# EXPLORING FARMER'S PERCEPTIONS TOWARDS THE USE OF HYDROGEL TECHNOLOGY TO IMPROVE FOOD SECURITY: A CASE STUDY OF MVUMA.

**A dissertation submitted in partial fulfillment of the requirements for the Master of Science Degree in Food Security and Sustainable Agriculture**
**(Policy)**

**Bindura University of Science Education**

**Faculty of Agriculture and Environmental Science**
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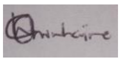
Signed: 

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## APPROVAL FORM

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# DECLARATION

I hereby declare that the research project entitled **‘Exploring farmer’s perceptions towards the use of hydrogel technology to improve food security: a case study of Mvuma.’** submitted to Bindura University of Science Education, Department of Agriculture Economics, Education and Extension is a record of an original work done by me under the guidance and supervision of **Dr N. Mafuse** and this work is submitted in partial fulfillment of the requirements for the award of a Master of Science Degree in Food Security and Sustainable Agriculture. The results embodied in this thesis have not been submitted to any University or Institute for the award of any degree or diploma.

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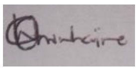
**Signature:** 

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**ABSTRACT**

Global climatic changes are causing unprecedented droughts which are affecting moisture available for sustainable crop production. This has been due to elevated temperatures and decreasing rainfall day with the lack of rain for an extended period causes a considerable hydrologic imbalance along with depletion of soil moisture, crop damage, and yield reduction. Therefore, enhancing water retention in the soil is considered as a vital measure to combat the adverse impact of drought on crop production. A lot of innovation have brought about many agricultural technologies that have potential to improve agricultural productivity and food security in many economies but with relatively little success in the Southern Africa region due to different perceptions of farmers on these technologies. Such technologies as the use of hydrogels have been made available and these are known for enhancing the water-holding properties of soils and thereby improving water availability to crops. This reduces the impact of the droughts especially in the Southern African region. This is because the uptake of the technologies is a complex process. Smallholder farmers often experience issues of sustainability, constraints for adoption, and scaling-up throughout the uptake process of technologies. This indicates a need for a systematic and simultaneous understanding of sustainability, constraints for adoption, and scaling-up to better guide agricultural strategy and policy interventions. This study takes on a case study approach, using the demonstration and group discussions approach, scaling-up assessment (ScalA) method and four focus group discussions with a total of 60 smallholder farmers to assess the sustainability, constraints for adoption, and scaling-up of four technologies (use of hydrogel and mulch, hydrogel alone, mulch alone, no hydrogel and no mulch) in Mvuma. A trial to demonstrate proof of performance of the technology was first carried out before engaging the farmers on their perception of the technology. This trial was done four treatments of hydrogel with mulch, hydrogel alone, mulch alone and no hydrogel and no mulch as one treatment on maize growth under rainfed conditions. Maize variety, Valley Seeds PAN53 was tested under these treatments in a Randomized Complete Block Design. Plant growth parameters were quantified which were days to 50% germination, days to physiological maturity, plant height, number of cobs per plant and yield per hectare. A significant difference was observed on physiological maturity, plant height and yield among the treatments. Hydrogel with mulch resulted in more days to maturity (128 days), taller plants (187cm) and higher yield (3t/ha). This treatment was comparable to hydrogel only on the yield obtained. Therefore, it was concluded that hydrogel with mulch could enhance the growth of maize effectively under dryland conditions when moisture is limiting. The farmers perceptions were then assessed based on the field performance and how they also viewed the technology. The farmers perceived that the use of hydrogel was sustainable when mixed with mulch and had high adoption rate and possibility of scaling up. The most significant constraints for adoption experienced by the farmers are lack of technical physical inputs, marketing facilities, and know-how. The farmers' perceptions partially indicated why the technologies is lacking in Mvuma and provide a basis for discussing targeted agricultural technology.

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# CHAPTER ONE

# 1.0 INTRODUCTION

## 1.1 Background

Moisture availability for sustainable crop production is being affected by global climatic changes due to elevated temperatures and low rainfall (FAO, 2023). Climate change effect on agricultural production are getting aggravated and food production is in crisis due to these prolonged drought conditions due to climate change (Falkenmark, 2013). Reduced rain being received recently has resulted in hydrologic imbalances, crop damage, depletion of soil moisture, and decreased production.

Therefore, enhancing water retention in the soil is considered as a vital measure to combat the adverse impact of drought on crop production. The physical properties of a particular soil determine the amount of water available to the plant in that soil which in turns influence the yielding capacity of that crop. One sure way of improving water retention has been observed to be the use of hydrogel (Rasaderee *et al*., 2021). They are particularly effective in sandy to sand loamy soils. Maize (*Zea mays* L.) is sensitive to moisture stress in the soil in any soil type and productivity will greatly improve if hydrogel technology is applied to the crop. This is a panacea to ameliorating food security in most developing countries.

Hydrogel is a unique material that can absorb a lot of moisture and do not easily release the absorbed liquids when pressure is applied to it (Yazdani et al., 2007). It has been used to increase water retention in many soils especially sandy soils which improves its water holding capacity. In studies that have been carried out, hydrogel have been observed to increase the water availability for plant use (Yazdani et al., 2007). The technology has been applied and greatly enhanced crop productivity in most countries yet remains to be highly adopted in Zimbabwe (Mudhanganyi *et al*., 2016).

Hydrogels can enhance soil agglomeration and water retention capacity (Yang *et al*., 2020). Evaporation losses from soils have been demonstrated to be reduced with the use of these hydrogels (Banedjschafie and Durner, 2015). It also minimizes the loss of nutrients from the soil since it significantly reduce surface runoff and soil erosion (Yang *et al*., 2020). As the hydrogel binds to the soil particles, thereby reducing the soil losses (Yang *et al*., 2020). This technology has not found a huge niche in Zimbabwe and introducing its wide scale use and adoption has great potential to improve crop yields and enhance food security in Zimbabwe (Mudhanganyi *et al*., 2016). However, numerous writers have demonstrated how farmers' opinions of this technology affect their adoption of it (Negatu and Parikh, 1999; Sinjaa *et al*, 2004; Mwangi and Kariuki, 2015).

The community's opinions and perceptions are crucial to the adoption of hydrogel use. Therefore, before its introduction, promotion, and implementation, Investigations into the farmers' perceptions of constraints are necessary. Several studies (Grant, 1981; Chirino *et al*, 2011) explored the uptake process of hydrogel in Zimbabwe but the majority of studies were conducted from an empirical, technological, governance, or policy perspective. This study therefore examined the perception by farmers on sustainability, adoption of hydrogel technology, and scaling-up of hydrogel technology.

## 1.2 Problem Statement

Soil structure plays an integral part in crop performance as it determines the level of nutrients and moisture that will be available to the plants. Adjuik *et al* (2022), stated that in agricultural soils, the distribution and flow of soil moisture were significantly influenced by the hydraulic properties of the soil. According to Soropa *et al* (2018), about two-thirds of soils are sands derived from granitic parent material which have low exchange capacity and low ability to hold adequate moisture for long to support plant growth. Agricultural practices which have minimal retention of organic material and overgrazing have not helped the situation resulting in low levels of soil organic material. Coupled with low usage of fertilizers and suitable soil amendment material, very low yields below the potentials of the crops have been obtained mainly by the smallholder farmers who are either unwilling or unaware of the complexities of balancing nutrient requirement and managing water retention by the soils. Most smallholder farmers rely on the knowledge transfer down generation and are not flexible to explore new technologies that help increase the yields. As observed by Meng *et al* (2021), low yields have been due to poor soils and low soil water holding capacity. It is imperative to understand the views of the farmers on introduction of new technology such as hydrogel use which enhances the integrity of the soil structure and limit the impact of moisture deficits in crop production which translates into increased food security at the household level.

## 1.3 Justification

Small scale farmers have no or little knowledge of new technologies that increase productivity and thus their views on technologies such as hydrogel is limited and would be reluctant to try them. Poor soil structure is common in most communal areas causing low yields, but farmers continue to overwork them and continue to have pathetic yields. These soils have been overused and grazing of crop residues result in less retention of organic material and sustainable alternatives must be introduced. It has been proposed that hydrogels could be used as soil additives to increase the soil's capacity to hold water. The adoption of hydrogel in maize has the potential of increasing yields because of its ability to retain water in the soil and reduce runoff and evaporation. Application of hydrogel technology has not been widely adopted in maize production in the smallholder sector in Zimbabwe and hence the need to understand what farmers feel about it before scaling it up for adoption. As climate change continues, food security has been dwindling because of low productivity of major food crops. Knowledge gained from the assessment of the farmers' perceptions will add up to the existing experience and knowledge to secure food sufficiency.

## 1.4 Objectives

### 1.4.1 Overall objective

To understand the smallholder farmers' perceptions on the adoption of hydrogel technology to improve crop production for food security attainment in Mvuma.

### 1.4.2 Specific objectives

- To ascertain the farmers' perceptions of the rationale behind the use of hydrogel technology in Mvuma.
- To determine the major constraints that are considered by farmers when implementing hydrogel technology.
- To identify and discuss the major obstacles to the hydrogel technology's scaling-up in Mvuma, according to the farmers.
- To assess the hydrogel technology's overall (integrated) success potential in Mvuma.

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## CHAPTER TWO

## 2.0 LITERATURE REVIEW

### 2.1 Introduction

Maize is the staple food crop in Zimbabwe and its production has been generally on the decline in the recent years. This has been due to a lot of problems that affect its production and productivity which include poor agronomic practices caused by lack of knowledge and poor extension services, lack of adequate inputs, erratic climate conditions, poor soil management and low producer prices. Poor judgment and little information that has been generated directly or indirectly on these factors affecting maize production, productivity and profitability seem to be contributing extensively to the problem. It is therefore imperative to understand the underlying causative factors and suggest sustainable solutions like the use of hydrogel to improve the soil conditions that enhances water retention and use by maize.

### 2.2 Production trends of maize in Zimbabwe

Since 1980, maize productivity has been declining based on various studies which resonates that it was once high, and Zimbabwe was considered Southern Africa's breadbasket (Basera, 2015). However, maize productivity has been falling as a result of numerous issues plaguing Zimbabwean agriculture, including disease, pest attacks, economic difficulties, and climate change. Fluctuation with a general decline trend from the 2000s was recorded and was mostly due to lack of productive resources which the new crop of smallholder farmers possessed (Basera and Makate., 2016). In addition, the output and productivity of maize in Zimbabwe were impacted by numerous maize marketing policies. Currently, production of maize in Zimbabwe is estimated at about 1.6 million tonnes (FAO, 2023), slightly below the five-year average. This is a significant increase from the previous year, when maize production was only 908 thousand tonnes, the lowest level in 50 years.

## 2.2 Factors affecting maize production.

### 2.2.1 Climatic conditions

Drought stress induced by climate change has seriously affected maize productivity. All growth stages of maize are affected when exposed to moisture stress (Jaleel *et al*. 2007). Prevalence of water stress at the seedling stage and early vegetative stages causes poor plant population and can cause the seedlings' establishment to fail completely. (Zeid and Nermin 2011). The reproductive growth stage of maize is relatively vulnerable to drought stress; in extreme cases, this could lead to barren ear production. (Yang *et al*. 2004). Cairns *et al.* (2012) reported that yield of maize decreases by 1% under favourable growing conditions and is reduced by 1.7 % under drought stress for every degree that the temperature rises above 30 degrees per day.

### 2.2.2 Knowledge and farmer's experience

Small scale farmers lack appropriate knowledge and skills on good agriculture practices for top notch maize production. Most of the farmers do not follow the standards in using inputs because in general they still adhere to family traditions from generation to generation (Saidah *et al*., 2021). There is also little attention paid to the soil condition as focus will be on the current available inputs mostly received as government support. This greatly reduces yield over the years with gross loss of soil health. The poor soils fail to support good crop growth especially in drought years as they have little water holding potential due to low organic material caused by grazing of crop residue and burning of plant material prior to planting. Furthermore, use of low fertilizer regimes, no liming to correct the soil pH and no use of soil conditioners further aggravate the situation under the maize smallholder sector.

### 2.2.3 Soil conditions in maize growing areas

Fertile soils occur in most large-scale maize producing areas around Zimbabwe, and these include the Vertisol group, Pellustert group, Cambisol group, and Silliatic group (Nyakudya and Stroosnijder, 2015) In Zimbabwe's semi-arid regions, the majority of soils are infertile sands made of basic gneiss (Grant, 1981). These infertile soils include Fersiallitic group and Ferralic Cambisol and Ferralic Arenosol in the FAO classification and Regosol group (Zimbabwean classification) characterised by a deep sandy profile with less than 10% silt plus clay within the upper 2 m. The Lithosol group, which includes soils have a shallow depth of <0.25 m which results in limited agronomic potential (Nyamapfene, 1991). Most smallholder farmers in Zimbabwe are located in semi-arid areas that have soils of low fertility and low water holding capacity. The majority of the maize farmers strive to produce the crop under these soil conditions and always have a yield cap that they fail to break. Coupled with poor weather conditions and poor agronomic practices this leads to unprecedented lower yields ranging from 0.5 to 2 tonnes per hectare (Nyakudya and Stroosnijder, 2015). Soil amendments have been suggested to remedy the failing soil conditions under the smallholder sector such as hydrogels.

### 2.4 Hydrogel technology

Hydrogels according to Peppas (2000) have found a niche as soil conditioners or soil amendment. Soil amendments are used to boost plant nutrient availability, retaining soil moisture, reducing soil drying, preserving soil microbiological activity, and boosting plant nutrient uptake (Garbowski *et al*., 2023). Hydrogels application to soil increases water use efficiency, trap water that would have otherwise leached out of the root zone, controls the release of agro-chemicals, used as a soil microbial inoculant and used to improve soil water properties (Andry *et al*., 2009; Islam et al., 2011).

### 2.5 Potential use of hydrogel in improving soil water retention and maize productivity.

Hydrogels absorb a significant amount of water, about 200–300 times its weight (Kalhapure *et al*., 2016). Thus, according to Jamnongkan and Kaewpirom (2010), hydrogel helps to retain moisture for a longer period of time and helps overcome dry spells. According to Roy et al. (2019), the application of hydrogel promoted wheat germination by 22% by increasing moisture availability in the surface soil layer. Hydrogel was applied at a rate of 5 kg/ha in a field of fodder sorghum and this increased soil moisture content of soil at different depths throughout the crop's life cycle (Dass *et al*., 2013).

According to Akhter *et al*. (2004), a maize field was applied hydrogel and moisture was retained at field capacity and withdrawal of water delayed wilting stage of maize seedlings by 4-5 days. Many researchers have observed that the use of hydrogel has a positive effect on yield of numerous crops. Studies on wheat (Dar and Ram, 2017), pearl millet (Singh, 2012), maize and soyabeans (Moazen *et al*., 2009; Khadem *et al*., 2010) have shown the potential of improving yield when hydrogel was applied either as a soil amendment or seed dresser.

### 2.6 Impact of hydrogel on sustainable agriculture and food security

Hydrogels have vast potential to play a crucial role in sustainable agriculture and bring about food security. Application of hydrogel improves soil drainage; increases water use efficiency and improve water retention by different soil types. They are able to enhance nutrient retention, support plant growth and performance in limited irrigation environments. Soil permeability is increased when hydrogel is applied to the soil and this decreases soil compaction. Soil erosion and leaching of fertilizer is reduced when hydrogel is applied. All these guarantees improved performance of many crops including maize which is the main staple crop in the Sub Sahara African region. Food security will be attained with the increased use of the hydrogel technology in the marginal areas with poor infertile soils and erratic climate conditions not supporting good crop growth. Technological developments of all kinds have promoted the use of polysaccharide hydrogels because of their many benefits, chief among them being the sustainability because the material is biodegradable and organic (Oladosu *et al.*, 2022). Hydrogels have proven to be an effective tool for protecting soil and enhancing crop yield in the face of moisture constraints, thereby enhancing the food security of numerous impoverished communities.

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# CHAPTER THREE

## 3.0 IMPACT OF HYDROGEL ON MAIZE PERFORMANCE UNDER DRYLAND CONDITIONS

### Abstract

Climate change has caused unprecedented food shortages due to moisture shortages. Hydrogels are known for enhancing the water-holding properties of soils and thereby improving water availability to crops. This reduces the impact of the droughts especially in the Southern African region. This experiment was conducted to evaluate the impact of four treatments which were hydrogel with mulch, hydrogel alone, mulch alone and no hydrogel and no mulch as one treatment on maize growth under rainfed conditions. Maize variety, Valley Seeds PAN53 was tested under these treatments in a Randomized Complete Block Design. Plant growth parameters quantified were number of days to 50% germination, number of days to physiological maturity, plant height in cm, number of cobs per plant and yield per hectare. A significant difference was observed on physiological maturity, plant height and yield among the treatments. Hydrogel with mulch resulted in more days to maturity (128 days), taller plants (187cm) and higher yield (3t/ha). This treatment was comparable to hydrogel only on the yield obtained. Therefore, it was concluded that hydrogel with mulch could enhance the growth of maize effectively under dryland conditions when moisture is limiting.

### 3.1 Introduction

In recent years, Southern Africa has been experiencing devastating droughts associated with climate change and food production is heavily threatened due to this (Falkenmark, 2013). The consequences of the climate change on agricultural production are getting much worse and this has been experienced in the 2023/24 season which had the El Nino induced dry spell that caused heavy crop failure. The dry spell caused a considerable hydrologic imbalance along with depletion of soil moisture, crop damage, and yield reduction which calls for critical well though solutions to avert food shortages. Enhancing water retention in the soil is the key to combat the adverse impact of drought on crop production. Rawls *et al*. (2013) envisaged that soil water retention was the soil's ability to hold water in its pores and not allow it to flow down the soil profile due to gravity and become unavailable to the plants or allow it to be lost due to the evaporative pressure exerted by the sun.  Soil enhancers play a critical role to improve water retention. Soil organic matter have been considered as a solution to increase the water holding capacity especially in sandy soils (Rasadaree *et al*., 2021). The limitation of organic material has always been its unavailability due to livestock grazing it after.  the rainy seasons. This calls for alternatives that equally solve the complexities surrounding organic matter unavailability and hydrogel have been suggested. These are known for enhancing the water-holding properties of soils and have been applied in agriculture with varying success. Therefore, the objective of this study was to evaluate the effectiveness of hydrogel to enhance water holding capacity and improve maize productivity in sandy soils under rain-fed conditions.

## 3.2 Materials and Method

### 3.2.1 Description of Study Area

The study area of Mvuma was used in the study. Mvuma was selected because the area experience moisture stress conditions coupled with sandy soils that have low water holding capacity. Mvuma receives 650–850 mm yearly rainfall, high temperatures ranging from 28 to 32$^{o}$C. The main crops grown in the area are maize, soyabeans, and tobacco.

### 3.2.2 Field performance of Hydrogel

As a first step the hydrogel technology was introduced and made known to the farmers through demonstrations of hydrogel against usual practice of moisture management which was mulching in maize plots established in the farming areas of Mvuma. The maize variety used was Valley Seeds PAN53. The demonstration was done in a randomised complete design with 4 replications. The treatment structure used is shown in Table 3.1. The measurements taken were number of days to 50% to germination, number of days to physiological maturity, plant height in cm, number of cobs, and grain weight. Farmer focus groups were carried out to assess the effectiveness of this demonstration at four various stages of the crop.

**Table 3.1 Treatment structure used in the demonstration.**

| Treament | Treatment description |
|---|---|
| Treatment 1 | Hydrogel and mulch |
| Treatment 2 | Hydrogel with no mulch |
| Treatment 3 | Mulch only |
| Treatment 4 | No hydrogel and mulch |

### 3.5 Data analysis

All measured quantitative parameters were analysed using the GenStat 18th package. The means with significance differences were separated using the Fischer Protected Least Significance Differences at 5% significant level.

### 3.6. Results and Discussion

#### 3.6.1 Field performance of Hydrogel

There was significant difference at $P<0.001$ on the number of days to physiological maturity, plant height and yield of the maize because of the treatment effect as shown in table 4.1. Results that are similar were reported by Rahman *et al*. (2001), which showed there was significant difference on wheat productivity when grown in hydrogel-loaded fertilizer soils. Hydrogel with mulch increased the duration to maturity to 128 days compared to the treatment that had no mulch and hydrogel which had forced maturity of 114 days. The maize in the plots with hydrogel and mulch grew taller to 187cm whilst the treatment where no hydrogel and mulch was applied had the shortest plants at 168cm. Similar results were observed by Rasaderee *et al*. (2021) who indicated that maize grown in hydrogel mixed with urea grew taller. The subsequent yield was more in the hydrogel and mulch combination with a yield of 3 tonnes per hectare and the no mulch and hydrogel treatment produced a crop with a yield of 1.4 tonnes per hectare. Weraduwage *et al*., 2015 also reported similar results *in Arabidopsis thaliana* when hydrogel was incorporated into the soil.

**Table 3.2 Effect of the hydrogel technology on maize performance**

| **Treatment** | **Number of Days to 50% to germination** | **Number of Days to physiological maturity** | **Plant height in (cm)** | **Number of cobs per plant** | **Yield (t/ha)** |
|---|---|---|---|---|---|
| Hydrogel and mulch | 6 | 128c | 187c | 2 | 3b |
| Hydrogel with no mulch | 7 | 124b | 173b | 2 | 2.8b |
| Mulch only | 7 | 116ab | 172ab | 1 | 2.2ab |
| No hydrogel and mulch | 8 | 114a | 168a | 1 | 1.4a |
| Mean | 7 | 121 | 175 | 2 | 2.4 |
| P-Value | 0.568 | 0.031 | 0.045 | 0.678 | 0.039 |
| CV% | 23 | 21 | 28 | 12 | 18 |

*Figures with same letters were not significantly different at 5% significance level.*

*CV – coefficient of variation*

### 3.7 Conclusion

The study found that firstly, the hydrogel technology especially in combination with mulch performed better than where no hydrogel and mulch was used under the dry conditions that was experienced during the season induced by the El Nino phenomenon.

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**CHAPTER 4**

# 4.0 FARMERS' PERCEPTIONS OF CONSTRAINTS FOR HYDROGEL ADOPTION

**Abstract**

Food insecurity in Southern Africa is a major concern and this has been due to low crop productivity that has been attributed to the droughts experienced in the region due to climate change. A lot of innovation has brought about many agricultural technologies that have potential to improve agricultural productivity and food security in many economies but with relatively little success in the Southern Africa region due to different perceptions of farmers on these technologies. Every time a new technology is introduced, smallholder farmers frequently face problems with continuity because of various barriers to adoption and subsequent scaling-up. Using a case study methodology, this research employs ScalA method (Scaling-up Assessment) and four structured focus groups of sixty smallholder farmers in total to gather their opinions on the potential for perpetual assumption, adoption barriers, and the widespread scaling-up of four technologies (using hydrogel and mulch, hydrogel alone, mulch alone, hydrogel and no mulch, and no hydrogel and no mulch) in Mvuma. The findings of the study were that farmers perceived the use of hydrogel to be sustainable with possible high adoption rate and scaling up. The most significant constraints for technology adoption experienced by the farmers are lack of technical and physical inputs, lack of know-how and shortage of marketing facilities. The farmers' perspectives serve as a starting point for a discussion of specific agricultural technology and partially explain why Mvuma lacks certain technologies.

## 4.1. Introduction

Food insecurity issues have become more complex due to factors such as population growth, climate change, low yields of important crops, and a lack of progress in crop improvement. (Otsuka and Kijima, 2010). The development of the rural areas agricultural sector and the assurance of food security can be greatly enhanced by the effective adoption and expansion of technologies that are sustainable (Kilima *et al.*, 2013). A lot of innovation have brought about many agricultural technologies that have potential to improve productivity in agriculture and food security in many economies but with relatively little success in the

Southern Africa region due to different perceptions of farmers on these technologies. Hydrogel technology is one of those trending solutions to water deficiencies caused by the changing weather. The technology enhances water retention according to Rasadaree (2021) and improve crop productivity in sandy soils and under reduced rain fed conditions. However, uptake of this technology in the Southern African region has been met with skepticism as there is general belief that the hydrogel will alter the soil status. A lot of constraints for adoption and scaling-up are faced in different areas because adoption processes are highly localized (Westermann *et al*. 2018). The views of farmers also affect their adoption and scaling-up decisions, as demonstrated by a number of writers. (Sinjaa *et al*. 2004; Mwangi *et al*. 2015). Therefore, before introduction, promotion and implementation of agricultural technology there is need to assess its suitability, possible continuation, interest by farmers before it is widely used.

## 4.2 Materials and Method

### 4.2.1. Assessment Method

This research employed Sieber et al.'s scaling-up assessment (ScalA) method. 2015), enabling a comprehensive, methodical evaluation of the three elements: adoption, scaling-up and sustainability. With little financial outlay and time commitment, the tool makes it easier to evaluate agricultural technologies quickly. Farmers are asked to respond to closed-ended questions using the tool by expressing their observations and preferences. The analysis is done in multiple steps. Firstly, discussions were held in farmer focus groups with sixty farmers at four various developmental stages of the maize at the demonstration site to establish what farmers think of the technology. It was anticipated that the farmers' perspectives on hydrogel technology produced varied results depending on the environment.

The sustainability, uptake, and expansion and overall success potential of hydrogel technology were assessed as follows.

1. Sustainability: Appendix 1 scores nine sustainability factors: social, ecological, and economic.

2. Adoption: Appendix 2 scores eight adoption factors.

3. 23 scaling-up factors are scored (see Appendix 3) in this process.

4. Combined evaluation of the sustainability factors, adoption factors, and scaling-up scores indicates the overall success potential (Seiber *et al*., 2015).

The hydrogel technology's social, economic, and ecological contributions were represented by the nine sustainability factors, each of which the farmers gave a score of 0 or 1. Whether or not the sustainability factor is satisfied (1) or not (0) was indicated by the sustainability scores. The farmers' scores for each of the eight adoption criteria represented the initial resource which are social, economic, ecological, and institutional resources required for the initial adoption of hydrogel technology. It was believed that the technology required either low, medium, or high resource inputs. On a scale of 0 to 3, the initial resource requirements were used to determine the adoption scores. A score of 0 meant the adoption factor irrelevant. A score of 1 meant low requirement of resource. A score of 2 meant medium resource requirement. A score of 3 meant high resource requirement.

The farmers also scored the 22 factors for scaling-up, which stood for the institutional, social, economic and ecological resources needed for more farmers to continue using hydrogel technology. It was felt that the technology's scaling-up factors were either well fulfilled, medium fulfilled, or partially fulfilled. On a scale from 0 to 6, the scaling-up scores represented people's perceptions of the technology. In this case, a score of 0 meant the scaling-up factor was irrelevant. A score of 1-2 meant high scaling-up factor which means well fulfilled. A score of 3-4 meant medium scaling-up factors meaning averagely fulfilled. A score of 5-6 meant low or partially fulfilled.

The combination of the three evaluation scores on factors for sustainability, factors for adoption, and scaling-up factors produced a result that showed the overall success potential of hydrogel technology.

### 4.2.2. Research Design

In order to gain insight into farmers' perspectives on the sustainability, uptake, and expansion of hydrogel technology, the research employed a random selection process to select representative farmers from Mvuma farming areas. A group of sixty smallholder farmers from Mvuma were chosen at random to test the technology. Fourteen to fifteen farmers participated in each of the four focus group sessions.

### 4.2.3 Data analysis

The qualitative data with categorical predictor variables were analyzed using Statistical Package for Social Sciences (SPSS) package.

## 4.3 Results and Discussion

### 4. 3. 1 Perceptions of Sustainability by Farmers:

Figure 4.1 provides a summary of the nine sustainability factors that farmers scored for every technology under consideration. The results indicated that the farmers considered the use of the hydrogel combined with mulch and hydrogel only as a tool to maximise water retention to increase crop productivity. The two technologies with hydrogel were noted to be sustainable and had no negative impact on the agricultural systems in Mvuma. The farmer scores were calculated basing on the average of results from 4 focus group discussion.

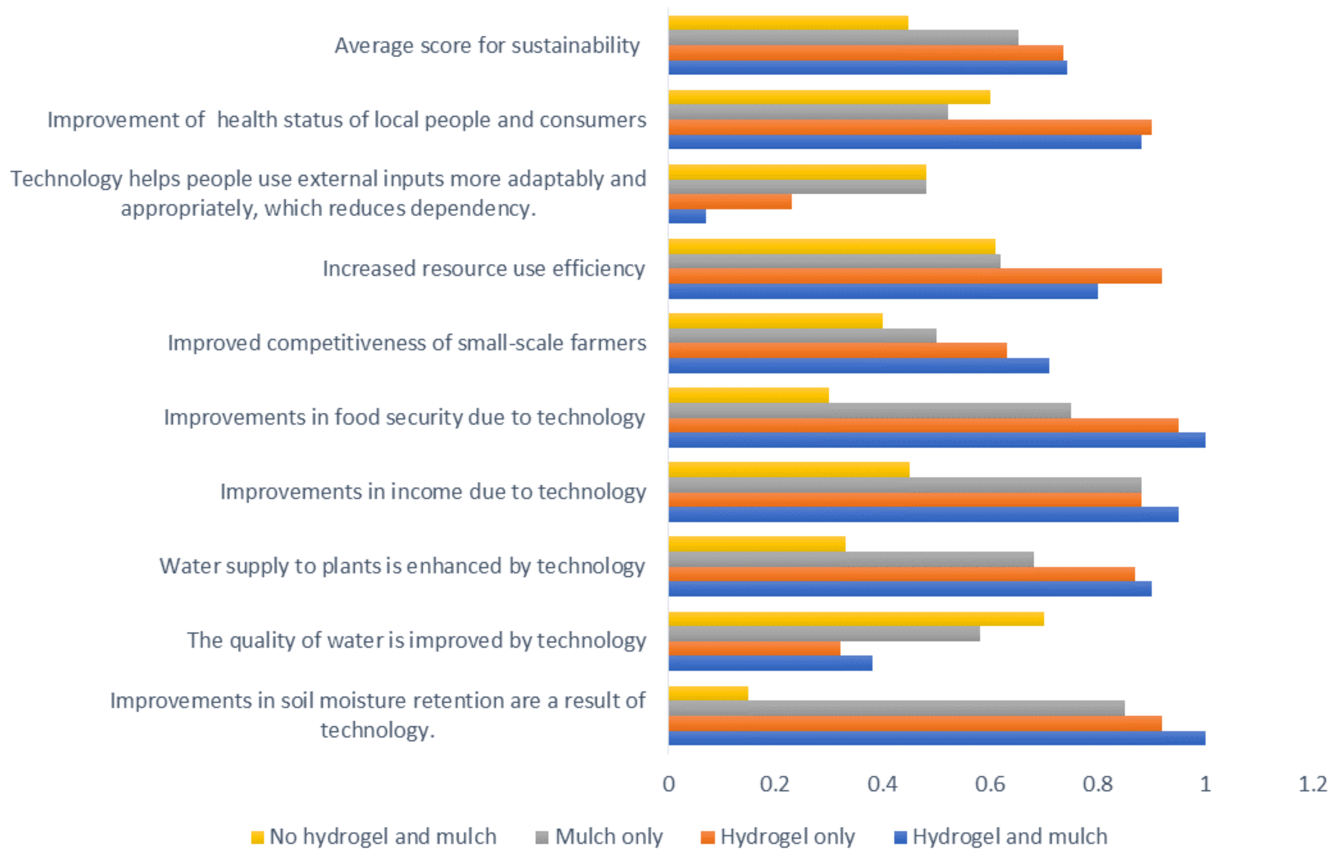


**Figure 4.1.** Farmers' scores for the four technologies and 9 sustainability factors overview

#### 4.3.2. Perception of Farmers on Constraints for Adoption

Figure 4.2 shows the factors for adoption and scores by farmers for each technology. All of the adoption factors were deemed relevant by the farmers and of the 8, the main obstacles to the farmers' adoption of the technologies were identified as marketing infrastructure, expertise, and physical and technical inputs.

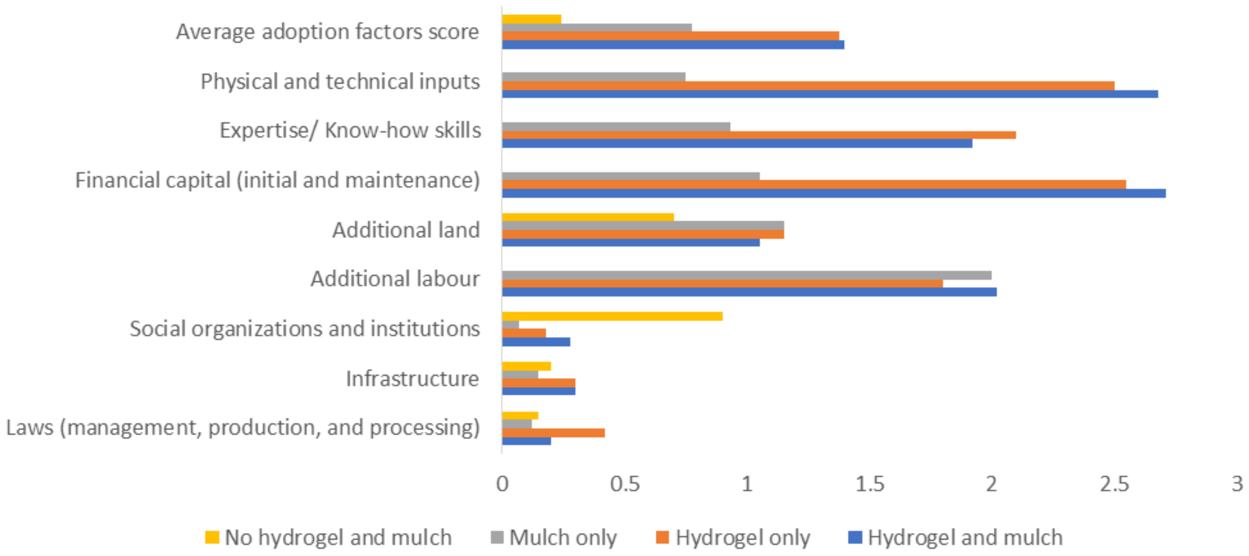


**Figure 4.2.** Overview of 8 Factors to adoption and scores by farmers for the four technologies

#### 4.3.3 Perception of farmers on Scaling-up Constraints

Figure 4.3 showed a summary of scaling-up factors and farmers scores for each technology, compiled during the four focus group discussions. Of the 23 scaling-up factors that were considered in the study, the farmers found 20 to be relevant. Of the 20, the farmers found that the affordability of the technology to the farmers or if they can carry the cost of the technology, whether the technology is easy to comprehend and use, the benefits of the technology if they are easily observable, if the economic risk for farmers is comparatively low, if the technology help the farmer maintain their independence and self-reliance.

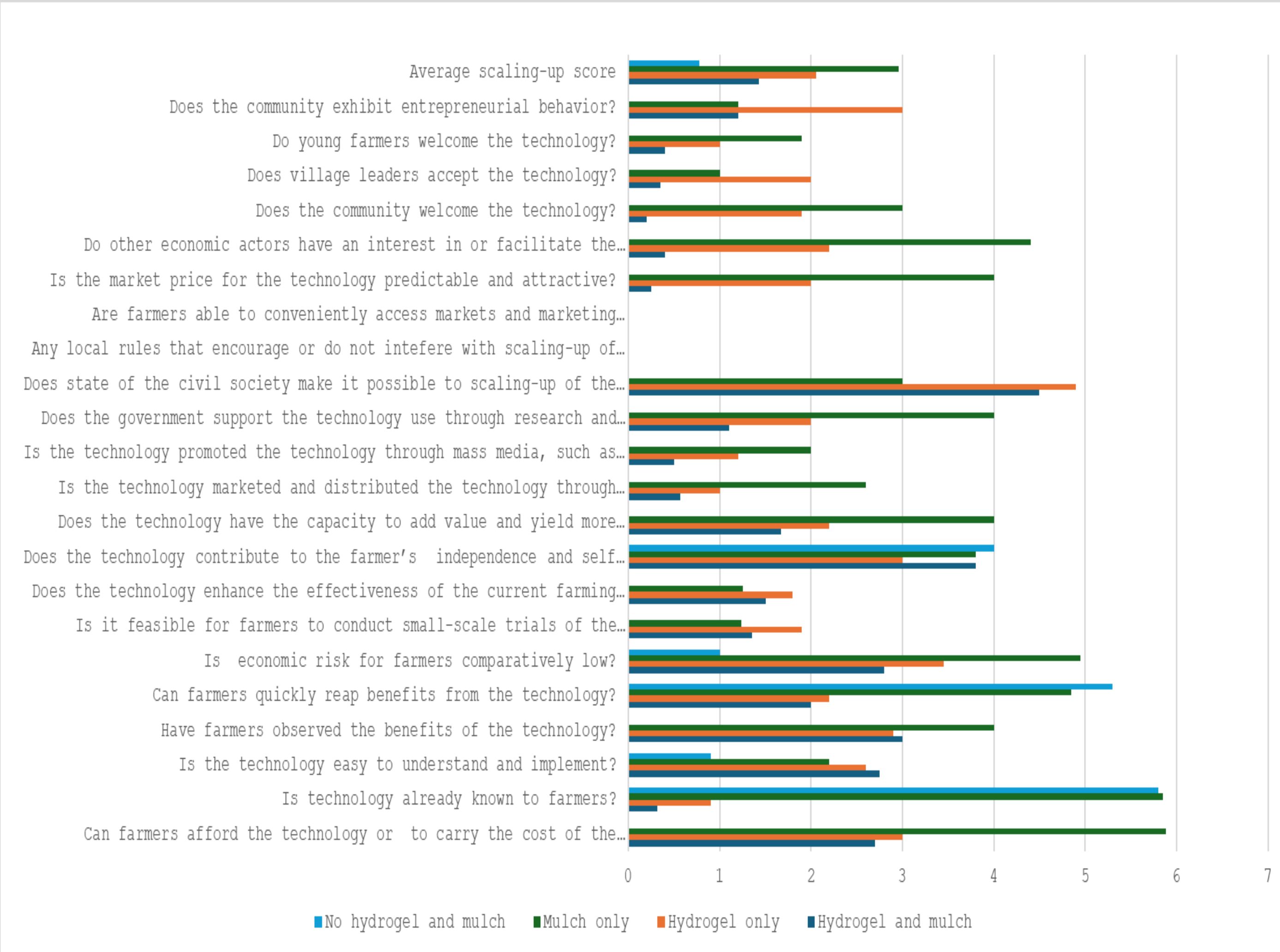


**Fig 4.3** Farmer scores on Scaling up factors

### 4.3.4. Overview of Farmer Perceptions

The results shown in Table 4.1 indicated that both the use of hydrogel in combination with mulch and hydrogel or mulch only were viewed to be most likely to be favoured by farmers and widely used in agricultural activities because of the high level of sustainability, and medium to high possible adoption.

**Table 4.1. The farmers' perceptions of sustainability factors, factors for adoption, and scaling-up factors potential overall results.**

| ScalA Assessment | Hydrogel and mulch | Hydrogel only | Mulch only | No hydrogel and mulch |
|---|---|---|---|---|
| Sustainability assessment | Sustainable | Sustainable | Sustainable | Low |
| Adoption assessment | Medium-low | Medium-high | Medium-high | Low |
| Scaling-up assessment | High | High | Low | Low |
| Overall success potential | High | High | Medium | Low |

### 4.4 Conclusion

Farmers were able to establish the technologies that they were most likely to uptake and widely use after identifying the limitations each technology possessed. Farmers' impressions closely mirrored other studies' findings, which justified further extensive research based on representative farmer perception data. The farmers in Mvuma noted that the use of hydrogel either alone or in combination with mulch was sustainable had little limitations associated with them in adoption and on agricultural systems and broadening their use to improve maize productivity. They however insinuated that the problem of low agricultural productivity and lack of immediate tangible benefits were the reasons that limited the adoption and expansion or scaling-up the agricultural technologies, specifically, use of hydrogel in the drought situation being encountered in recent years.

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# CHAPTER FIVE

# 5.0 GENERAL DISCUSSION

## 5.1. Field performance of hydrogel

The study revealed that the hydrogel technology improved crop performance in a dry environment which was so apparent in the season due to the drought induced by El Nino. The performance of the technology was further amplified by addition of mulch as more positive results were obtained from the treatment. Hydrogel was observed to be a technology that increase soil water retention capacity, promote plant germination and growth in soils with extreme conditions, especially when there is no water available (Dimitri et al., 2013; Das and Ghosh, 2022).

The results of this study agreed with what Gehring (1980) observed that hydrogels had beneficial effect on plant growth under low moisture environment. Hydrogels were observed to create a water reserve in the soil, which can increase the efficiency of plant water uptake (Huttermann *et al.,* 1999). Plants became more resilient because water was available for longer periods of time. Kaur *et al*. (2023), reviewed the prospects of using the hydrogel technology over varying soil and climate conditions and concluded that it indeed provided drought tolerance to crops, reserve critical nutrients and prevented transplanting shock of plants. They also observed hydrogel to be biodegradable and to have environmental compatibility properties. This was also the same case in this study as crop performance improved greatly and high yields obtained. On further visual assessment, the hydrogel completely dissipated in the soil without causing any environmental issues. Mulch also improved water retention to an extent but did better in the presence of hydrogel. The only challenge with mulch is on its aggregation into the fields and maintaining it before the planting season due livestock issues.

## 5.2 Farmers' Perceptions of Sustainability

Each of the technologies except for the system that had no hydrogel and mulch meets the minimal standards for sustainability and the prerequisites for further adoption and expansion (scaling-up). The technologies were believed to increase farmers' income, enhance food security, increase small-scale farmers' competitiveness, and improve efficiency of resources. Mulching have already been adopted in practices like Pfumvudza and is already popular but the only challenge it still pose is the issue of finding enough vegetation cover and livestock grazing on it prior to the planting season. Inclusion of hydrogel as a moisture retention technology proved to increase crop productivity and thus was perceived to be easily adopted.

The study discovered that not all technologies contributed to every sustainability element in the same way, indicating that farmers saw the contributions of each technology to sustainability as varied and occasionally unique. A study carried by Otsuka and Muraoka (2017) concluded that introduction of agricultural technologies increased yields of staple crops, such as maize which was experiencing unprecedented water shortage in some years due to climate change. Voortman (2013), argued that the technology (use of hydrogel) failed in SSA because there was little information on the promoted technologies. Farmers in the research area believed that the most applicable and sustainable technology was the application of hydrogel in combination with mulch. Other authors concluded similarly. Pirzada *et a*l (2020) highlights the contributions of biodegradable matrices to crop protection, enhanced production, food security, and adaptive capacity. Banedjschafie and Durner (2015) also observed the same positive properties of the technology especially in sandy soils. In line with the farmers' perspectives, numerous writers discovered that the technologies that were being studied were sustainable and relevant under drought conditions (Bai *et al*, 2013; Mudhanganyi *et al*, 2018; Sobrino and Barbosa, 2020). These authors also stress that, rather than just being implemented from one area to another, the adoption of hydrogel may need to be enhanced and tailored to the local situation in order to guarantee long-term sustainability and food security.

According to the farmers, the technology met the bare minimal sustainability requirements and was applicable to the research region. The findings suggest that combining many technologies into one integrated package would enhance sustainability characteristics more than applying each technology separately.

## 5.3. Perception of Farmers on Constraints for Adoption

According to the ScalA assessment, farmers generally view the use of hydrogel in combination with mulch and hydrogel alone as moderately restrictive, whereas they view the use of mulch alone as having fewer limits.

This indicated that farmers expected the usage of mulch to be relatively easy to adopt, while hydrogel with mulch or hydrogel alone is expected to have a rather difficult adoption pathway. The farmers highlighted that use of hydrogel required high technical and physical inputs through the focal group discussions held. They also realized that the usage of hydrogel might require a lot of knowledge and be heavily reliant on the market facilities that farmers have access to. Use of mulch was identified to be constrained on the sourcing of the vegetation material and maintaining them in the field prior to the planting season. They also projected that the usage of hydrogel might need for improved infrastructure, labor, financial resources, and the backing of institutions and social groups.

The farmers remarked that other economic actors do not provide support for the use of the technology, and that occasionally the current farming system is not suitable to use the technology and that the technology is for those with high expertise. A common explanation for agricultural technology studies' failure is a deficiency of physical and technical input. Sanchez (2015) discussed that limited inputs and high fixed costs as the reasons that are largely attributed to low technology adoption. Mugisha and Diiro (2010) in their study highlighted that access to credit relaxed income problems for farmers, as this provided them the ability to procure inputs which eventually led to high productivity. In addition, Mugisha and Diiro's (2010) study discovered that credit access eased farmers' income restrictions and gave them access to procure key supplies, which ultimately resulted in high productivity. Additional research offered additional explanations for the technology's poor uptake and use, including its unavailability, credit restrictions, and expensive transaction fees (Otsuka and Muraoka, 2017). All of which is related to the physical and technical input requirements for adoption.

We discovered that one of the main barriers to adoption identified by the farmers is absence of marketing facilities. The farmers observed that there was a lack of a steady market and marketing infrastructure for the purchase or sale of products and inputs like hydrogel. When they are present, they are difficult to get to (Amjath-Babu *et al*. 2016). Suri (2011) indicated that a practical way to increase adoption rates would be to eliminate barriers to supply and infrastructure such as lengthy travel times to input retailers.

A significant barrier to the technology's adoption was also mentioned: a lack of expertise and know-how. According to the study farmers, they neither had prior experience with the technology's use nor have access to the information they needed to successfully apply the hydrogel technology. They also noted restrictions brought about by the difficult-to-understand complexity of the material at hand. One of the main obstacles to the adoption of agricultural technologies is frequently mentioned is lack of agricultural information (Matsumoto *et al*. 2013). According to a report by Greenberg and Jones (2015) new technologies are not always bad. Rather, farmers need to be provided with a comprehensive information that outlines advantages and disadvantages of various technologies so that they are able to make informed decisions.

### 5.4. Farmers' Views on Constraints for Scaling Up

According to the study, a significant barrier to scaling up a technology is the narrow view of its added value (benefits) in relation to a farmer's livelihood, autonomy, and reputation. Over time, farmers shown a lower propensity to adopt technology whose benefits they cannot fully comprehend or perceive.

Kahimba and colleagues (2014) perceived that added value, to be one of the most crucial scaling up elements to be taken into account drives a farmer's motivation to embrace and scale-up an agricultural technology, Another study by Mustapha (2017) discovered that information about the application and added value (benefits) of agricultural technologies was more effectively obtained from demonstration plots, input providers, and extension agents, which improved the uptake of these technologies.

The farmers discovered that a significant barrier to scaling up was the absence of consistent and fair producer prices in the study area, which is consistent with our adoption results.

According to a study by Pingali *et.al* (1988) it concluded that quick beneficiation from a technology was the main determinant of uptake of a technology. In a study by Singh (2012), it was observed that hydrogel quickly gave noticeable results on plant performance under water stressing conditions and subsequently gave better yields due to the increased water use efficiency. This gave farmers enough confidence to want to adopt and scale up the technology besides other immediate constraints. In addition to the amount of time and resources invested as a result of the adoption of the technologies, a study conducted in 2013 by Hartmann and colleagues found that the absence of immediate, measurable productivity has a detrimental effect on scaling up agricultural technologies.

The farmers noted that access to both physical and technological inputs such as equipment, animal draft power, and the hydrogel material needed to complete the scaling-up was extremely important. Similar to this, Sanchez (2015) discovered that a key barrier preventing most Sub-Saharan African farmers from yielding more than 1 t/ha of maize in arid environments is a lack of options for accessing inputs, such as nutrient enhancers and soil conditioners. This, in turn, limits the success of agricultural technologies.

According to a previous study by Mosley (1994), scaling up important crops like cereals and groundnuts is accomplished by allocating key inputs like hybrid seeds, credit facilities, and soil nutrition and condition enhancers. These inputs are necessary for increased productivity during drought conditions.

The assessment for scaling-up identifies a number of additional requirements for scaling-up to be significant. Farmers discover that in order for agricultural technologies like the use of hydrogel to be widely adopted, there are a few key factors that must come into play. These factors include training, the technology's ease of use and appeal among young people, its capacity to support farmers' autonomy, and the financial risk the technology poses to them. Mosley (1994) argued that the income of farmers, their access to finance, and the ratio of input to product prices all have a significant role in determining the investments that enable the

successful adoption of technologies.

### 5.5. Overall Farmer Perceptions

The final findings demonstrate the connections between farmers' views of sustainability, the resources needed for adoption, and the expansion of technologies being studied. Farmers view the adoption, sustainability, and scaling up of agricultural innovations as collaborative processes rather than discrete, clearly demarcated procedures. Furthermore, the way one is perceived has a big influence on how the other is perceived, therefore studying the adoption of agricultural technologies requires a thorough, integrated approach. This study found (Table 4.2) that hydrogel use either in combination with mulch or not was perceived by the farmers that it is highly sustainable although it had low to medium or medium to high possibility of adoption because of some constraining factors. However, the technology had high chance of being scaled-up as compared to using mulch alone or not even using the hydrogel and mulch. This is because the farmers expected a comparatively greater number of adoption barriers for the technologies. This shows that, despite the fact that the use of mulch and hydrogel is highly desirable for sustained productivity, the first difficulties faced farmers may result in a adoption rate that is low, which could have a detrimental effect on the process of scaling up, even though the data seem to imply otherwise.

Use of mulch only or no use of the hydrogel and mulch had low possibility of scaling up due to the constraints raised by farmers of gathering vegetative matter and maintaining them during the pre-planting season and that it was labour intensive. In the same vein not using the mulch or hydrogel greatly exposed the crop to the water stress conditions causing them to dry before they bear any harvest. The research revealed that farmers' inclination to adopt new technologies was influenced by their perspectives on sustainability, barriers for adoption, and scaling up challenges related to agricultural technology. The farmer will be less likely to adopt the technology and vice versa if they believe the uptake process is relatively difficult and that there are several obstacles to adoption and scaling up. These obstacles could include concerns about the technology's sustainability and other issues. Since farmers are the key people in agricultural productivity, it is crucial to comprehend the barriers to hydrogel technology adoption as they are seen and experienced by farmers in order to provide light on some of the causes for the poor uptake.

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# CHAPTER SIX

# 6.0 GENERAL CONCLUSIONS AND RECOMMENDATIONS

## 6.1. Conclusions

The study found that firstly, the hydrogel technology especially in combination with mulch performed better than where no hydrogel and mulch was used under the dry conditions that was experienced during the season induced by the El Nino phenomenon. Secondly, farmers used a complex set of processes to understand and explain the uptake process of a technology and are effective at using the ScalA framework as a valuation tool. The results and valuation reflect that the integrated approach to assess the sustainability, adoption, and scaling-up of hydrogel technology was comprehensive and reflective of the complexities experienced by the farmers.

Farmers' perceptions closely match the results of other studies, thus, providing a rationale for broader investigations stemming from representative data of farmer perceptions. The farmers in Mvuma perceived that the issue of low agricultural productivity and lack of immediate tangible benefits were the reasons of limited adoption and scaling-up the agricultural technologies, specifically, use of hydrogel in the drought situation being encountered in recent years, rather than the issues of unsuitability (not sustainable) and irrelevance of the technology.

Interestingly, the farmers experience the issue of affordability, technical know-how, technical and physical input, and if the use of hydrogel will fit into the existing agricultural systems as major constraints for both adoption and scaling-up. Overall, the farmers indicated the readiness to adopt and scale up the hydrogel technology as a mitigation against droughts caused by the climate change phenomenon.

## 6.2 Recommendations

Agriculture and policy interventions must therefore first and foremost address the lack of technical and physical inputs the farmers anticipate, along with providing better marketing facilities. Other constraints indicate that agriculture and policy interventions may better promote knowledge dissemination regarding agricultural technologies and emphasis more on the added value of technologies for food and livelihood security. It was then recommended that farmers be equipped with adequate knowledge on the use of hydrogel, its benefit especially when used in combination with mulch. More localized cases that shed light on farmer level experiences should be explored as they are important to complement information generated from smaller surveys as they can capture socially differentiated experiences and explore locally relevant factors significant for the success of the technology.

## 7.0 APPENDIX

**Appendix 1: Sustainability: Summary of every sustainable element that was considered during the investigation.**

| No. | Elements of Sustainability |
|---|---|
| 1 | Hydrogel technology leads to soil moisture retention improvements |
| 2 | Hydrogel technology have positive impacts on the quality of the water |
| 3 | Hydrogel technology enhances  water supply to plants |
| 4 | Hydrogel technology leads to improvements in income |
| 5 | Hydrogel technology leads to improvements in food security |
| 6 | Hydrogel technology increases small-scale farmers’ competitiveness |
| 7 | Hydrogel technology increases resource use efficiency |
| 8 | Hydrogel technology leads to a modified or sufficient use of outside resources to reduce reliance |
| 9 | Hydrogel technology improves the health status of local people and consumers |

**Appendix 2. Adoption: Overview of all the factors of adoption included in the analysis.**

| No. | Adoption Factors |
|---|---|
| 1 | Laws (management, production, and processing) |
| 2 | Infrastructure |
| 3 | Social organizations and institutions |
| 4 | Additional labour |
| 5 | Additional land |
| 6 | Financial capital (initial and maintenance) |
| 7 | Know-how skills |
| 8 | Technical and physical inputs |

**Appendix 3: Scaling-Up Factors**

| | Factors for Scaling-Up |
|---|---|
| 1 | Can farmers afford the technology or to carry the cost of the technology? |
| 2 | Is the technology familiar? |
| 3 | Is the technology easy to comprehend and use? |
| 4 | Have farmers observed the benefits of the technology? |
| 5 | Are there quick benefits from the technology? |
| 6 | Is there low economic risk for farmers? |
| 7 | Is it feasible to conduct small-scale trials of the technology to confirm its effects? |
| 8 | Does the technology enhance the effectiveness of the current farming system and does it fit into it? |
| 9 | Is technology contributing to the farmer's independence and self-reliance? |
| 10 | Is technology having the capacity to add value and yield more benefits? |
| 11 | Is the technology marketed and distributed the technology through efficient and successful channels? |
| 12 | Does mass media promote the technology through the radio, TV, or newspapers? |
| 13 | Is government supporting hydrogel technology use through research and extension? |
| 14 | Is the civil society making it possible to scaling up the technology locally, regionally or internationally? |

| | |
|---|---|
| 15 | Any local rules that encourage or do not interfere with scaling-up of hydrogel technology? |
| 16 | Are farmers able to conveniently access markets and marketing facilities? |
| 17 | Is the market price for the technology predictable and attractive? |
| 18 | Do other economic actors have an interest in or facilitate the use of hydrogel technology? |
| 19 | Does the community welcome hydrogel technology? |
| 20 | Do village leaders accept the hydrogel technology? |
| 21 | Do young farmers welcome the hydrogel technology? |
| 22 | Does the community exhibit entrepreneurial behaviour? |