. is diligent in financial record keeping	No		Sometimes		Mostly		Yes		Definitely	
	22	.. knows what is most important now prioritise it.	No		Sometimes		Mostly		Yes		Definitely	
	23	.. thinks ahead and plans ahead (pro-active)	No		Sometimes		Mostly		Yes		Definitely	
			Total	0	**Total**	0	**Total**	0	**Total**		**Total**	0

4.3.5 Cabbage calculator

As mentioned, before it should be noted that cabbage is used as a reference crop to develop a business plan and should not be considered as the actual crop that farmers are planting. For example, all the farmers discussed in **Section 4.3.3** are planting cabbage together with a variety of other crops. Cabbage is, however, an easy crop, with four heads per m^2, making it easy to classify crop success as 25%, 50% and 75%. The income derived from cabbage in the local communities is also a good average, with spinach typically producing higher and onions lower income. The calculator can be adapted for other products if the relevant data is available.

4.3.5.1 Cabbage calculator for the food garden farmers

The food garden farmer's main aim is to produce food for the household. Local resources must be used as far as possible to reduce costs and to ensure that the practice is sustainable. Financial management is needed to make sure that the costs of food production do not exceed the prices of nutritious food in the local markets. But in many cases, the household does not have access to local fresh markets and this form of agriculture can play an important role in the food security of the country. Extension officers and NGO's can use the cabbage calculator to assist food garden farmers to plan their production. The income calculated is based on total income if all produce is sold. In reality, most of the produce will be consumed by the household, and any excess food can be sold. At 75% crop success and the typical costs of R20 per cabbage head in communities, the food garden farmer can potentially produce R740 of cabbage per month (**Table 4-8**). Estimated expenses are based on actual farms where local resources are used optimally to reduce costs. **Figure 4-10** provides a graphic illustration of the cabbage calculator for the food garden farmer.

Table 4-8: Cabbage calculator for the food garden farmer

Level 1: Food garden /survivalist (50 m^2)			
Planting potential	200 Cabbages per growing season		
Crop success	**75% (plant 4 per m^2; 1 dies)**	**50% (plant 4 per m^2; 2 dies)**	**25% (plant 4 per m^2; 3 dies)**

Yield/growing season	150 cabbages (450 kg)	100 cabbages (300 kg)	50 cabbages (150 kg)
Yield/month	37 cabbages per month)	25 cabbages per month	12 cabbages per month
Sales per day	**2 cabbages per day**	**1 cabbage per day**	**1 cabbage every second day**
Selling price	**Potential monthly income**		
R20 per cabbage	**R740**	**R500**	**R240**
R15 per cabbage	R550	R375	R180
R10 per cabbage	R370	R250	R120

Production inputs	**Costs (R / month for whole farm)**
Labour (No additional labour)	R0
Seeds/seedlings	R10
Fertiliser (2 bags of manure) 200 ℓ liquid fertiliser	R0
Water	R0
Electricity	R0
Pesticide	R20

4.3.5.2 *Cabbage calculator for the early livelihood farmer*

Extension officers and NGO's can use the cabbage calculator presented in **Table 4-9** to assist the early livelihood farmers in planning their production. Local resources must be used as far as possible to reduce costs and to ensure that the practice is sustainable. Financial management is needed to make sure that the costs of food production does not exceed the income from the food produced. At 75% crop success and the typical costs of R20 per cabbage head in communities, the early livelihood farmer can potentially produce R3 000 of cabbage per month, while expenses can be minimised. Estimated expenses are based on actual farms where local resources are used optimally to reduce costs. **Figure 4-10** provides a graphic illustration of the cabbage calculator for the early livelihood farmer.

Table 4-9: Cabbage calculator for the early livelihood farmer

Level 2: Early livelihood (200 m²)			
Planting potential	800 Cabbages per growing season		
Crop success	**75% (4 plants/m²; 1 dies)**	**50% (4 plants/m²; 2 dies)**	**25% (4 plants/m²; 3 dies)**
Yield/growing season	600 cabbages (1800 kg)	400 cabbages (1200 kg)	200 cabbages (600 kg)
Yield/month	150 cabbages	100 cabbages	50 cabbages
Sales	**8 cabbages per day**	**5 cabbages per day**	**2 / 3 cabbages per day**
Selling price	**Potential monthly income**		
R20 per cabbage	**R3000**	**R2000**	**R1000**
R15 per cabbage	R2250	R1500	R750
R10 per cabbage	R1500	R1000	R500
Production inputs		**Costs (R / month for whole farm)**	

Labour (No additional labour) Seeds/seedlings Fertiliser (2 bags of manure) 200 ℓ liquid fertiliser Water Electricity Pesticide	R0 R20 R0 R0 R0 R40

4.3.5.3 Cabbage calculator for the livelihood farmer

Extension officers and NGO's can use the cabbage calculator presented in **Table 4-10** to assist the livelihood farmers in planning their production. Local resources must be used as far as possible to reduce costs and to ensure that the practice is sustainable. Financial management is needed to make sure that the costs of food production does not exceed the income from the food produced. At 75% crop success and the typical costs of R20 per cabbage head in communities, the livelihood farmer can potentially produce R6 000 of cabbage per month, while expenses can be minimised. Estimated expenses are based on actual farms where local resources are used optimally to reduce costs. **Figure 4-11** provides a graphic illustration of the cabbage calculator for the livelihood farmer.

Table 4-10: Cabbage calculator for the livelihood farmer

Level 3: Livelihood (400 m²)			
Planting potential	1600 Cabbages per growing season		
Crop success	**75% (4 plants/m²; 1 dies)**	**50% (4 plants/m²; 2 dies)**	**25% (4 plants/m²; 3 dies)**
Yield/growing season	1200 cabbages (3600 kg)	800 cabbages (2400 kg)	400 cabbages (1200 kg)
Yield/month	300 cabbages	200 cabbages	100 cabbages
Sales	15 cabbages per day	10 cabbages per day	5 cabbages per day
Selling price	**Potential monthly income**		
R20 per cabbage	R6000 per month	R4000 per month	R2000 per month
R15 per cabbage	R4500 per month	R3000 per month	R1500 per month
R10 per cabbage	R3000 per month	R2000 per month	R1000 per month

Production inputs	**Costs (R / month for whole farm)**
Labour (No additional labour) Seeds/seedlings Fertiliser (2 bags of manure) 200 ℓ liquid fertiliser Water Electricity Pesticide	R0 R40 R150 R0 R0 R100

4.3.5.4 Cabbage calculator for the early commercial farmer

Extension officers and NGO's can use the cabbage calculator presented in **Table 4-11** to assist the early livelihood farmers in planning their production. Local resources must be used as far as possible to reduce costs and to ensure that the practice is sustainable. Financial management is needed to make sure that the costs of food production does not exceed the income from the food produced. At this level the farmer needs to make use of market agents or street hawkers to sell their produce, and can expect about R15 per cabbage head. At 75% crop success and R15 per cabbage head, the early commercial farmer can potentially produce R13 500 of cabbage per month. Labour (operational), transport and farm equipment (capital and operational) costs typically increase at this level. **Figure 4-11** provides a graphic illustration of the cabbage calculator for the early commercial farmer.

Table 4-11: Cabbage calculator for the early commercial farmers

Level 4: Early commercial local market (1 200 m²)			
Planting potential	4 800 cabbages per growing season		
Crop success	**75% (4 plants/m²; 1 dies)**	**50% (4 plants/m²; 2 dies)**	**25% (4 plants/m²; 3 dies)**
Yield/growing season	3600 cabbages (10 800 kg)	2400 cabbages (7 200 kg)	1200 cabbages (3 600 kg)
Yield/month	900 cabbages	600 cabbages	400 cabbages
Sales	45 cabbages per day	30 cabbages per day	20 cabbages per day
Selling price	**Potential monthly income**		
R20 per cabbage	18000 per month	12000 per month	8000 per month
R15 per cabbage	R13500 per month	R9000 per month	R6000 per month
R10 per cabbage	R9000 per month	R6000 per month	R4000 per month

Production inputs	**Costs (R / month for whole farm)**
Labour (No additional labour)	R3500
Seeds/seedlings	R20
Fertiliser (2 bags of manure) 200 ℓ liquid fertiliser	R300
Water	R0
Electricity	R0
Pesticide	R200

4.3.5.5 Cabbage calculator for the emerging farmer

Extension officers and NGO's can use the cabbage calculator presented in **Table 4-12** to assist the emerging commercial farmers in planning their production. Financial management is needed to make sure that the costs of food production does not exceed the income from the food produced. Informal markets are widespread, and formal markets are needed to sell the quantities produced at this level. Prices vary greatly in the formal market; we work with R10 per cabbage head, but it can go lower. At 75% crop success and R10 per cabbage head, the emerging commercial farmer can potentially produce R37 500 of cabbage per month. However, at this level expenses increase notably, estimated to be approximately R20 000 based on data from the enterprise budget (Western Cape Government, 2023). **Figure 4-12** provides a graphic illustration of the cabbage calculator for the emerging commercial farmer.

Table 4-12: Cabbage calculator for the emerging commercial farmer

Level 5: Emerging commercial farmer (5 000 m²)			
Planting potential	20 000 Cabbages per growing season		
Crop success	**75% (4 plants per m²; 1 dies)**	**50% (4 plants per m²; 2 dies)**	**25% (4 plants per m²; 3 dies)**
Yield/growing season	15000 cabbages (45 000 kg)	10 000 cabbages (30 000 kg)	5000 cabbages (15 000 kg)
Yield/month	3750 cabbages	2500 cabbages	1250 cabbages
Sales	190 cabbages per day	125 cabbages per day	62 cabbages per day
Selling price	**Potential monthly income**		
R20 per cabbage	R75 000 per month	R50 000 per month	R25000 per month
R15 per cabbage	R56 250 per month	R37 500 per month	R18750 per month
R10 per cabbage	R37 500 per month	R25 000 per month	R12 500 per month

Production inputs	Costs (R / month for whole farm)
Labour (No additional labour)	R8 406.68
Planting material	R3 953.13
Fertiliser (2 bags of manure) 200 ℓ liquid fertiliser	R3 510.66
Weed, pest and fungal control	R2 729.91
Fuel	R354.48
Maintenance	R242.45
Interest	R527.93

*Adapted data from the Enterprise Budget for cabbage (Western Cape Government, 2023)

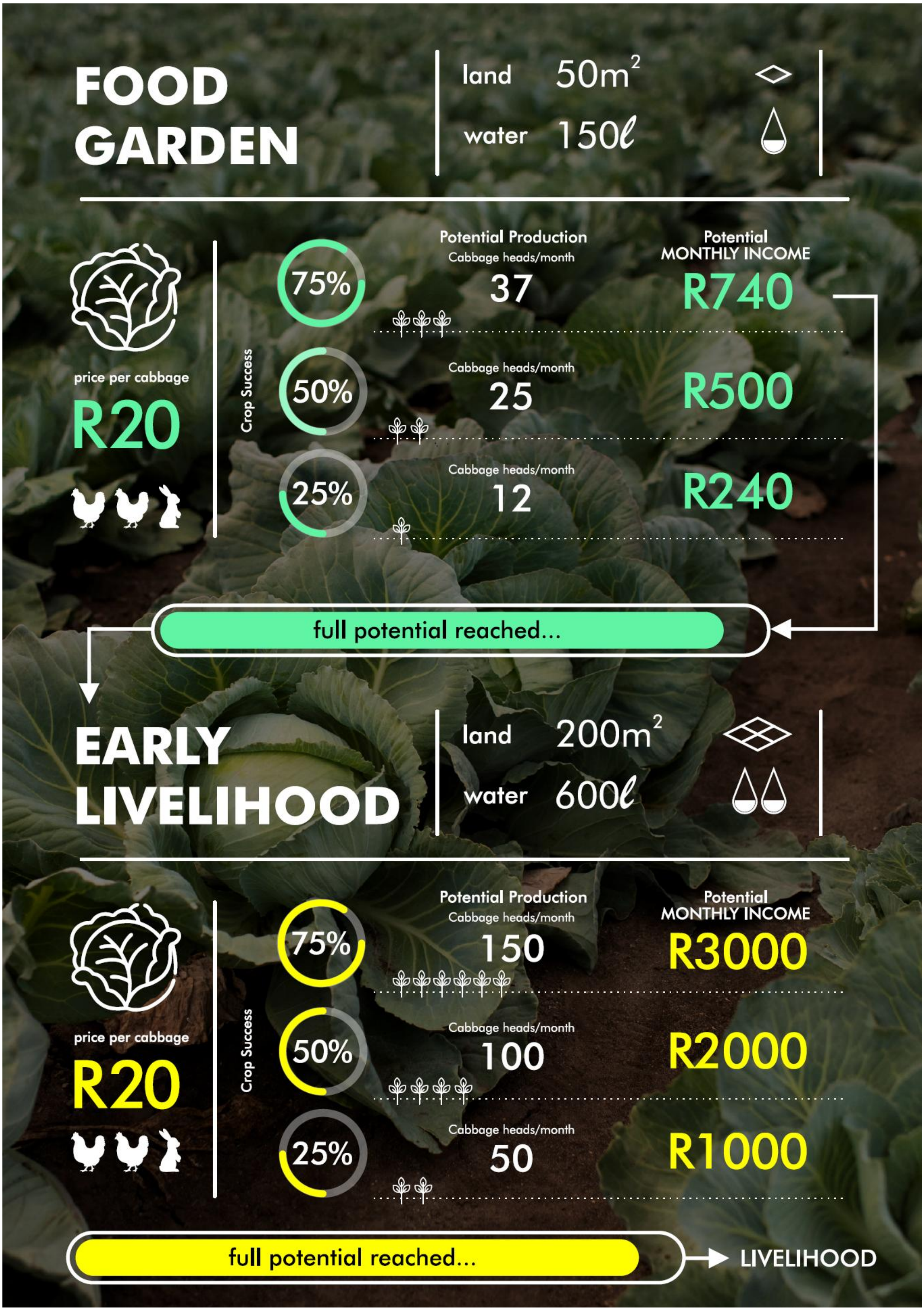


Figure 4-10: Graphic summary of the food garden and early livelihood farmers' cabbage calculator

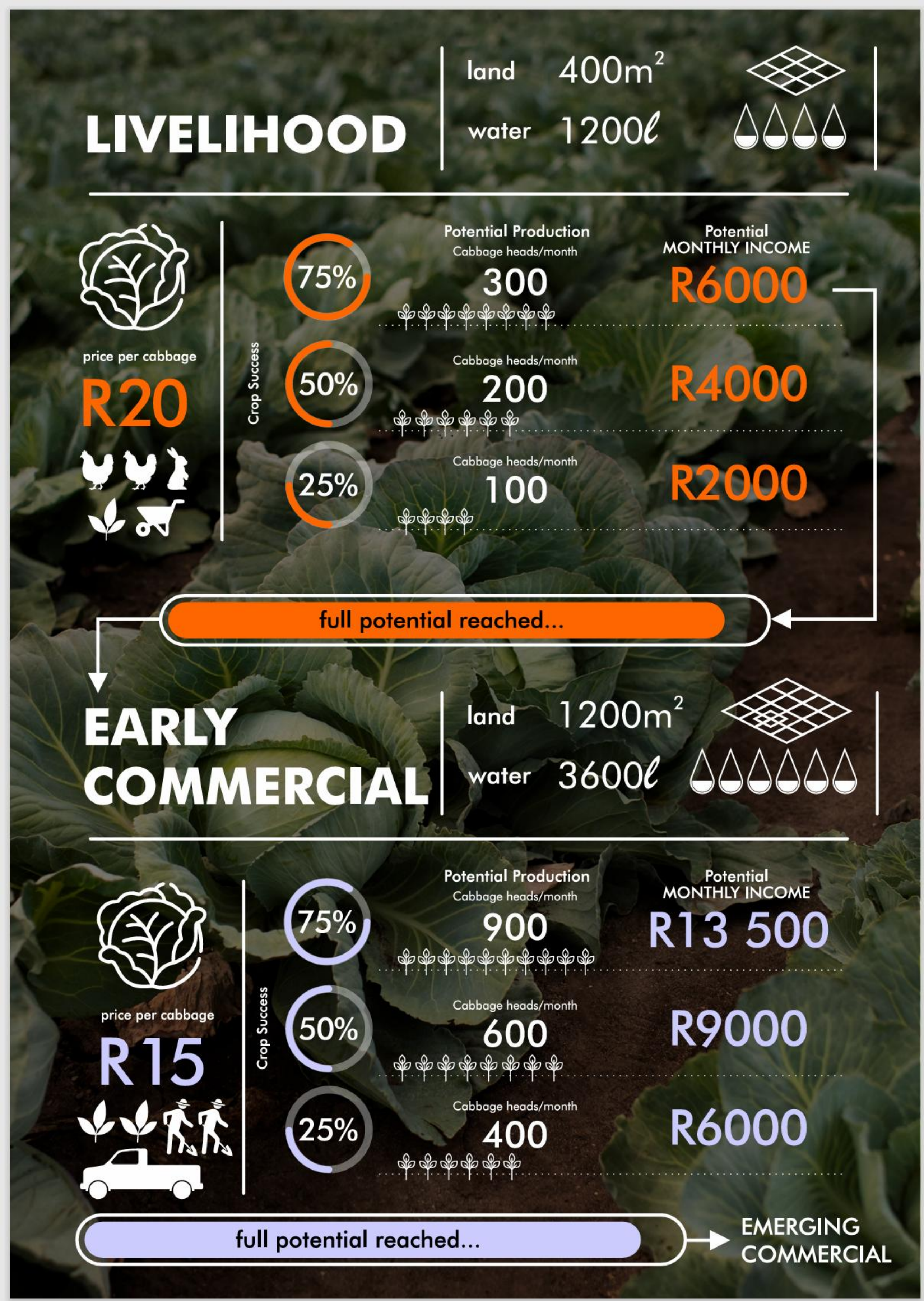


Figure 4-11: Graphic summary of the livelihood and early commercial farmers' cabbage calculator

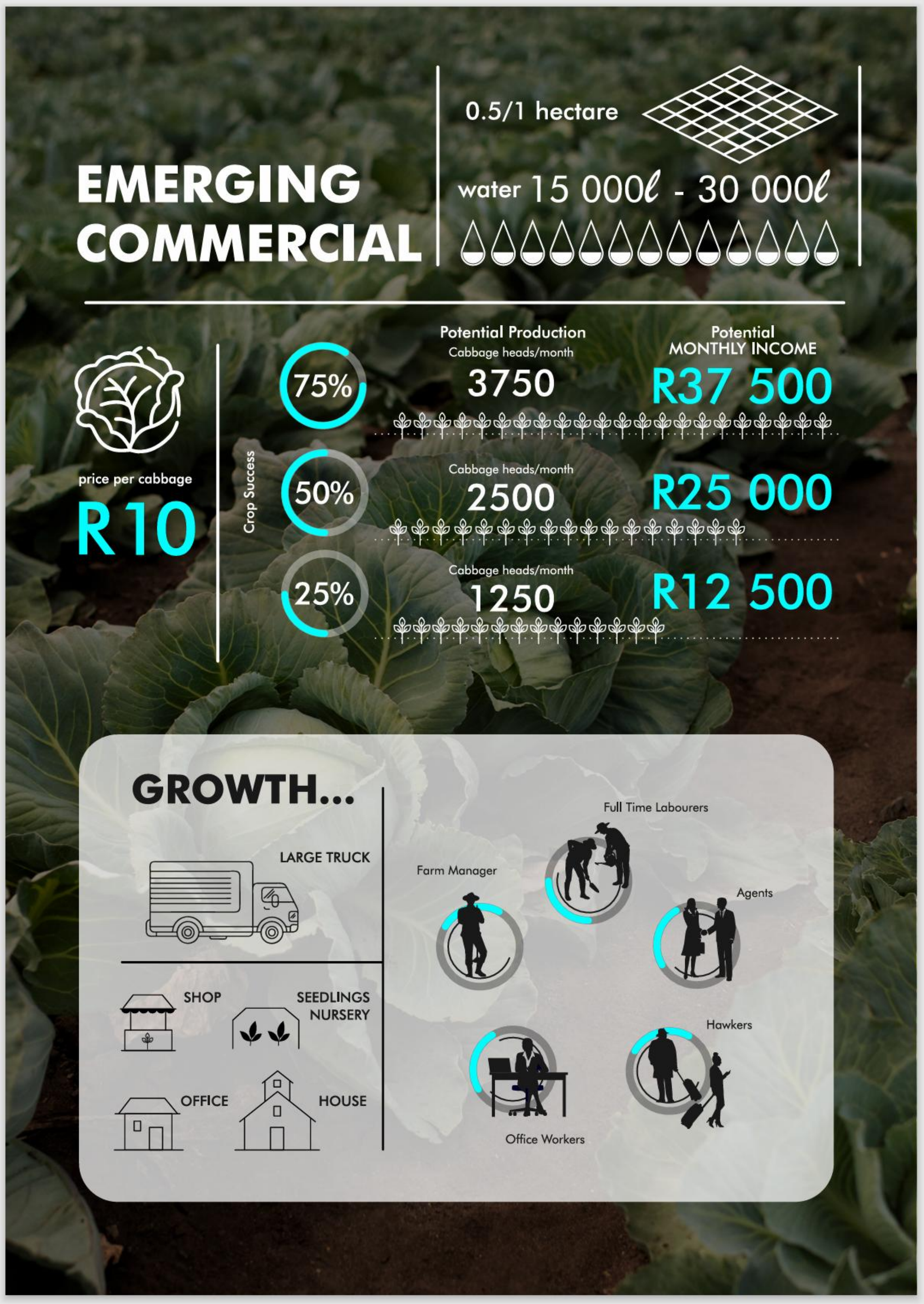


Figure 4-12: Graphic summary of the emerging commercial farmers' cabbage calculator

4.3.6 Verification of the Sukuma Transformation Tool

After completing the questionnaires and working through the cabbage calculators, farmers and government officials responded positively. During the final meeting, farmers and officials completed the questionnaires to evaluate themselves or another farmer, and the team explained the cabbage calculators. The two questionnaires showed that one farmer was at Level 5 in terms of her own personal skills, but her farm was at Level 1. She indicated that she has a small piece of land on a communal ground in Soshanguve, and there are issues with water and conflict between farmers. However, she boasted that she can sell one cabbage head for R80, because she processes it into products like coleslaw. An official from the CoT immediately responded that she should rather stop farming entirely and just buy the vegetables for processing and selling. The farmer left the meeting in very high spirits and said that she now has a new perspective and entirely new strategy for her career.

Other comments from farmers included that they never knew that they had to determine the amount of water they have available to farm. Another farmer said that he now realises that he should stop blaming the government for his failures and go home and do some introspection and that this tool is ‘not just bones, it has meat on it as well’.

Responses from the government were similarly positive. Officials indicated that the different levels between food gardens and commercial farming are currently missing from their approach. They acknowledged that the description of the farming levels is a contribution and that they immediately realised the importance of it. As a business partner said, it is so simple and so important, now that I have seen it, I cannot miss it. A GDARDE official recommended that together with this tool we should provide business plans for each level, as this will be the next step for officials to support the farmers with. These business plans are recommended for future research.

4.4 INTEGRATED MANAGEMENT ACTION PLAN

Our fundamental philosophy is that each person has a responsibility to work themselves out of difficult situations, and people from outside cannot take that responsibility from them. However, in many cases, people need support, even if they do take that responsibility. The question is what such support should look like.

4.4.1 Suitable and unsuitable farmer support

In this report we mention suitable and unsuitable farmer support, which was observed during the research done at Rooiwal. Unsuitable support strategies can sometimes seem to be successful in developing emerging farmers into large commercial farmers, but we are looking for strategies that will also result in government being able to withdraw the support, i.e. develop a farmer to be independent. This seems to be an unsolved problem. **Table 4-13** summarises the support strategies that generally fail to uplift emerging farmers to become independent from government, compared to strategies that may work better.

Table 4-13: Summary of farmer support that consistently did not enable farmers to become independent from government, compared to strategies that can work better

Support that does not work	Support that works
Aim for the commercial level for all	Aim for the next farming level if / when the farmer is ready and willing
Supporting farmers on government land	Supporting farmers on private land
Providing generic support	Targeted support suitable for farm and farmer level, shortcomings and context

Support that does not work	Support that works
Providing free supplies	Provide loans for suitable interventions
Provide extension services only	Extension services in cooperation with a support network
Market access through the government	Market access through a support network

4.4.2 Roles and responsibilities

The roles and responsibilities where the government supports land-owning farmers are poorly defined and/or poorly communicated. This results in government spending time and resources on problems that farmers must deal with and neglecting the duties that farmers cannot deal with. If the government takes over farmers' responsibilities, it undermines the process of teaching farmers to manage their farms independently. We suggest that the responsibilities are allocated as follows:

- Government role: Protect markets by regulating the import of produce, provide and regulate the use of water resources, provide electricity and security, support farmers with SA Gap registration and business plans.

- Farmers' role: Production (WUE, pest management, planting schedules, nursery etc), finance management (budget, purchase supplies, ensure profit), marketing (identify the target market, determine the size and market requirements, plan for transport of produce and packaging if applicable)

- Working groups' role: Working groups can serve as a platform for networking and farmer support. It requires a manager to drive the group and to continue adding more stakeholders in the network. The manager could either be a commercial farmer who volunteers or a paid government official. The group must have a realistic and shared vision. The group should not be concerned with the problems at farm level but mainly facilitate interactions between role-players.

5 RESULTS: WATER MANAGEMENT PLAN

5.1 CURRENT WATER MANAGEMENT IN THE ROOIWAL AGRI-PARK

There are four main water supply areas in the Rooiwal Agri-park. Internally, within each main supply area, there are numerous pipes criss-crossing the land and delivering water to specific fields and tunnels. Tenants at the Agri-park know where the pipes start and where they end, but internal routing is unknown as pipes have been replaced over the years and have changed from the original layouts.

The current abstraction is not measured by flow; the allocation of water is time-based. **Table 5-1** presents the schedule with farmers' allocated hours. The borehole pump runs for 20 hours per day. Assuming the borehole yield is at 2 ℓ / s, the total daily abstraction is estimated to be 14.4 m^3 / day.

Table 5-1: Water allocation at Rooiwal Agri-park

Farmer	Slot 1	Slot 2	Slot 3	Slot 4	Slot 5
1. Tau Fresh- Simon Selwane: 9 hours	10:00 – 14:00		16:00 – 17:00		
2. Faranani Sechaba- Emma Mutavhatshindi: 9 hours				21:00 – 6:00	
3. Ngomane Farming- Nomsa Ramasoka: 2 hours		14:00 – 16:00			
Resting time: 4 hours					6:00 – 10:00.

The farmers at Rooiwal have a general idea of how long they must irrigate depending on the crop. There is, however, no defined demand analysis to determine if they are over- or under-irrigating. A water use assessment is required to estimate the actual crop requirements per season and match that with the availability of water. Once completed, an efficiency assessment can be made. This assessment will need to plan for water use per farmer, per hectare, per crop. This would be part of the WUL.

An assessment of water use (i.e., water volume measurement) must be undertaken to prepare a water balance for the farm. The CoT and GDARDE, custodians of the Agri-park, need to develop a detailed plan including maps of water pipes, tanks, pumps and areas of surface and groundwater resources. Once the plan is in place, everyone on the farm must be made aware of the plan and of the limitations in adding new pipework. Farmers also need to be made aware that they share water resources, not only with other farmers but also with other users in the broader catchment.

5.2 USE OF SEWAGE EFFLUENT IN HYDROPONICS PILOT STUDY

5.2.1 Water quality of irrigation water

A summary of minimum, maximum and average values of daily morning and afternoon measurements for electrical conductivity (EC), pH and temperature during the four pilot studies is presented in **Table 5-2**. The number of samples taken in each pilot studies were 42, except in summer drip bags, where 70 samples were taken.

Table 5-2: Summary of water quality data from the daily water monitoring programme for summer and winter trials

Parameter			**EC (mS/cm)**		**pH**		**Temperature (°C)**	
Treatment			SWE*	HNS*	SWE	HNS	SWE	HNS
Winter: Flood & drain	**Morning sample (n=42)**	**Min**	7.3	11.8	4.2	5.7	11.2	9.7
		Mean	**8.6**	**24.2**	**6.9**	**6.7**	**14.4**	**13.6**
		Max	10.7	51.2	7.9	7.1	18.0	29.1
	Afternoon sample (n=42)	**Min**	7.3	12.3	3.7	5.9	17.6	18.0
		Mean	**9.0**	**23.6**	**7.0**	**6.8**	**21.7**	**22.2**
		Max	10.5	51.2	7.5	7.1	25.4	29.1
Winter Drip bags	**Morning sample (n=42)**	**Min**	8.3	12.6	6.7	6.8	12.3	16.9
		Mean	**9.6**	**18.0**	**7.2**	**7.2**	**15.0**	**20.8**
		Max	11.1	22.8	7.8	7.7	18.9	26.9
	Afternoon sample (n=42)	**Min**	8.2	8.3	6.7	6.5	11.8	17.9
		Mean	**9.4**	**17.7**	**7.0**	**6.9**	**15.1**	**23.1**
		Max	10.8	24.2	7.2	7.3	19.3	28.4
Summer: Flood & drain	**Morning sample (n=42)**	**Min**	4.3	16.4	6.6	6.3	20.4	20.4
		Mean	**4.8**	**17.1**	**6.9**	**6.6**	**22.5**	**21.3**
		Max	5.7	17.9	7.5	6.8	26.7	22.6
	Afternoon sample (n=42)	**Min**	4.3	16.5	6.6	6.4	27.7	28.6
		Mean	**4.8**	**17.2**	**7.0**	**6.6**	**29.7**	**30.0**
		Max	5.2	18.0	7.2	6.7	31.6	31.2
Summer: Drip bags	**Morning sample (n=70)**	**Min**	8.3	13.3	6.7	6.5	12.8	13.3
		Mean	**9.0**	**19.1**	**7.1**	**6.9**	**15.9**	**16.3**
		Max	11.1	22.8	7.8	7.1	18.9	23.2
	Afternoon sample (n=70)	**Min**	6.0	13.3	6.8	6.5	16.9	13.3
		Mean	**8.8**	**19.0**	**7.2**	**6.8**	**22.2**	**19.0**
		Max	10.8	24.2	7.7	7.0	27.3	24.2

*SWE: Sewage water effluent; HNS: Nutrient solution

5.2.1.1 Daily Electrical Conductivity results

Electrical conductivity (EC) is a measurement of salinity and nutrients and results showed notable differences between the SWE and HNS treatments in both seasons. Mean EC values were consistently lower in the SWE treatment (4.8 mS/cm – 9.6 mS/cm), compared to the HNS treatments (17.1 mS/cm – 24.2 mS/cm) of each study.

Although the SWE EC values exceeded the generally recommended hydroponic range (1.5 to 5.0 mS / cm for leafy greens), it did not adversely affect the growth of plants. The EC of SWE remained lower than that of the HNS across both hydroponic systems.

5.2.1.2 Daily pH results

Maintaining appropriate pH levels is crucial for nutrient availability and plant uptake. In the flood & drain system, SWE mean pH values was 6.9 (mornings) and 7 (afternoons) in both seasons. There was more variation in pH during winter, with the lowest recorded values of 3.7 (afternoon) and the highest of 7.9 (morning). In summer, the lowest recorded pH was 6.6 (morning and afternoon) and the highest recorded pH was 7.5 (morning). In the drip bag systems, SWE pH was consistently within or near the ideal range, from 6.7 to 7.8 (morning) and 6.7 to 7.2 (afternoon) during winter and from 6.7 to 7.8 (mornings) and 6.8 to 7.7 (afternoons), with narrow fluctuations. HNS values were similarly stable.

The data indicate that while SWE showed significant pH variations in the flood & drain systems, likely due to system design and effluent properties, these were effectively mitigated through pH adjustments using phosphoric acid. The drip bag system, however, showed far more stable SWE pH values, suggesting that the system was more effective in maintaining ideal pH levels. In all studies, corrective measures appeared sufficient to avoid nutrient lockout or pH-related plant stress, but requires more careful management and monitoring.

5.2.1.3 Daily temperature results

Temperature influences plant metabolism, nutrient absorption, and microbial activity. In both SWE and HNS treatments, temperatures fell within acceptable ranges for leafy vegetable production (10 to 30°C), but notable differences were observed. In the flood & drain winter system, SWE temperatures ranged from 11.2 to 18.0°C (morning) and 17.6 to 25.4°C (afternoon), compared to HNS, which had broader fluctuations, reaching 29.1°C. In the flood & drain summer system, the water temperatures of the two treatments were more similar, with mean values of 22.5°C for SWE and 21.3°C for HNS in the mornings and 29.7°C for SWE and 30.0°C for HNS in the afternoons.

In the drip bag winter system, SWE temperatures remained more moderate (morning: 12.30 to 18.90°C and afternoon: 11.80 to 19.30°C), while HNS again trended warmer up to 28.40°C. In the drip bag summer system, the mean temperature of SWE varied between 15.9°C in the mornings and 22.2 in the afternoon, while HNS temperatures varied between 16.3°C in the mornings and 19.0°C in the afternoon.

The results indicate that the SWE tanks were relatively cooler than the HNS tanks. There was no difference in the layout of the tanks, so each tank would have received the same thermal energy. The only change was the higher EC levels in the HNS water, which may have distributed the heat in the tanks more uniformly than the SWE tanks. Increased salinity in water has a lower specific heat capacity than water with low salinity; the temperature of water with more salts requires less thermal energy input to raise its temperature by 1°C per unit of mass (Byrne, 2025).

5.2.2 Water quality fluctuations in flood & drain system

Table 5-3 shows the percentage changes in water quality parameters in SWE and HNS water samples that are ascribed to plant uptake in both winter and summer trials in the flood & drain hydroponics system. The weekly water quality results showed clear differences between the treated SWE and HNS.

Table 5-3: Weekly changes in water quality parameters due to plant uptake

	Week	EC (%)	TSS (%)	Calcium (%)	Potassium (%)	Magnesium (%)	Phosphorus (%)	Nitrates (%)	E. coli (%) Start	E. coli (%) End
HNS Treatment Winter	1	38.5	0.0	201.4	6.7	43.3	-22.9	-	0.0	-
	2	-4.0	0.0	44.4	-11.1	0.0	18.9	-	0.0	-
	3	26.3	0.0	62.5	0.0	33.3	69.2	-	0.0	-
	4	0.0	0.0	-4.9	0.0	26.8	109.5	-	0.0	-
	5	12.5	0.0	-43.9	-12.5	22.0	114.3	-	0.0	-
SWE Treatment Winter	1	-28.2	0.0	-34.9	-69.7	-40.7	371.4	100	0.0	0.0
	2	-7.1	0.0	-6.1	-40.0	0.0	275.0	93	0.0	0.0
	3	16.5	0.0	24.0	-11.8	26.7	471.4	0	0.0	0.0
	4	-6.1	-41.7	3.3	-31.8	0.0	291.3	0	0.0	0.0
	5	-1.0	-41.7	3.3	-27.3	0.0	628.3	0	0.0	0.0
HNS Treatment Summer	1	222.0	0.0	599.0	942.0	224.0	529.0	1210.0	-100.0	-
	2	-77.0	-48.0	-10.0	-21.0	-5.0	-36.0	-15.0	-99.0	-
	3	0.0	-5.0	-6.0	-12.0	-5.0	-11.0	0.0	-100.0	-
	4	-34.0	100.0	-7.0	-59.0	-55.0	-77.0	-42.0	0.0	-
	5	0.0	0.0	-3.0	-17.0	3.0	-12.0	-3.0	>2420	-
	6	-4.0	176.0	0.0	0.0	2.0	-8.0	1.0	0.0	-
	7	4.0	-30.0	0.0	0.0	3.0	-30.0	-13.0	-100.0	-
	8	-20.0	-30.0	11.0	87.0	-21.0	-99.0	0.0	-96.0	-
SWE Treatment Summer	1	-25.0	-38.0	3.0	12.0	6.0	-14.0	-29.0	-99.0	-
	2	171.0	0.0	-4.0	-9.0	-8.0	1362.0	-11.0	-98.0	-
	3	-3.0	-34.0	-11.0	-30.0	-18.0	355.0	-34.0	-100.0	-
	4	-3.0	0.0	13.0	20.0	22.0	809.0	-50.0	-97.0	-
	5	-3.0	0.0	-3.0	-14.0	5.0	47.0	-31.0	-100.0	-
	6	-2.0	0.0	0.0	-3.0	-5.0	221.0	-47.0	33.0	-
	7	5.0	-66.0	24.0	62.0	32.0	-99.0	-74.0	-92.0	-

5.2.2.1 Water quality of the HNS systems

Overall, the HNS system exhibited stable chemical and physical characteristics, with EC maintained within the optimum hydroponic range (typically 10–13 mS / m) and pH regularly adjusted to 5.5–6.5 using phosphoric acid to promote nutrient solubility and uptake efficiency.

- **Changes in HNS water quality in winter:**

During the winter pilot, there was a variation of EC from +38.5% in week 1 to -4% in week 2, as displayed in **Table 5-3**, due to nutrient dilution (from the treatment works) as well as concentration from replenishing cycles, plus plant uptake rates as part of the experimental process. Environmental TSS remained at or below detectable limits, which validated the HNS as a clear solution during the entire trial period.

Calcium levels increased significantly in the first measurement, reaching +201%. This element varied extensively, and there was a drop in Calcium concentrations to -43.9% by Week 5. This pattern may indicate strong initial nutrient availability followed by rapid uptake, or chemical precipitation from solution caused by changing pH.

Magnesium showed a constant decline throughout the study, indicating that the plants made effective use of Mg, an element that is essential to the formation of chlorophyll. Potassium data fluctuated only slightly, indicating a relative balance in plant uptake and supply, as there were no K deficiency signs observed. Sodium concentrations showed a slight rise, mainly due to the relatively low uptake rate by plants, which likely accumulated gradually through the study duration.

- **Changes in HNS water quality in summer**

During the eight-week monitoring period, EC fluctuations ranged from +222 % in Week 1 to −20 % in Week 8, as shown in **Table 5-3**. The initial rise corresponded to nutrient enrichment and stabilisation after system setup and early flood cycles. Later, gradual declines reflected consistent nutrient uptake by basil plants and dilution from weekly refills. The absence of severe spikes or rapid declines indicates that the HNS maintained steady nutrient availability throughout the growing cycle, an essential factor for basil's continuous vegetative development and yield consistency.

Total Suspended Solids (TSS) remained undetectable or minimal for most of the trial. Temporary increases in Week 4 (+100 %) and Week 6 (+176 %) were likely due to minor sedimentation or biofilm detachment within the tanks, but these fluctuations were temporary. The consistently low TSS confirms the clean and well-maintained state of the hydroponic system.

Initially, Ca showed a sharp increase of +599 % in Week 1, indicative of high initial solubility and low uptake by young basil plants with developing roots. Moderate decreases (−10 % to −3 %) observed in Weeks 2 and 5 indicate steady Ca absorption as the crop matured, while a slight increase in Week 8 (+11 %) may reflect concentration effects toward the end of the trial. These results suggest a well-balanced Ca dynamic throughout the experiment, with sufficient supply for cell wall development and overall plant structure.

The early K enrichment (+942 % in Week 1) followed by sustained declines (up to −87 % by Week 8) corresponds to the nutrient's high mobility and the substantial demand for K during leaf expansion and photosynthetic activity of leafy green plants. The steady decreases indicate active uptake and utilisation rather than nutrient loss or precipitation, confirming effective K management. Magnesium concentrations increased moderately in Week 1 (+224 %), then stabilised with minor variations (−5 % to +3 %) through the later weeks. This indicates consistent Mg availability and steady uptake for chlorophyll synthesis and enzyme activation, with no evidence of depletion or deficiency stress.

The initially spiked in P concentrations by +529 %, followed by a gradual decline (up to −99 % by Week 8), showing a typical pattern of initial oversupply followed by rapid plant utilisation and possible precipitation under aerated, high-pH conditions. Such pronounced reductions highlight the need for P rebalancing in future formulations to prevent potential depletion late in the crop cycle. Nitrate (NO_3) levels showed a substantial increase in Week 1 (+1210 %), reflecting nutrient enrichment and initial mixing before plants reached full uptake capacity. Thereafter, NO_3 levels gradually declined or stabilised (−42 % to 0 %) through Week 8, indicating efficient nitrogen uptake and well-regulated nutrient dosing. The absence of excessive accumulation or rapid depletion demonstrates nitrogen sufficiency and balance throughout the growth period.

E. coli was not detected in any weekly HNS sample, confirming complete microbiological safety and compliance with WHO (2006) guidelines for irrigation water used in edible crops. The absence of *E. coli* and other microbial indicators throughout the 8 weeks validates the sanitary reliability of the borehole source and the closed-loop hydroponic design. This also demonstrates that, under proper management, recirculating nutrient solutions remain pathogen-free and safe for food production.

5.2.2.2 Water quality of the SWE system

- **Changes in SWE water quality in winter**

The weekly EC percentage changes in the SWE system indicate a considerable instability, showing a notable decrease of -28.18% in Week 1, likely due to rapid nutrient uptake. The nutrient levels in Week 3 showed an increase of +16.46 %. Fluctuations in EC indicate unstable nutrient availability, which could explain the poor growth performance of the lettuce crop grown under SWE treatment. Improvements must be made to both nutrient management and possibly pre-treatment of the SWE to achieve stable and optimal EC levels in the hydroponic system. Meanwhile, TSS levels were observed in the later weeks and may have been affected by organic residue, microbial growth, or root exudates.

Phosphorus levels were very high, showing +628.3% in the fifth week, possibly due to the inherent high P concentrations in the SWE. Phosphorus management in the use of SWE in hydroponics needs to be considered in the future. Nitrite (NO_2) and Nitrate (NO_3) levels decreased significantly in the first weeks and NO_3 reached -99.8%. The rapid drop indicates a highly effective uptake by plants or denitrification by microbes in the SWE.

- **Changes in SWE water quality in summer**

Fluctuations in EC throughout the growing season show instability in ionic strength early in the season. The spike in EC in Week 2 suggests salt accumulation or reduced nutrient uptake at the start of the growing season, while later declines reflect improved nutrient absorption and system flushing. Overall, EC in SWE was within an acceptable range but required active management to avoid osmotic stress. TSS rapidly dropped to below detection limits after Week 2, indicating effective filtration and sedimentation in the system. The flood & drain system supported natural clarification of the water.

Concentrations of Ca showed mild alternating increases and decreases. Uptake was strongest during Weeks 2, 3 and 6, aligning with periods of rapid vegetative growth. Increases in Ca in other weeks likely resulted from evaporation or reduced uptake. Overall, Ca remained available but was influenced by plant demand and concentration effects. In the SWE systems, K was highly unstable. Early fluctuations reflected variable uptake linked to physiological activity. Very large increases in Weeks 4 and 7 suggest accumulation due to reduced plant absorption, possibly linked to warm temperatures or pH effects. The SWE had sufficient K for crop growth, but uptake efficiency varied. Moderate Mg decline was observed during active growth (Weeks 2 and 3) and an increase in later weeks. The pattern mirrors typical Ca–Mg antagonism and pH-driven nutrient competition.

Levels of P were extremely unstable, with large mid-season spikes caused by accumulation and mineralisation of organic phosphates. The near-total drop in Week 7 likely resulted from rapid uptake or precipitation under varying pH. While SWE provided abundant P, it also posed risks of over-accumulation and losses through precipitation. Nitrate gradually decreased every week, with the largest reduction occurring at peak plant growth in Week 7. This reflects consistent and substantial N uptake by basil and confirms that SWE supplied adequate N while reducing nutrient loads in the recycled water.

E. coli decreased by over 90% most weeks, reaching total removal in Week 5. This indicates strong self-sanitising effects from UV exposure, oxygenation, and microbial competition. A temporary increase in Week 6 suggests minor recontamination. Overall, the system achieved ~99% reduction.

5.3 VEGETATIVE GROWTH PERFORMANCE

5.3.1 Lettuce (*Lactuca sativa*)

Table 5-4 shows mean values (± standard deviation) of various vegetative growth parameters of lettuce (*Lactuca sativa*) grown with SWE and HNS. Parameters included the number of leaves, plant height, and leaf length.

Table 5-4: Effect of Treated Sewage Wastewater Effluent (SWE) and Conventional Nutrient Solution (CNS) on the Number of Leaves, Plant Height and Leaf Length of Lettuce (Lactuca sativa).

Crop parameter	Week (growing season)	Unit	Sewage Wastewater Effluent:	Nutrients Solution:	*F-statistics*
Number of Leaves	**Week 2**	per plant	10.2±0.30[b]	13.5±0.32[a]	*54.52*
Number of Leaves	**Week 6**	per plant	18.3±0.40[b]	35.1±0.94[a]	*268.95*
Plant Height	**Week 2**	cm	92.2±6.31[b]	111.8±5.08[a]	*5.86*
Plant Height	**Week 4**	cm	96.5±5.5[b]	102.37±7.2[a]	*0.42ns*
Plant Height	**Week 6**	cm	83.3±7.5[b]	118.7±3.6[a]	*17.92*
Leaf Length	**Week 2**	cm	82.6±7.9[b]	107.4±6.1[a]	*6.13*
Leaf Length	**Week 4**	cm	93.5±6.4[b]	108.0±7.00[a]	*2.35ns*

Different superscripts (a, b) indicate significant differences between treatments ($p < 0.05$). ns = not significant.

- **Number of Leaves**

Leaf number was a main indicator of vegetative growth performance and photosynthetic potential. **Table 5-4** indicates that there is a clear and consistent indication of greater leaf number development in the HNS treatment over the entire growing season.

At the early growth stages, the mean number of leaves under HNS was notably higher than the SWE treatment ($p < 0.001$), indicating more favourable nutrient availability in the early stages of development. The difference increased throughout the growing season. By week 2, plants under the HNS treatment had a mean of 13.5 leaves, while SWE plants produced a mean of only 10.2 leaves ($p < 0.001$). The difference by week 6 became more marked, with mean leaf numbers of 35.1 leaves in the HNS treatment versus 18.3 leaves in the SWE treatment ($p < 0.01$), as indicated in **Table 5-4**.

- **Plant Height**

Plant height symbolises general vegetative vigour, resource allocations and nutrient uptake efficiency. During the initial plant growth, there was little difference between treatments (SWE: 94.47 cm; HNS: 93.43 cm; $p > 0.05$), suggesting that both systems supported similar rates of growth during the propagation period.

After week 1, HNS plants showed noticeably improved vertical growth. By week 2, HNS-treated plants reached 111.8 cm, while SWE-treated plants were much shorter, at 92.2 cm ($p < 0.05$). In week 3, HNS plants grew to 118.37 cm, with SWE plants declining to 83.5 cm ($p < 0.001$). This trend continued to the end of the growing season (week 6), when the HNS plants averaged 118.73 cm and SWE plants fell to an average of 83.3 cm ($p < 0.001$). It is noteworthy that SWE plants regressed in height at the end of the growing season, suggesting possible nutrient depletion or physiological stagnation.

- **Leaf Size (Leaf Length and Width)**

Leaf area estimated by measuring leaf length and width is an important factor in light interception, gas exchange and transpiration. At the beginning of Week 2, lettuce grown in the HNS treatment produced longer leaves compared to the SWE treatment. By week 5, average leaf length of HNS was 122.47 cm, and SWE was an average of 96.87 cm ($p < 0.001$). These differences likely indicate nutrient assimilation effectiveness under the HNS treatment, which has been designed specifically to meet optimal nutrient requirements for lettuce growth. Poor growth performance under SWE treatment can indicate poor uptake of essential nutrients due to high pH or EC, or the presence of inhibiting compounds to growth found in effluent.

- **Biomass Accumulation**

Biomass yield, a key indicator of crop productivity, was assessed using both fresh weight (harvested crop with water) and dry weight (harvested crop after drying). Lettuce grown with HNS had an average fresh biomass weight of 349.7 ± 7.9 g / plant, which is higher than the SWE grown plants with an average fresh weight of 98.3 ± 3.9 g / plant ($p < 0.01$; $F = 823.2$). However, dry weight was more similar between treatments with 43.9 ± 7.8 g / plant for SWE and 53.7 ± 7.1 g / plant for HNS.

5.3.2 Swiss Chard (*Beta vulgaris*)

Table 5-5 shows mean values (± standard deviation) of various vegetative growth parameters of Swiss card (*Beta vulgaris*) grown with SWE and HNS. Parameters included the number of leaves, plant height, leaf length, leaf width, fresh weight and dry weight biomass over the six weeks of the sampling period.

Table 5-5: Effect of treated sewage wastewater effluent (SWE) and hydroponic nutrient solution (HNS) on vegetative growth parameters and biomass accumulation of Swiss chard

Crop parameter	Week (growing season)	Unit	Wastewater effluent	Nutrient Solution	F-statistics
Number of Leaves	Week 2	per plant	14.9±0.73[a]	13.25±0.61[b]	3.01
	Week 4	per plant	20.9±0.90[a]	19.9±0.91[a]	0.67ns
	Week 6	per plant	26.2±1.14[a]	26.5±1.28[a]	0.25ns
Plant Height	Week 2	cm	107.2±0.79[a]	104.3±6.77[a]	0.19ns
	Week 4	cm	103.6±4.17[b]	115.9±4.70[a]	3.86
	Week 6	cm	92.7±7.79[b]	119.5±1.51[a]	11.43
Leaf Length	Week 2	cm	103.7±4.98[a]	103.75±7.51[a]	0.08ns
	Week 4	cm	106.5±0.85[a]	104.5±7.42[a]	0.07ns
	Week 6	cm	103±4.85[a]	110±5.43[a]	0.94ns
Leaf Width	Week 2	cm	96.9±7.03[a]	110.9±5.62[a]	2.42ns
	Week 4	cm	99.0±7.03[a]	108.2±7.69[a]	0.78ns
	Week 6	cm	104.9±5.10[a]	112.8±5.56[a]	1.10ns
Fresh Weight Biomass		g/plant	347±26.28[a]	355±33.03[a]	0.04ns
Dry Weight Biomass		g/plant	46.35±4.25[a]	52.50±4.91[a]	0.90ns

Different superscripts (a, b) indicate significant differences between treatments ($p < 0.05$). ns = not significant.

- **Number of leaves**

At Week 2, SWE treatment plants had more leaves (14.9 ± 0.73) compared to HNS treatment (13.3 ± 0.61) as indicated by the F-statistic (3.01, $p < 0.05$). However, no significant differences were observed from SWE treatment compared to HNS at Weeks 4 and 6, and this suggested that early vegetative growth of leafy vegetables could be enhanced using organic nutrients supplied in wastewater, but without a proper balance of nutrients, crop performance may eventually become less favourable.

- **Plant Height**

During the second week, the two treatments produced plants with similar heights. However, in Weeks 4 and 6, HNS resulted in taller plants (119.5 ± 1.51 cm) compared to SWE (92.7 ± 7.79 cm).

- **Leaf Size (Leaf Length, Leaf Width)**

Between Weeks 2, 4, and 6, statistical analysis did not show any differences in the mean leaf length and width for SWE and HNS. This indicates that SWE has the necessary nutrients to maintain leaf morphology, which is an important measurement for marketing of leafy vegetables (Santos et al., 2024).

- **Biomass accumulation**

Fresh biomass yield under SWE (347 ± 26.28 g / plant) was slightly lower than under HNS (355 ± 33.03 g / plant). Similarly, there was no notable difference between dry biomass under SWE (46.4 ± 4.25 g / plant) and HNS (52.5 ± 4.91 g / plant). These findings indicate that SWE can sustain biomass production at levels comparable to HNS and align with Pardossi et al. (2018), who reported that treated wastewater can support biomass accumulation in leafy crops under controlled hydroponic conditions.

5.3.3 Basil (*Ocimum basilicum*)

Table 5-6 shows mean values (± standard deviation) of various vegetative growth parameters of basil (*Ocimum basilicum*) grown with SWE and HNS. Parameters included number of leaves, plant height, leaf length, leaf width, fresh weight and dry weight biomass.

Table 5-6: Effect of Treated Sewage Wastewater Effluent (SWE) and Hydroponic Nutrient Solution (HNS) on Vegetative Growth Parameters and Biomass of Basil (Ocimum basilicum)

Crop parameter	Week (growing season)	Unit	SWE	HNS	F-statistics
Number of leaves	**Week1**	Per plant	15.40±0.24[b]	20.65±1.30[a]	24.39
	Week3	Per plant	53.75±0.88[b]	72.15±3.58[a]	24.89
	Week5	Per plant	84.40±1.38[b]	113.40±5.66[a]	24.76
Plant height	**Week1**	cm	5.57±0.27[b]	7.49±0.13[a]	39.20
	Week3	cm	19.45±0.96[b]	26.19±0.47[a]	39.49
	Week5	cm	30.59±1.51[b]	41.14±0.73[a]	39.45
Leaf length	**Week1**	cm	1.61±0.04[b]	2.19±0.04[a]	105.94
	Week3	cm	5.65±0.13[b]	7.71±0.15[a]	108.58
	Week5	cm	8.92±0.19[b]	12.11±0.24[a]	105.26
Leaf width	**Week1**	cm	1,00±0.03[b]	1.46±0.03[a]	121.12
	Week3	cm	3.53±0.11[b]	5.12±0.08[a]	133.03
	Week5	cm	5.54±0.17[b]	8.04±0.14[a]	128.13
Fresh Weight Biomass		g/plant	170.0±0.00[b]	257.50±7.66[a]	111.13

Dry Weight Biomass	g/plant	5.89±0.17[b]	15.90±1.21[a]	67.19

Different superscripts (a, b) indicate significant differences between treatments ($p < 0.05$); ns = not significant.

- **Number of Leaves**

During the first week, HNS-treated basil plants developed a greater number of leaves (20.7 ± 4.63) than SWE plants (15.4 ± 1.10). This difference persisted and increased towards the end of the growing season. By Week 5, basil under HNS averaged 113.40 ± 25.32 leaves per plant, compared to 84.40 ± 6.18 leaves per plant under SWE ($F = 28.62$, $p < 0.001$).

- **Plant Height**

The HNS treatment consistently outperformed SWE in terms of plant height from Week 2 onward. By Week 5, basil plants under HNS reached an average height of 45.00 ± 3.83 cm, whereas SWE plants achieved 36.05 ± 2.99 cm ($F = 31.47$, $p < 0.001$).

The SWE-treated plants maintained steady growth, confirming that the treated effluent contained sufficient nutrients to sustain basic vegetative development, *albeit* below optimal hydroponic standards.

- **Leaf Size (Leaf Length and Width)**

Leaf size contributes substantially to basil's market quality and photosynthetic potential. Throughout the trial, HNS plants produced longer and wider leaves than SWE plants. At week 5, HNS leaves averaged 10.9 ± 0.78 cm in length and 8.0 ± 0.61 cm in width, while SWE leaves measured 9.26 ± 0.72 cm and 5.54 ± 0.77 cm, respectively.

This reduction in lamina expansion under SWE may be explained by limited N and Ca availability, both vital for cell division and expansion and potential interference from excess Na in the effluent. Despite smaller leaves, SWE maintained acceptable morphology, suggesting that with slight nutrient enrichment, SWE could sustain commercial-grade basil production.

- **Fresh and Dry Weight Biomass**

At harvest, plants irrigated with HNS exhibited significantly higher fresh biomass (257.5 ± 34.28 g / plant) compared to SWE (170.0 ± 14.14 g / plant, $p < 0.01$). Similarly, dry weight biomass followed the same trend (15.9 ± 5.41 g / plant for HNS vs 5.9 ± 0.77 g / plant for SWE, $p < 0.001$).

The disparity in biomass accumulation reflects the cumulative effect of reduced leaf area and lower nutrient uptake efficiency under SWE. Limited N and P likely constrained chlorophyll synthesis and carbohydrate translocation, resulting in lower dry matter formation. The higher fresh biomass in HNS suggests more efficient water uptake and turgidity, whereas the lower fresh biomass in SWE plants indicates partial osmotic restriction from elevated EC levels in the effluent.

5.3.4 Green Pepper (*Capsicum annuum*)

Table 5-7 shows mean values (± standard deviation) of various vegetative growth parameters of green pepper (*Capsicum annuum*) grown with SWE and HNS. Parameters included number of leaves, plant height, leaf length, leaf width, fresh weight, number of fruits and dry weight biomass.

Table 5-7: Effect of Treated Sewage Wastewater Effluent (SWE) and Hydroponic Nutrient Solution (HNS)

Crop parameter	Week (growing season)	Unit	SWE	HNS	F-statistics

Number of leaves	**Week 1**	cm/plant	8.60±0.37^{b}	10.55±0.37^{a}	13.93
	Week 5	cm/plant	67.10±0.66^{b}	92.35±1.22^{a}	333.55
	Week 10	cm/plant	122.55±1.36^{b}	174.50±2.48^{a}	336.47
Plant height	**Week 1**	cm/plant	20.24±0.44^{a}	17.53±0.69^{b}	10.86
	Week 5	cm/plant	41.09±0.33^{b}	45.77±0.57^{a}	50.61
	Week 10	cm/plant	44.57±1.61^{b}	56.04±3.63^{a}	167.08
Leaf length	**Week 1**	cm/plant	7.88±0.09^{a}	7.84±0.16^{a}	0.044ns
	Week 5	cm/plant	12.74±0.21^{b}	15.48±0.35^{a}	45.31
	Week 10	cm/plant	13.98±0.22^{b}	17.92±0.35^{a}	89.86
Leaf width	**Week 1**	cm/plant	4.53±0.07^{a}	4.41±0.12^{a}	0.68ns
	Week 5	cm/plant	7.37±0.09^{b}	8.78±0.11^{a}	88.50
	Week 10	cm/plant	8.79±0.22^{b}	13.36±0.25^{a}	187.96
Number of Fruit	**Week 4**	cm/plant	2.70±0.18^{a}	2.90±0.29^{a}	0.33ns
	Week 6	cm/plant	5.20±0.24^{a}	5.70±0.27^{a}	1.92ns
	Week 8	cm/plant	5.85±0.30^{b}	8.10±0.43^{a}	18.44
	Week 10	cm/plant	6.10±0.35^{b}	9.40±0.46^{a}	33.21
Fresh Weight Biomass		cm/plant	128.75±2.81^{b}	168.25±3.79^{a}	70.103
Dry Weight Biomass		cm/plant	9.17±0.31^{b}	16.86±0.75^{a}	90.79

Different superscripts (a, b) indicate significant differences between treatments ($p < 0.05$). ns = not significant.

- **Number of Leaves**

Table 5-7 indicates that HNS-treated green pepper plants consistently produced more leaves than those grown with SWE throughout the 10-week growing period. At early growth stages, leaf number was already higher under HNS (10.6 ± 0.37) compared to SWE (8.6 ± 0.37) ($p < 0.05$), reflecting more favourable nutrient availability during establishment. By Week 5, this difference widened (HNS: 92.4 ± 1.22 vs SWE: 67.1 ± 0.66), and by Week 10, HNS plants had developed a mean of 174.5 ± 2.48 leaves, significantly surpassing SWE plants (122.6 ± 1.36, $p < 0.001$).

- **Plant Height**

Plant height represents general vegetative vigour and nutrient uptake efficiency. As shown in **Table 5-7**, there was little difference in height between treatments at the start of the trial, indicating that both nutrient sources supported similar initial growth conditions. However, from Week 3 onward, differences became evident, with HNS plants showing superior elongation rates. By Week 10, HNS plants had a mean height of 56.0 ± 3.63 cm, while SWE plants reached only 44.6 ± 1.61 cm.

- **Leaf Size (Leaf Length and Width)**

At Week 10, HNS-treated plants had a mean leaf length of 17.9 ± 0.35 cm and width of 13.4 ± 0.25 cm, while SWE-treated plants measured 14.0 ± 0.22 cm and 8.8 ± 0.22 cm respectively ($p < 0.001$). This substantial difference indicates more efficient nutrient assimilation and cellular expansion under HNS conditions.

- **Reproductive Growth Parameter**

Fruit count is a direct indicator of reproductive success and yield potential in green pepper. As shown in **Table 5-7**, flowering and fruit initiation began around Week 4 in both treatments. However, the HNS treatment showed a significantly higher fruit count throughout the reproductive stage.

At Week 5, HNS plants averaged 5.1 ± 0.16 bells per plant, while SWE plants had 3.7 ± 0.10 ($p < 0.01$). By week 10, the difference widened further, with HNS plants averaging 10.8 ± 0.33 bells per plant compared to 7.5 ± 0.26 under SWE ($p < 0.001$).

- **Fresh and Dry Weight Biomass**

Green peppers ground with HNS outperformed SWE-treated plants in both fresh and dry biomass. Fresh biomass was 30% lower under SWE, reflecting fewer and smaller leaves, reduced plant height, and lower water content, likely caused by osmotic stress from higher EC. Dry biomass showed the same trend, with SWE plants accumulating substantially less structural material due to nutrient and ion imbalances. Overall, the results show that untreated SWE cannot support green pepper growth as effectively as standard HNS.

5.4 COST ASSESSMENT OF USING SEWAGE EFFLUENT FOR IRRIGATION

A summary cost comparison between the various options is presented in **Table 5-8.**

Table 5-8: Cost comparison between fertigation with sewage effluent versus borehole water

Expenses	Lettuce SWE	Lettuce HNS	Swiss chard SWE	Swiss chard HNS	Basil SWE	Basil HNS	Green Pepper SWE	Green Pepper HNS
Seeds	R112.50	R112.50	R112.50	R112.50	R30.00	R30.00	R40.00	R40.00
Fertiliser	-	R193.75	-	R193.75		R193.75		R193.75
pH correction	R114.13	R114.13	R114.13	R114.13	R114.13	R114.13	R114.13	R114.13
Borehole Pumping cost	-	R17.50	-	R17.50		R17.50		R17.50
Fuel	R38.88		R38.88		R38.88		R38.88	
Sub Total	**R265.51**	**R437.88**	**R265.51**	**R37.88**	**R183.01**	**R355.38**	**R193.01**	**R365.38**
				Production				
Yield per plant	R0.10	R0.35	R0.35	R0.36	R0.17	R0.26	R0.90	R1.25
Number of plants	R60.00	R60.00	R40.00	R40.00	R30.00	R30.00	R40.00	R40.00
Total yield kg	R5.88	R20.94	R13.88	R14.20	R5.10	R7.71	R36.00	R49.92
Price per kg	R9.10	R9.10	R1.50	R1.50	R35.00	R35.00	R11.42	R11.42
Sub-total	**R53.51**	**R190.55**	**R20.82**	**R21.30**	**R178.50**	**R269.85**	**R411.12**	**R570.09**
Expense-to-produce ratio	4.96	2.30	12.75	20.56	1.03	1.32	0.47	0.64

The key takeaways from this assessment are:

- At the scale of the trial, the expenses far outweigh the produce revenue for lettuce and Swiss chard. This is because the number of plants grown was small compared to the expenses.
- The biggest expense was the fertiliser, followed by the phosphoric acid for pH correction. The need to purchase extra chemicals affects the value proposition, especially since the Agri-park farmers are not paying for water.

- Swiss chard is not economical to produce using hydroponics.
- Lettuce grown using HNS shows the greatest promise.
- Basil grown in both systems shows good promise as the expenses are similar to the revenue.
- Green pepper shows the most promise, as both systems produce a reasonable amount of fruit, but while the number of fruits in the SWE system is less than that of the HNS, the lower costs mean that it is more economically viable.

Profitability is dependent on the price of the produce. Higher-value crops show promise using the treated sewage effluent. Lower value crops are better suited to drip bag systems using borehole water and fertiliser.

5.5 GROWTH OF SPINACH IN A FLOATING POND WITH KELPAK SUPPLEMENT

- **Influence of Kelpak concentration**

Across all weeks, Kelpak 100% (A) consistently enhanced plant growth compared to the 50% concentration (B). The higher bio-stimulant concentration likely supplied greater levels of auxins and cytokinins, promoting cell division, leaf expansion and chlorophyll synthesis (Rouphael and Colla, 2020).

- **Effect of water source**

Plants grown in treated wastewater demonstrated reduced growth, confirming that nutrient quality and composition strongly influence hydroponic productivity. Treated effluent likely contained lower N and P levels and possible salinity stress, contributing to smaller plant size and fewer leaves (Christou et al., 2017).

- **Statistical patterns and growth dynamics**

Statistical evidence shows significant treatment effects from Week 2 onwards, stabilising after Week 3. The fertiliser error in Week 2 temporarily reduced growth, but once corrected, the performance of standard treatments improved markedly. The order of growth performance across all weeks was (G1) Std + Kelp A > (G2) Std + Kelp B > (G3) Waste + Kelp A > (G4) Waste + Kelp B (**Figure 5-1**)

- **Sustainable and Practical Implications**

The findings demonstrate that bio-stimulant application can improve crop productivity even under suboptimal water conditions. Although wastewater use led to lower yields, it sustained viable growth and offers potential in water scarce regions if the nutrient supplementation is applied. Integrating full-strength Kelpak with treated wastewater presents a viable sustainable solution when environmental or resource constraints limit conventional nutrient use (Colla et al., 2015, Du Jardin, 2015).

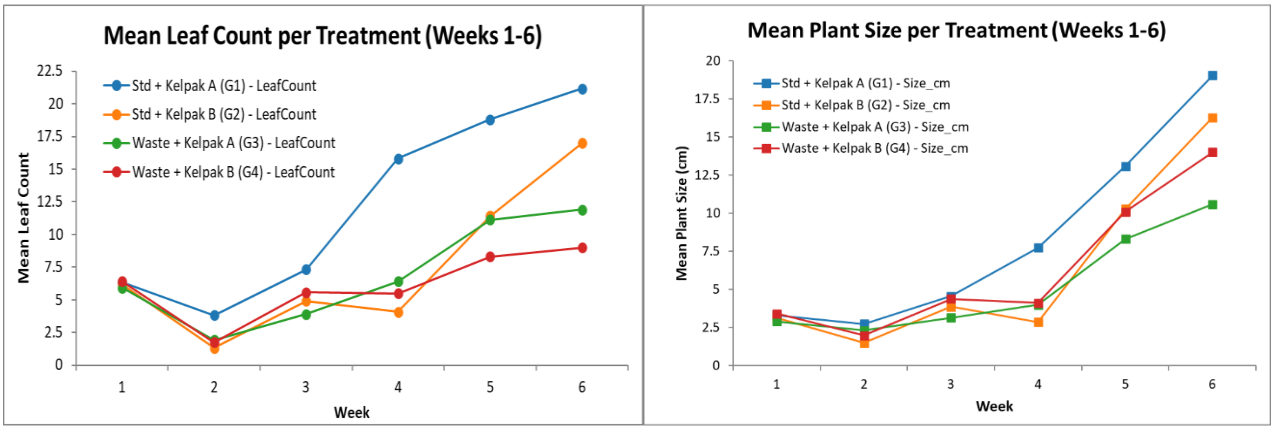


Figure 5-1: Mean leaf count per treatment (left) and Mean plant size per treatment (right)

6 DISCUSSION

Our initial assessment of Gauteng Agri-parks in general, through discussions with various farmers and officials, was that government support is often not successful in developing independent farmers. Some farmers can be very successful with government support, but the universal problem is that these farmers do not maintain their production without the support. This problem defined the fundamental question that the project aimed to address.

6.1 UNDERSTANDING THE PROBLEM OF DEVELOPING EMERGING FARMERS

6.1.1 Marketing problems

There are different problems related to market access for emerging farmers:

1. Emerging farmers are unable to access retail markets because:
    a. The markets are often saturated,
    b. In some cases, they are unable to compete with cheap imported products,
    c. Large farms have existing agreements with markets.
2. Government is unable to support farmers with marketing, because conflict arises when the prices that Government officials can get for the produce are less than what the farmers expected.
3. Farmers do not consider market opportunities before they start production. Government officials admitted that they also often do not consider it when they advise farmers.
4. Most emerging farmers who participated in our project did not have the motivation to register for SA Gap and to do recordkeeping for food safety purposes.

6.1.2 The problems with existing government support

During our discussions, government officials and farmers indicated that the following types of support cause more problems without solving any:

1. Providing agricultural supplies to farmers:
    a. Due to lengthy government processes, seed supplies are not on time.
    b. Many emerging farmers only operate when supplies are available, and their businesses are limited by the availability of supplies.
    c. Farmers become more dependent on government if supplies are given, rather than using the supplies as an opportunity to become independent.
    d. Supplies can only be given to selected farmers, and farmers who do not have access to government support are excluded.
    e. Some recipients are not motivated to be farmers and sell the supplies for cash.
2. Training and information: Information is very important for making good decisions, but there are two ways in which information is not useful or even dangerous:
    a. An expert from outside the context may promote solutions without knowing the entire context of the trainees in which the solutions will be applied. These solutions are often not used because they do not fit into the farmer's context.
    b. During training, trainees may feel like the expert has knowledge that they are unable to fully acquire. They might feel that their problems are too difficult for them to solve, because they do not have the extensive knowledge of an expert. This causes trainees to feel that they are dependent on the expert from outside, rather than feeling uplifted by the information that they have received.

3. Financial inputs are avoided because farmers often do not spend them to improve their farms.

Officials are at a loss to understand what kind of support remains for them to give to develop a farmer into an independent commercial farmer. We believe the underlying problem is systemic in nature and are suggesting a probable theory to explain it.

6.1.3 Poor connections to networks of stakeholders

The AIP consists of four steps to uplift emerging farmers into successful independent farmers: 1). build a network of relevant role-players, 2) discuss the problems in the systems with the different role-players, 3) determine the vision of the farmer for his farm and 4) undertake an innovation process to work towards that vision. The first and the third steps are particularly relevant in understanding the current limitations in the Agri-park system.

The network of role-players is currently poorly developed in emerging farming communities. Farmers complain that their fellow farmers are jealous and would not share their information and experience for fear of supporting their own competition. Failures in establishing cooperatives in the Agri-park context resulted in a general rule against any attempts to cooperate at production level. However, farmers can still be connected to other role-players from government and various markets. Connections that we have established have shown to make a difference to farmers in difficult situations.

6.1.4 Poor understanding of the vision for the farm

The other important step in the AIP that has proven to fundamentally limit the development of emerging farmers is the vision for development as defined by farmers and the government. The vision of the farmer should be realistic and shared with the government actors. In some cases, we found that farmers aspire to become commercial at a large scale, but are not yet ready to grow into that space. These farmers often make purchases that are in line with large-scale farming, but they do not yet have the income to maintain or use the equipment, to pay the investment back, or to make the investment worthwhile. In other cases, we found that the government ascribed ambitions to farmers that the farmers do not share and likewise invested in the wrong way. The ability of farmers and the government to formulate a realistic vision is currently greatly limited by a poor definition of the various levels of agriculture before a farmer becomes successful on a large scale. The responsibilities and the complexity of the system increase so dramatically from the first to the final level that we believe a gradual growth process is the only way to become successful at a large-scale commercial level.

6.2 FINDING THE SOLUTION TO EMPOWERING EMERGING FARMERS

6.2.1 Establishing a network through working groups

Toward achieving the last aim of this project, we have tested the possibility of establishing working groups where farmers can be connected to a network of various stakeholders in the food and agricultural industry, as an alternative to the current Agri-park model. Farmers participating in these groups farm independently, but connect freely with each other and other actors from, for example, the government and the market.

Six working groups were established during the project, and each group had successes and failures. In principle, it was clear that such working groups provided a useful platform for the farmers to access a network of other farmers, government officials, market agents and other specialists to find support. There are, however, requirements for a group to be successful:

1. The group needs a motivated facilitator, whether it is an official or a farmer or any other interested party. This facilitator must be able to establish a network with a variety of role-players from all kinds of backgrounds. For example, the seed saving group made good progress until they lost their facilitator, who moved away. Another facilitator was introduced, but the group lost momentum and many continued to harvest seeds privately, without participating in the group. This highlighted the importance of the facilitator.

2. The group must be motivated to work together and share information and contacts. Farmers in general complain that other farmers are unwilling to share information. Many farmers do not cooperate within the group, and the group cannot be successful if the facilitator is working alone.

3. The group must have a shared vision that is realistic. The vision is key to the success of the group. Each member of the group must share the vision and work hard to achieve it. But it is also important to have a realistic vision, or else the group becomes demotivated. The poultry group had a vision of building a poultry forum to support each other in chicken production. They managed to get four motivated participants, but the rest of the group did not take part actively. It is generally accepted that cooperation between farmers in the production phase is not sustainable. There will always be some who work harder than others, which causes conflict. Cooperation at marketing level is more realistic. The experience of the poultry farmers again reminded us of the importance of setting realistic goals.

6.2.2 Developing a farm as a business

Any successful business needs three key role-players: someone to produce the product / provide the service, someone to sell it and someone to take care of the money. If any of these three functions is lacking, the business will not succeed. Commercial farming is a business, and it is a very complex one. London Business School (2016) found that by providing small businesses in South Africa with either marketing or financial management skills, business incomes were doubled compared to the control, where no skills were given. Most emerging farmers in our groups are focused on production, but they lack the marketing and financial management skills. Government subsidies relieve them of the financial and marketing burdens, and it temporarily helps them to grow, but this level of production only lasts while the support is given. Once the government withdraws this support, the farmer will fall back to a farming level where profit is easier to manage (like a food garden), or they become a struggling small-scale farmer. As a farmer grows from a food garden to being successful at a commercial level, the finance and marketing aspects become more difficult. It is important to note that financial management is important at all levels; even a food garden farmer must be sure that he/she produces food for less than what they will pay for it at the market.

The effect of the financial and marketing support given to farmers can be better understood using the analogy of a trainer who is helping an athlete to practice for a marathon. Suppose the athlete is unfit and cannot run the distance and the trainer gives the athlete a car to drive the route instead of running it. By the time of the marathon, the athlete will have covered the distance many times, but he has not built the muscle to run it without support. Training in a classroom is also not effective and can be explained using the same analogy. Talking about running is not going to help an athlete run, his trainer would rather stand next to him while he is running and give advice. Being profitable as a farmer is like running, it takes discipline, hard work, experience and mentorship. You cannot bypass these requirements and still achieve success.

6.2.3 Using the Sukuma Transformation Tool (STT) to guide farmers towards a realistic vision

Government support for emerging farmers is currently divided into subsistence (food garden) farming support and commercial farming support. Commercial farming support works with the ‘minimum viable unit’, which is the minimum farm size needed for a farmer to be profitable. This size is specific to each crop, but is usually more than one hectare. The viable unit is calculated based on the typical commercial farming situation, where supplies are bought commercially and produce is packed, stored and transported to a market. We find that there are opportunities to produce crops on smaller scales with locally available resources, and there are market opportunities for smaller-scale farmers in the communities. We have now identified a profitable farmer on different levels below one hectare and the practices of these farmers are described in **Section 4.3.3**. The lack of understanding the various farming levels between subsistence and large commercial farming is a gap in the current knowledge, and we believe that better information on these levels is needed to address the observed failures of emerging farmers to become successful at commercial levels.

We suggest that a smallholder farmer must be categorised according to his/her current farming level, and how efficient he/she is at the current level. Once 75% efficiency is achieved at a level, the farmer can decide to scale the farm to the next level. The questionnaire in **Section 4.3.4** can be used to characterise the farmer and to determine specific factors that are currently lacking and causing poor efficiency. The cabbage calculator in **Section 4.3.5**, provides a simple framework to assess and compare finances at each level. It can help a farmer to determine whether the next level will be worth the effort, because it includes the potential reductions in produce prices and the realistic expectation of reduction in efficiency that a farmer may initially experience.

Through this project we have developed the STT as a tool to support farmers and extension officers to identify the farmer's current levels of farming and the potential to upscale to the next level. The tool also provides a calculator that can be used to determine the potential profit at each level. Preliminary feedback from farmers and officials suggests that this tool is extremely useful and enables farmers to identify particular gaps and limitations on the farm and in their own operations.

6.2.4 Finding niche markets

Niche markets are generally poorly utilised and often overlooked due to the drive of many farmers to farm at a large scale. The retail markets that serve large farms are very competitive; prices vary greatly and are relatively low. In contrast, the prices at markets in rural communities are higher because produce is sold directly to the consumer, and they are more stable. In some communities, the local markets are not saturated, as many rural communities do not have access to nutritious fresh produce. Local communities are best served by smaller-scale farmers who reside in the community and sell directly to consumers. The lack of transport in rural areas can necessitate a decentralised production of food by many smaller farms in each street, rather than one big farm that sells at a central location.

Agro-processing provides a niche market to the few farmers who are successful at a small but profitable level. Processing is beneficial because it extends the shelf life of the produce, it reduces food wastage, and it increases the value of the produce. SA Gap is a requirement for all farmers who wish to supply processors in the retail markets. Many farmers were not motivated to do the recordkeeping and paperwork required for SA Gap. The reality is that these farmers should not aim to grow into large-scale farmers, because this kind of work is characteristic of high farming levels. It is also true that there are opportunities for these farmers to run profitable businesses in the informal market and we met people who do that. The traceability and food safety in the local informal markets requires research, and can be done in partnership with other stakeholders, such as Boxer who has expressed interest in simplifying the requirements for small-scale farmers.

6.2.5 Promoting smallholder farming for healthy communities

The stigma that small-scale farming is not profitable, and that small farmers will always struggle, is an important reason why farmers are attempting to farm at a commercial level before they master the lower levels. However, we believe this stigma is incorrect and saw that with good agricultural practices and financial planning, a lower farming level can sometimes be more profitable than the next. If a farmer decides to go to the next level, he/she must be aware of how this situation will change and what new problems he/she will have to face. For example, a larger farm may require more labour (adding costs), and the increase in produce may necessitate buying a truck (adding costs) or making use of street hawkers (reducing income).

6.3 POTENTIAL OF DEVELOPING NEW WATER RESOURCES FROM WASTEWATER

6.3.1 Dynamics of water quality in the hydroponic systems

The HNS treatment in both hydroponic systems and in both seasons demonstrated strong consistency in maintaining nutrients, pH and EC balances. This treatment also contained no microbes that can be harmful to human health. The HNS treatment therefore, created good conditions for plant growth and the safety of the produce. In contrast, the results show that treated SWE treatment exhibited a greater variation in water quality. The SWE treatment had nutrient imbalances, with too much phosphorus, too little potassium and constant microbial contamination with high levels of *E. coli* and other microbes. The SWE treatment was also inconsistent in terms of pH and EC, because of daily variations in the operations of the wastewater treatment plant. This was reflected in variations in the initial water quality measured at the beginning of each week. Although the SWE system showed minor improvement in chemical balance under basil cultivation, it continued to suffer from high microbial loads and nutrient variability.

While the SWE flood and drain systems were pumped with water every day, and the roots were continuously subjected to water with microbes, flood & drain SWE never showed a self-remediating effect to lower the microbial levels. This raises questions about the assumptions regarding hydroponic recirculation as being enough to lessen pathogens and demonstrates the relationship with needing an integrated water treatment system. Therefore, while SWE has potential for nutrient recycling, additional treatment (like filtration, UV, or disinfection) and monitoring interventions and site management remain necessary before it can safely replace standard hydroponic nutrient solutions.

6.3.2 Vegetative growth of the various crops in the hydroponic systems

Although the SWE contained sufficient nutrients to sustain vegetative growth, the bioavailability of key macronutrients, particularly nitrogen (N) and potassium (K) were likely inadequate for maximal leaf initiation and expansion. As leaf number correlates directly with photosynthetic surface area and essential oil biosynthesis potential in basil, this underperformance suggests reduced assimilate capacity and overall yield potential under SWE.

The reduced height in SWE-treated plants can be attributed to osmotic stress from elevated EC levels and imbalanced nutrient composition, both of which restrict water uptake and cell elongation. This suggests that, although treated effluent can sustain basic vegetative development, it does not provide a consistently balanced nutrient profile to promote vigorous vertical growth comparable to that achieved under HNS.

Leaf size, measured through leaf length and width, is a critical determinant of photosynthetic capacity and transpiration efficiency. In green pepper, leaves under the HNS treatment were significantly longer and broader across all weeks of measurement. The smaller, narrower leaves under SWE suggest reduced cell enlargement likely caused by moderate salinity stress and nutrient limitation. Previous studies (Hussain et al., 2021; Kumari et al., 2019) indicate that excess sodium ions and reduced nitrogen or magnesium concentrations commonly observed in treated effluent can restrict chlorophyll synthesis and photosynthetic efficiency, leading to reduced leaf expansion and smaller leaf blades. Therefore, SWE-grown plants likely experienced mild physiological stress that constrained optimal leaf growth.

The reduced fruiting, in the case of green peppers in SWE-treated plants, may be attributed to limited nutrient availability during the critical reproductive phase, particularly phosphorus and potassium, which are vital for flower initiation, fruit set, and development. Additionally, elevated EC in SWE can create osmotic stress that restricts water movement into developing fruit, potentially reducing fruit number and size. Despite these reductions, the ability of SWE-grown plants to produce multiple fruits indicates that the effluent maintained adequate macronutrient levels for partial reproductive success. This suggests that with supplemental nutrient correction, SWE could effectively support both vegetative and reproductive growth.

1.1.1 Crop growth using a nutrient supplement - Kelpak

Using 100% Kelpak delivers the strongest vegetative growth in spinach, producing both more leaves and larger plants than any other treatment. A 50% Kelpak dose provides some benefit but shows greater variability, likely due to reduced hormone concentrations. Treated wastewater effluent (SWE) results in lower yields than standard hydroponic nutrient solution, but it remains a feasible alternative where freshwater availability is limited—provided nutrients are adjusted to correct deficiencies. For commercial spinach production, the most effective approach is a standard nutrient solution combined with 100% Kelpak. SWE with Kelpak can serve as an alternative only if the effluent is well-treated and nutrient-balanced.

1.1.2 Management of hydroponic systems to utilise treated effluent

Management actions employed during the summer and winter pilot studies included pH correction, EC monitoring, and weekly solution renewal. The effectiveness of these actions varied between systems. In the two studies on the drip bag system, the management actions effectively maintained SWE water quality parameters within acceptable ranges for plant growth, with little intervention required after initial adjustments were made. The evidence of stable EC and pH and stable temperature suggests that the system's zero turnover and constant drip delivery with less complex dynamics allowed better control and performance.

In the two studies on the flood & drain system, the management plan showed mixed results. While the pH and EC were regularly corrected to acceptable levels, SWE had much more variability, particularly because of variation in pH. The flooding and draining system dynamics may have amplified variability in the system, due to oxygenation cycles, solute resettling in the flood and drain pots, or residual molecules from previous effluent being reintroduced during the flood cycle. Thus, while the management plan was still adequate, it was less effective in the flood and drain system, since it required much more effort and intervention to manage SWE parameters into a target range.

7 CONCLUSION AND RECOMMENDATIONS

Agri-park and emerging farmers face multiple problems that seem to be impossible to solve. These problems include the difficulties in accessing markets, inability to farm profitably with expensive supplies (because of small quantities purchased) and low market prices, sourcing water and irrigating efficiently, inefficient extension services, inconsistent availability of electricity, theft and many other problems. We agree with Bjornlund et al., (2020) that the multitude of problems faced by emerging farmers cannot each be solved on their own, but can only be overcome if addressed within the full complexity of the entire system.

We have detected a systematic problem in the way farmers are currently entering the commercial space, namely that there are various levels of farming between the food garden farmer and the large commercial farmer, which are poorly understood and described. Therefore, the necessary changes that are required when moving between these levels are currently not implemented. Some farmers are aiming for the emerging commercial level (Level 5), but operating on the livelihood level (Level 2). Other farmers are looking for market opportunities that are suitable for Levels 2 or 3, but are purchasing infrastructure suitable for Levels 4 or 5. Government are pushing for farmers to operate at levels above Level 5 (large commercial agricultural scale), while many farmers are still struggling to farm efficiently below Level 3.

The Agri-park farmers at Rooiwal who have entered into the large-scale commercial level are currently limited by a lack of water resources. They can potentially make use of sewage waste effluent (SWE) water from the adjacent wastewater treatment facility, like many of the farmers in the area. In the project, we found that more research is required to optimise the SWE fertigation of crops in hydroponics, and such use will require:

- System-specific management,
- Nutrient supplementation to correct deficiencies,
- Pre-treatment to stabilise water quality, and
- Strict food safety and microbial monitoring.

The key outcome of our study is that technologies that are introduced into a farm must suit the capacity of the farmer and the current farming system, in terms of the financial system, the market and the productive capacity. Large-scale farmers may have the capacity and finances for technologically advanced methods like hydroponics, but small farmers need simpler farming solutions.

7.1 RECOMMENDATIONS

From our research in the Rooiwal Agri-park and surrounding communities, we have defined the following recommendations for farmers and government officials who support them:

- Based on actual farms in Hammanskraal, we have described 5 farming levels from food garden to emerging commercial. We recommend that a farmer move up only one level at a time when he/she is efficient at the current level.
- Farmers and extension officers should use our Sukuma Transformation Tool to determine the current farming level of the farmer and the aspects that are lacking, which are limiting growth.
- Farmers should utilise the potential niche markets that are currently available, including local communities and small food processors, and these markets should fit the farmer's current farming level.
- The formation of working groups in agricultural communities can act as a platform for networking and farmer support (refer to **Section 6.2.1)** for the requirements for such working groups.

- The government should refrain from micro-managing farmers through financial inputs or supplies, and instead support them with developing new water resources, managing crime, protecting industries through import policies and regulations (refer to **Section 4.3.6** for more detail).
- The government should maintain a water resource and use inventory for farmers within the Rooiwal Agri-park and develop a water management plan to manage their water use more effectively.
- Farmers should explore the option of using drip bag irrigation as an alternate to in-soil crop production.
- The safety and efficiency of using wastewater from the Rooiwal WWTWs are not confirmed in this study.

7.2 FUTURE RESEARCH

It is recommended that the following topics be included in future research:

- Agri-park management: The Sukuma Transformation Tool can be further developed into an application for electronic devices and to include a framework to work out business plans for each farming level.
- Market: There are untapped market opportunities within the local communities, where nutritious food is unavailable, and in small-scale food processing, that need to be developed. There is a need for research to regulate food safety in the informal market.
- Water: Two irrigation practices have been identified that have significantly improved the farming outcomes of small farmers in Hammanskraal. (1) Self-constructed boreholes that utilise shallow groundwater, (2) the gravity-driven irrigation system developed by Sukuma Community Transformation. These practices are ready to be upscaled to other communities.
- Further studies are needed to improve the efficiency of irrigating with wastewater in drip bag systems.
- Research is needed to determine the presence of other chemicals, such as organic pollutants in the water and how these are taken up in plants when irrigated with water containing these chemicals.

After a site visit to a successful food garden in Hammanskraal, which is discussed in more detail under **Section 4.3.3.2**, an honours student mentioned that the house reminds him of a blue zone. Blue zones are hotspots in the world where high percentages of centenarians reside, and their living conditions often involve small-scale farming (Buettner and Skemp, 2016). We believe that this is a good alternative to the current stigma around small-scale farming, and it could be a great resolution for future research to develop 'African blue zones'.

8 CAPACITY BUILDING

8.1 STUDENTS

This section gives background on the contributions of each student. The student abstracts are included in **Appendix 1**.

8.1.1 Ms Kwena Winnie Mpati

Ms Kwena Winnie Mpati is a **PhD student** under the supervision of Dr Aluwani Tagwi from Unisa. Her project focused on marketing cooperatives in an Agri-park context. Ms Mpati surveyed ten Agri-parks across Gauteng during March to October 2025 to understand how the participation in the Agri-parks initiative influenced the productivity, irrigation practices, income and constraints of smallholder farmers.
Ms Mpati is a full-time employee from the City of Tshwane (CoT), and she can take the lessons learned from this project to important role-players in the Agri-parks programme. Key Policy and Programme Recommendations that she will communicate to the CoT Agri-parks team include:

- Support landowning farmers surrounding the Agri-parks, aligning with the original Agri-park model.
- Promote active participation of surrounding landowning farmers in Agri-parks programmes.
- Strengthen outreach and reduce barriers to entry into the Agri-parks programmes for nearby farmers.
- Expand value-addition infrastructure such as dryers and packhouses.
- Improve access to affordable energy technologies, especially solar-powered systems.
- Enhance technical training in irrigation, energy efficiency, and market readiness.

8.1.2 Ms Amahle Kunene

Ms Amahle Kunene was a **Master of Science** student under the supervision of Dr Keletso Mohale at the University of South Africa (UNISA). Her research investigated the feasibility of irrigating crops with treated wastewater effluent in different hydroponic systems at the Rooiwal Agri-park. The project evaluates plant growth performance, water quality dynamics, and nutrient accumulation under two nutrient sources: sewage wastewater effluent (SWE) and a hydroponic nutrient solution (HNS).

Summary of Fieldwork and Experimental Activities
Ms. Kunene completed a comprehensive literature review and played a central role in carrying out the pilot studies. She was responsible for the day-to-day maintenance and monitoring of the hydroponic systems, as well as the collection and recording of experimental data throughout the study period. In addition, she prepared vegetative samples for laboratory analysis, performed statistical analyses to interpret the results, and compiled her findings into a final dissertation document.

Her literature review covered the following areas:

- Global and local trends in wastewater reuse in agricultural production, benefits and challenges.
- Hydroponic systems and their advantages over traditional soil-based farming.
- Water quality requirements for hydroponic crop production.
- Growth performance and nutritional quality of leafy vegetables in hydroponic cultivation.
- Health and food safety considerations associated with wastewater-irrigated crops.

Fieldwork activities included:

- A winter (July – September 2024) and summer pilot (January – April 2025)

- Routine management for two pilot studies (winter and summer) followed the same schedule, including irrigation/fertigation, weekly tank discharges, nutrient mixing, pH correction, and weekly water quality monitoring.
- Collecting weekly data on growth parameters (plant height, leaf length, width, number of leaves, and fresh and dry weight). Twice daily water quality measurements (pH, EC, temperature).

Preparation of vegetative samples for laboratory testing included:

- Harvesting and weighing entire plants at final harvest to determine fresh weight.
- Drying and weighing plant material for dry weight. For the winter study, harvested plants were air-dried at room temperature for seven weeks until completely dehydrated. For the summer study, basil was oven-dried at 60–70 °C at the UNISA Florida Campus, while green pepper fruit samples were freeze-dried to protect heat-sensitive compounds.
- Grinding dried samples into a homogeneous powder.
- Packaging and labelling ground samples in airtight zipper bags.
- Sending prepared samples for nutrient content analysis at Elsenburg Plant Science Institute.

Statistical analyses included:

- Processing and organising raw data in Microsoft Excel for accuracy, consistency and alignment with the Randomised Complete Block Design (RCBD) used in the study.
- Descriptive statistics such as minimum, maximum, mean, median, percentiles (5th and 95th), and standard deviation to summarise water quality and growth performance trends.
- Inferential testing using Two-Way ANOVA ($p < 0.05$) to determine whether treatment type (SWE vs. nutrient solution) and crop type had statistically significant effects on growth performance and nutrient composition.
- Post-hoc comparison using Tukey's HSD test to separate treatment means and identify which groups differed significantly when ANOVA showed significance.
- Regression analysis to examine relationships and trends over time in parameters such as nutrient concentrations, EC, pH, and microbial activity.
- Standards comparison analysis comparing trial water quality values against SANS 241, DWS agricultural standards, and FAO irrigation guidelines for safety and suitability interpretation.

Through conducting this study, Ms Kunene gained practical experience in managing controlled hydroponic experiments, systematic water quality monitoring, preparation of plant tissue for laboratory nutrient analysis, and statistical interpretation of experimental data. She developed a deeper understanding of the potential and limitations of treated sewage wastewater effluent (SWE) in hydroponic crop production, particularly relating to water quality dynamics, nutrient uptake, and crop performance under different seasonal conditions. This research has strengthened her interest in advancing sustainable water reuse strategies in agriculture, which she would like to further explore through long-term system optimisation, microbial risk management, and economic feasibility of SWE-based hydroponics in commercial environments.

8.1.3 Ms Kysha Razawo

Ms Kysha Razawo received funding from the project, which included a stipend plus materials and operational costs for her research project for her BSc Honours in Agricultural Sciences at UNISA. Her role included executing and managing the research system.
The focus of Ms Razawo's study was to assess the use of biostimulants and treated wastewater in hydroponic spinach production under a deep-water culture (DWC) system. The study aimed to:

- Investigate the effects of full-strength (100%) and diluted (50%) Kelpak biostimulant on spinach growth.

- Compare the performance of plants grown using treated wastewater effluent versus standard hydroponic nutrient solutions.
- Analyse growth patterns over six weeks based on leaf count, plant size, and biomass yield.

Her research provided insights into how biostimulants and alternative water sources might influence hydroponic spinach growth. While preliminary, the findings contribute to understanding approaches that could enhance crop performance in resource-limited settings and offer a foundation for further investigation in this area.

8.1.4 Ms Thando Bulwane

Ms Thando Bulwane was funded by the project to do her Bachelor of Agriculture Honours in Extension at the University of Pretoria. Ms Bulwane's study aimed to assess the safety of treated sewage from wastewater treatment plants as a fertiliser in agriculture. This objective was addressed through the following sub-aims:

- To learn and understand the processes involved in wastewater treatment and how they contribute to producing treated sewage that is suitable for agricultural use.
- To investigate the presence of potential contaminants such as pathogens, heavy metals and emerging pollutants such as pharmaceuticals and microplastics that may pose risks to human health and the environment.
- To review the existing safety regulations and management practices that ensure biosolids are applied responsibly and within approved environmental standards.

8.2 INSTITUTIONAL DEVELOPMENT

This project provided an opportunity for government officials to learn and to improve their abilities to manage the farmers.

1. **Officials from the City of Tshwane (CoT)** were involved in our meetings with all stakeholders, and they have made valuable contributions. These meetings were a space for all stakeholders to discuss their problems and aspirations, and to clarify the roles and responsibilities. It was a learning experience for all who were involved. Officials at the CoT learned agricultural and water management skills that they can use in other locations. Ms Kwena Mpati became part of the project team as a PhD student and is in a position to communicate important findings to the Agri-parks management team at the CoT.
2. **Officials from the Gauteng Department of Agriculture, Rural Development and Environment (GDARDE)** were also involved in the stakeholder meetings and were also making valuable contributions. These officials indicated that they have a lot of difficulty in rolling out the Agri-parks model, and they specifically indicated that our meetings were very valuable to them. One official said that they have never before discussed these problems in a multi-stakeholder environment. It seems as if the officials on the ground are struggling with problems that those higher up are not aware of, and the participation in these groups gave them a chance to voice their concerns.
3. **Officials from the Rooiwal Wastewater Treatment Works** (WWTW) supported the project with access to the effluent and selected the effluent source that was used in the pilot study on SWE and HNS in hydroponics.
4. **Partner institutions:** Food and Water Research, the Nova Institute, Sukuma Community Transformation (NGO), Urban Foodscape, National Agricultural Marketing Council (NAMC), and the University of South Africa (UNISA) are partner institutions on the project team who are benefiting from the project and learning from the process and project outcomes.

8.3 COMMUNITY DEVELOPMENT

8.3.1 Rooiwal farmers

Rooiwal farmers within the Agri-park and surrounding landowning farmers benefited from this project by participating in various working groups, which provided a platform for building networks, connecting with markets and accessing production support, training sessions and knowledge sharing. Farmer-to-farmer training was done by taking Rooiwal farmers to successful organic farmers in Hammanskraal. The Hammanskraal farmers presented their farms, explained their irrigation systems (including their self-constructed boreholes, irrigation application and soil water management), their fertiliser production and pest control methods. More than 50 farmers received training on SA Gap registration and one successfully received her certificate through this support. The Sukuma Transformation Tool was presented and tested at the final working group meeting, and farmers indicated that the tool helped them to do self-reflection and some changed their farming visions based on the information from the tool. Through this research the Rooiwal farmers within the Agri-park learned about irrigation with wastewater, and production in hydroponics systems. Most notably, Ms Advine Mutavhatsindi, a young farmer on the Rooiwal Agri-park assisted in managing the hydroponics studies and then took initiative to attend a course on hydroponics to extent her training on it.

8.3.2 Johannesburg Agri-parks

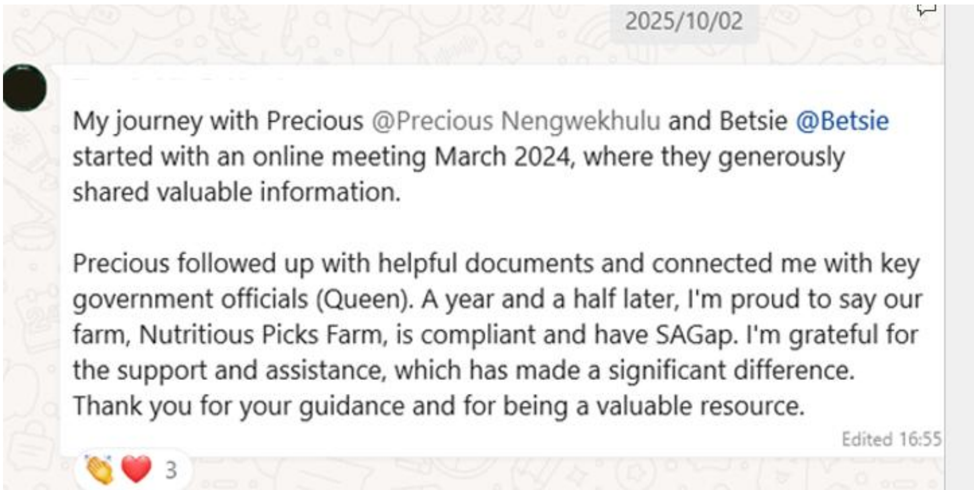
A survey was done on the impact of Agri-parks on farmer production and economic outcomes, and this included the Johannesburg Agri-parks. A total of 21 Gauteng farmers with SA Gap certificates received support to update their registration and to register on the Simply Garlic database. These farmers are now selling to Simply Garlic.

8.3.3 Highlights of farmer developments

During the project, there were many success stories that were reported in the preceding chapters. The following stories can be highlighted:

- Through the project 22 Gauteng farmers in Rooiwal and Johannesburg were connected with Simply Garlic and are now selling their produce to them.
- One farmer in Rooiwal initiated her application process and obtained her SA Gap certification during this project
- Farmers indicated that the Sukuma Transformation Tool changed their understanding of their problems and their strategies for their farms. One lady realised that she should stop farming and concentrate on marketing instead.
- Some farmers started to harvest their own seeds and are now growing their produce with seeds from their previous crops
- Officials and extension officers indicated that the working groups were the first space they had to voice the problems that they are dealing with on the ground, and that they believe it is an important platform.

8.3.4 Farmer feedback



2025/10/02

My journey with Precious @Precious Nengwekhulu and Betsie @Betsie started with an online meeting March 2024, where they generously shared valuable information.

Precious followed up with helpful documents and connected me with key government officials (Queen). A year and a half later, I'm proud to say our farm, Nutritious Picks Farm, is compliant and have SAGap. I'm grateful for the support and assistance, which has made a significant difference. Thank you for your guidance and for being a valuable resource.

Edited 16:55

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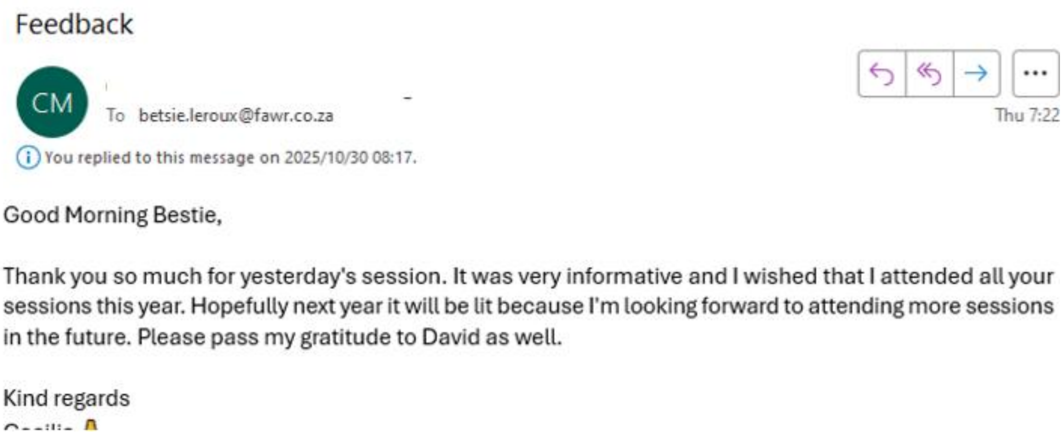

Feedback

CM

To betsie.leroux@fawr.co.za

Thu 7:22

You replied to this message on 2025/10/30 08:17.

Good Morning Bestie,

Thank you so much for yesterday's session. It was very informative and I wished that I attended all your sessions this year. Hopefully next year it will be lit because I'm looking forward to attending more sessions in the future. Please pass my gratitude to David as well.

Kind regards

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10 APPENDICES

10.1 STUDENT ABSTRACTS

10.1.1 Kwena Mpati

Title: How the participation in the Agri-parks initiative influenced the productivity, irrigation practices, income and constraints of smallholder farmers.

Abstract
This study assessed the influence of Gauteng's Agri-park programme on smallholder farmers' productivity, irrigation practices, income, and constraints. A survey of ten Agri-parks conducted between March and October 2025 examined three farmer groups: those operating within Agri-park hubs, farmers outside the hubs who participate in the programme and non-participants. Data were collected through structured questionnaires and analysed using logistic and linear regression models. Results show that willingness to provide agricultural waste for biomass-energy production is strongly predicted by gender and education, with male and more educated farmers significantly more likely to participate. Agri-park participants demonstrate greater access to modern irrigation technologies and more diversified energy sources than non-participants. Income analysis reveals that farmers located within 30 km of an Agri-park and actively using its services earn substantially higher total agricultural income (R230,643 more) than those inside the hubs, while nearby non-participants show no income gains. Education and age positively influence income, whereas gender has no significant effect. Key constraints vary across groups: non-participants face greater market access barriers, higher post-harvest losses, and limited credit, while all farmers experience inadequate value-addition infrastructure and high energy costs. Overall, active participation in Agri-parks, rather than proximity alone, is linked to improved productivity, income and resource access. The findings highlight the need to enhance farmer engagement, expand value-addition infrastructure, improve access to affordable irrigation and energy technologies, and strengthen technical training to realise the full potential of Agri-parks as a driver of smallholder development.

10.1.2 Amahle Kunene

Title: Assessing growth, yield, and quality response of lettuce (Lactuca sativa), Swiss chard (Beta vulgaris var. cicla), basil (Ocimum basilicum) and green pepper (Capsicum annuum) to treated sewage wastewater effluent (SWE) under a hydroponics system.

Abstract
The increasing global demand for sustainable food production and freshwater scarcity have increased interest in alternative water sources for agriculture. This study evaluated the potential of treated sewage wastewater effluent (SWE) as an alternative nutrient source for hydroponic cultivation of lettuce (*Lactuca sativa*), Swiss chard (*Beta vulgaris var. cicla*), basil (*Ocimum basilicum*), and green pepper (*Capsicum annuum*). Two trials were conducted at Rooiwal Agri-park, each using SWE and a conventional hydroponic nutrient solution (HNS) under controlled hydroponic systems: a flood-and-drain system for lettuce and basil, and a drip bag system for Swiss chard and green pepper.

In the winter trial, SWE displayed higher electrical conductivity (EC) and variable pH compared to HNS, though values were effectively managed through phosphoric acid adjustment and weekly system renewal. Lettuce grown under SWE exhibited significantly reduced growth and yield performance, including fewer leaves, smaller leaf area, and lower fresh biomass (98.33 g plant^{-1}) compared to HNS (349.67 g plant^{-1}). In contrast, Swiss chard under SWE achieved comparable yields to HNS, with no significant differences in biomass

accumulation, reflecting greater tolerance to nutrient and salinity fluctuations. Nutritional analysis revealed elevated phosphorus and micronutrient concentrations (Fe, Zn, Mn) in SWE-grown crops but also higher sodium and aluminium levels, indicating possible ion imbalance and toxicity risks, especially in lettuce.

In the summer trial, SWE supported basil and green pepper growth under warmer conditions with improved EC and pH stability, particularly in the drip bag system. Basil and green pepper showed satisfactory vegetative development, suggesting that SWE can sustain crop performance when environmental conditions and system design are favourable. The drip bag system consistently demonstrated superior parameter stability and plant response compared to the flood-and-drain system across both trials.

Overall, the findings indicate that SWE possesses valuable nutrient potential for hydroponic crop production but requires system-specific management, nutrient supplementation, and microbial control before safe application. While sensitive crops such as lettuce show growth inhibition under SWE, tolerant species like Swiss chard, basil, and green pepper can be cultivated successfully with proper effluent management. The study concludes that integrating treated wastewater into hydroponics supports circular water use and sustainable urban agriculture, provided that effluent quality, safety, and system design are carefully optimised.

10.1.3 Kysha Razawo

Title: Assessing the Growth and Yield of Spinach (*Spinacia oleracea*) Under Hydroponic Cultivation with Kelpak Biostimulant and Wastewater Effluent

Abstract

This study examined the effects of treated wastewater effluent (SWE) and two Kelpak biostimulant concentrations (100% and 50%) on the growth and yield performance of spinach (Spinacia oleracea) cultivated in a deep-water culture (DWC) hydroponic system. Four treatments were evaluated in a randomised full-block design: standard nutrient solution + Kelpak 100% (G1), standard solution + Kelpak 50% (G2), SWE + Kelpak 100% (G3), and SWE + Kelpak 50% (G4). Over six weeks, two growth parameters—leaf number and plant size—were recorded weekly. Plants that died (zero leaves) were excluded from the analysis.

The results showed a consistent trend of superior growth in the Standard + Kelpak 100% treatment (G1), which achieved the highest mean leaf count and plant size across all weeks. ANOVA indicated significant treatment effects from Week 3 onward ($p < 0.05$), and Tukey HSD tests confirmed highly significant differences ($p < 0.001$) between G1 and all other treatments by Weeks 5 and 6. The Standard + Kelpak 50% treatment (G2) also performed well but displayed greater variability, while wastewater-based treatments (G3 and G4) showed comparatively reduced growth.

Overall, the findings demonstrate that Kelpak biostimulant enhances the performance of hydroponically grown spinach, with full-strength (100%) applications providing the greatest benefit. Although spinach can be produced using treated wastewater effluent, yields remain lower than those achieved with conventional nutrient solutions. With appropriate nutrient management and water-quality control, these results highlight the potential of integrating biostimulants with wastewater as a sustainable approach for hydroponic production in water-scarce regions.

10.1.4 Thando Bulwane

Title: Safety of Reusing Treated Sewage as Fertiliser in Agriculture

Abstract

The reuse of treated sewage as fertiliser offers a sustainable approach to recycle nutrients, improve soil fertility, and reducing dependence on synthetic fertilisers. Treated sewage provides essential nutrients, such as nitrogen and phosphorus, but its safe use depends on effective treatment, contaminant control, and adherence to safety guidelines. Pathogens, including bacteria, viruses, and parasites, can pose health risks if inadequately treated; processes such as composting, anaerobic digestion, and thermal drying reduce these risks. Chemical contaminants, particularly heavy metals, can accumulate in soil and crops, necessitating monitoring and compliance with regulatory limits. Improper application may also cause nutrient leaching, groundwater contamination, or the spread of emerging pollutants. When appropriately treated and applied at recommended rates, treated sewage can safely enhance soil fertility and contribute to sustainable agriculture. This study highlights the importance of balancing nutrient recycling with precautionary measures to protect human health and the environment, demonstrating that treated sewage can be a valuable resource in agricultural production.

10.2 MEETING AGENDAS

This section includes the agendas for the quarterly meetings at Rooiwal, which were the events where all participants came together. Agendas for all meetings and activities that were undertaken within working groups are not included because such meetings were more informal and outcomes emerged through interactions.

AGENDA

EMPOWERMENT OF AGRI-PARKS FARMERS TO INCREASE IRRIGATED FOOD PRODUCTION AND MARKET ACCESS

Exploratory meeting

Place: Rooiwal Community Hall

Date: 7 June 2023

Time: 9:00 – 12:00

Time	Agenda item	Facilitator
9:00	Introduction	Betsie le Roux
9:30 – 11:30	Group sessions to discuss the current problems of each group	**Government officials:** Aluwani Tagwi and Betsie le Roux **Agri-park Farmers:** Mike Howard and Oupa Lebese **Land owners:** Attie van Niekerk and Charné Muller
11:30	Feedback and closure	Betsie le Roux
12:00	Refreshments	

AGENDA

EMPOWERMENT OF AGRI-PARKS FARMERS TO INCREASE IRRIGATED FOOD PRODUCTION AND MARKET ACCESS

Follow-up meeting

Place: Rooiwal Community Hall

Date: 29 June 2023

Time: 10:00 – 13:00

Time	Agenda item	Facilitator
10:00	Introduction and feedback from first meeting	Betsie le Roux
10:30 – 12:30	Group sessions: 1. Visioning: Ideal situation 2. How to reach the ideal situation? 3. Roles & responsibilities	**Government officials:** Aluwani Tagwi and Betsie le Roux **Agri-park Farmers:** Mike Howard and Oupa Lebese **Land owners:** Attie van Niekerk and Charné Muller
12:30	Feedback and closure	Betsie le Roux
13:00	Refreshments	

AGENDA

EMPOWERMENT OF AGRI-PARKS FARMERS TO INCREASE IRRIGATED FOOD PRODUCTION AND MARKET ACCESS

Training on water conservation in agriculture and seed saving

Place: Rooiwal Agri-park

Date: 30 August 2023

Time: 9:00 – 16:00

Time	Agenda item	Facilitator
9:00 - 10:00	Water conservation in agriculture (1)	Charné Muller
10:00 – 10:30	Feedback and discussion	Betsie le Roux
10:30 - 10:45	Break	
10:45 – 11:30	Water conservation in agriculture (2)	Charné Muller
11:30 – 12:00	Feedback and discussion	Betsie le Roux
12:00-13:00	Lunch	
13:00 – 14:00	Seed saving (1)	Charné Muller
14:00 – 14:30	Feedback and discussion	Betsie le Roux
14:30 – 14:45	Break	
14:45 – 15:30	Seed saving (2)	Charné Muller
15:30 – 16:00	Feedback and closure	Betsie le Roux

AGENDA

EMPOWERMENT OF AGRI-PARKS FARMERS TO INCREASE IRRIGATED FOOD PRODUCTION AND MARKET ACCESS

Market and agro-processing information day

Place: Rooiwal Agri-park

Date: 12 September 2023

Time: 9:00 – 15:30

Time	Agenda item	Facilitator	
9:00 – 9:15	Opening and welcome	Betsie le Roux	
9:15 - 11:15	Producing, processing and market opportunities of essential oils	Karen Swanepoel	
11:15 - 11:30	**Break**		
11:30 – 12:00	Information on government support systems	Vusi Ntuli	**GDARDE**
		Betty Komote	**Tshwane Fresh Produce Market**
		Precious Nengwekhulu	**National Agricultural Marketing Council**
12:00 – 12:15	Discussion and questions	Betsie le Roux	
12:15-13:30	**Lunch**		
13:30 – 15:15	Strategic planning session	Betsie le Roux	
15:15 – 15:30	Feedback and closure	Betsie le Roux	

AGENDA

EMPOWERMENT OF AGRI-PARKS FARMERS TO INCREASE IRRIGATED FOOD PRODUCTION AND MARKET ACCESS

Launch of Farmer Working Groups

Place: Rooiwal Community Hall

Date: 18 January 2024

Time: 9:00 – 13:00

Time	Agenda item	Facilitator
9:00	Introduction Feedback on progress Way forward	Betsie le Roux
10:00	Group introduction	Betsie le Roux
	1. Water use efficiency	Charné Muller
	2. Seed saving	Linky Molatoli
	3. Agro-processing	Betsie le Roux / Kwena Mpati
	4. Essential oils	Attie van Niekerk
	5. Freshmark market cooperation	Precious Nengwekhulu
	6. Farmers graduation programme	TBC
11:00 – 12:00	Divide into groups, first meeting & planning session	Betsie le Roux
12:00	Feedback and closure	Betsie le Roux
12:30	Refreshments	

STANDARD AGENDA FOR QUARTERLY WORKING GROUP FEEDBACK SESSIONS

Empowerment Of Agri-Parks Farmers To Increase Irrigated Food Production And Market Access

Time	Agenda item	Facilitator
9:00	Opening Feedback on working groups progress	Betsie le Roux
10:00	Working group session	
	1. Water use efficiency	Group leader
	2. Seed saving	Group leader
	3. Agro-processing	Group leader
	4. Essential oils	Group leader
	5. Farmers graduation programme	Group leader
	6. Poultry	Group leader
11:30 – 11:45	Break	
11:45 – 13:00	Session on market access	Precious Nengwekhulu
13:00	Refreshments / Lunch	