INVESTIGATING FACTORS CONTRIBUTING TO THE UNDERPERFORMANCE OF MBAHELA IRRIGATION SCHEME THAT BENEFITTED FROM THE REVITALISATION OF SMALLHOLDER IRRIGATION SCHEMES PROGRAMME

by

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Declaration

I, Mosatiwa Brenda Mongwai, student number 11532610, hereby declare that this research for Master of Science in Agriculture in Agricultural Mechanization (AGMARE) submitted to the Department of Agricultural and Rural Engineering (DARE) in the Faculty of Science, Engineering and Agriculture at the University of Venda (UNIVEN), has not been previously submitted for a degree at this or any other institution, and that it is my own work in design and execution and that all reference material contained therein has been duly acknowledged.

Signature……………….. **Date**…05/03/2026…………….

Dedication

I dedicate this study to my children, Mutshinyalo M and Mutshinyalo T, as an encouragement for them to further their studies and strive for academic success in the future. I also dedicate this study to my mother, who never had the opportunity to attend school, yet strongly believed that education is the key to success. I am who I am today because of her unwavering support and tireless efforts to ensure that I had the opportunity to study at university and obtain my first degree.

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Abstract

The Limpopo Department of Agriculture revitalised several irrigation schemes in Limpopo Province between 2001 and 2008; however, most of them later collapsed again, while others are underutilised. Revitalisation of the collapsed and underutilised irrigation schemes was necessary because of the importance of irrigation schemes for socio-economic development, food security, and poverty alleviation. The study investigated the socio-economic and biophysical factors that cause smallholder irrigation schemes (SIS) to fail, with a view to recommending mitigation strategies and best practices that ensure full operation and sustainability of the irrigation schemes. The irrigation schemes failed to maintain the commercial farming standards set during the Revitalisation of Smallholder Irrigation Schemes (RESIS) programme due to several factors, such as lack of training, poor access to finance and markets, and division of the irrigation schemes back into individual plots. The study also investigated water losses from the water supply and infield canals. Poor water conveyance efficiency is also thought to have contributed to the failure of the irrigation schemes. The study was conducted at the Mbahela Irrigation Scheme. Two sets of data, experimental and questionnaire data, were collected for this study. Researcher-administered questionnaires were presented to 61 individual plot-holders at the Mbahela Irrigation Scheme using their preferred languages. Data obtained through questionnaire administration was analysed using descriptive statistics and a logistic regression model. Experimental data were collected using water flow meters. Water flow measurements were performed on the main and field canals. The canal network transmits water diverted from the Mutale River to the irrigation scheme. The water flow data were used to compute water losses using the inflow-outflow approach. The experimental data were analyzed using descriptive statistics and analysis of variance (ANOVA). Significant differences were tested using the t– test. The study results revealed that canal water losses contributed significantly to the failure of the irrigation scheme. The overall conveyance efficiency of the canal system was found to be 56%, meaning 44% of the water abstracted from the Mutale River escapes the canal before reaching its destination. Analysis of other factors affecting the Mbahela Irrigation Scheme showed a complex interplay of socio-economic, governance, and infrastructure-related variables. The presence of both positive and negative influences was observed, suggesting that success in such a scheme requires an integrated approach, addressing education, infrastructure, governance, and farmer incentives. There is a need to improve the deteriorated canal lining to minimize water losses and improve the velocity of water.

Keywords: Failure, Revitalisation, Smallholder Irrigation Scheme, Strategic partnership, Water loss

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List of Acronyms and Abbreviations

DAFF	-	Department of Agriculture, Forestry and Fisheries
DARE	-	Department of Agricultural and Rural Engineering
FIS	-	Floppy Irrigation System
FSP	-	Farmers Support Programme
ICT	-	Information and Communication Technology
LDA	-	Limpopo Department of Agriculture
MIS	-	Mbahela Irrigation Scheme
PTO	-	Permission to Occupy
RESIS	-	Revitalisation of Smallholder Irrigation Schemes
SA	-	South Africa
SIS	-	Smallholder Irrigation Schemes
SPP	-	Strategic Partnership Programme
UNIVEN	-	University of Venda

CHAPTER ONE: INTRODUCTION

1.1 Background

Smallholder irrigation refers to the practice of providing water to smallholder farmers for the purpose of growing crops. When discussing smallholder irrigation, it is essential to begin with a clear definition of a smallholder farmer. According to Machethe et al. (2004) and Pienaar (2015), various terminologies were commonly used in literature to refer to smallholder farmers, including smallholder farmers, impoverished farmers, peasant farmers, food-insecure farmers, emerging farmers, and land reform beneficiaries. Generally, there is no universally accepted definition of a smallholder farmer. However, in the South African context, the phrase is commonly used to describe producers who are Black people and differ from the predominant large-scale commercial farmers, who are mostly White people (Kirsten & van Zyl, 1998). Carelsen et al. (2021) classified and characterised South African smallholder farmers as "those farmers who produce for household consumption and markets, subsequently earning ongoing revenue from their farming businesses, which form a source of income for the family. The farmers have the potential to expand their operations and to become commercial, but they need access to comprehensive support (technical, financial, and managerial instruments)." Therefore, there is no reference to the size of the farm when referring to a smallholder farm in South Africa. There is no clear distinction between smallholder, subsistence, communal, and emerging farmers, and different academics employ them interchangeably in diverse circumstances. Normally smallholder farmers are impacted by factors such as subsidies, prices, and markets. Although their input and output markets are not completely developed, they tend to be localized to some degree.

In South Africa, smallholder irrigators have been classified into four distinct types (Crosby et al., 2000; Du Plessis et al., 2002; Van Averbeke, 2008). These groups are (i) farmers who are part of irrigation schemes, (ii) independent irrigation farmers, (iii) community gardeners, and (iv) home gardeners. Denison et al. (2016) reported around 200 000 to 250 000 smallholder irrigators in these four groupings within the country. In this view, smallholder irrigation refers to the process of managing the provision of water to crops, which is initiated, organised, and controlled by the landholder(s). The scope of these activities does not surpass 10 hectares per household and can be as small as 0.1 hectares (Adam & Carter, 1986). Smallholder irrigation can also be categorised as either 'formal' or 'informal'. Formal irrigation systems refer to projects that have been established by either private or public entities. These projects adhere to well-recognised technical requirements and are overseen by state agencies.

The specific details of these systems are documented in a national database (Gutiérrez-Malaxechebarría, 2013). In this database, a smallholder irrigation scheme (SIS) refers to a formal irrigation scheme that is larger than 5 hectares and is built or established in former homelands or resource-poor areas specifically for occupation and use by Black farmers (Van Averbeke, 2012; 2011; 2008). On average, a formal irrigation farmer typically possesses approximately 1.5 hectares of land. Drechsel et al. (2006) define informal irrigation systems as sections of the irrigation sector that were developed without official recognition and funding, i.e., in the shade of government-initiated 'formal irrigation' schemes. Irrigation schemes are organised systems designed to provide water to a group of farmers in a coordinated manner. Reinders et al. (2010) defined an irrigation scheme as an agricultural project that involves multiple holdings that depend on a shared distribution system for access to irrigation water. Van Averbeke et al. (2011) defined irrigation as the artificial application of water to the land for the purpose of enhancing plant growth. Irrigation plays a significant role in low rainfall areas to supplement the inadequate rainfall to satisfy crop water needs for improved crop yield. It is due to a lack of sufficient rainfall that irrigation schemes are deemed important in agriculture. Water is an important aspect of plant growth. Without sufficient water, crop production will be poor, i.e., either the crop will not reach maturity or will not produce a good-quality yield. Water is a scarce resource in South Africa (Prins et al., 2023).

In South Africa, agriculture accounts for approximately 62% of the national water demand (SSA, 2010), mainly for crop irrigation. Despite this high level of consumption, water use efficiency at South African irrigation schemes remains generally low (DWA, 2013). This highlights the need for irrigation schemes to improve water management through the adoption and proper use of effective irrigation systems. Irrigation systems are deemed effective when they can deliver the required amount of water as per the design specifications. Irrigation schemes play a major role in contributing to food security, job creation, poverty alleviation, and the eradication of hunger. The South African smallholder irrigation sector occupies 0.1 million ha of the 1.3 million ha of total irrigated land in the country (Backeberg, 2006). Most smallholder irrigation schemes in South Africa underperform. Underperformance refers to their inability to meet expected outputs due to factors that include lack of farmer participation in water management, poor infrastructure, limited knowledge of crop production and irrigation scheduling, and lack of markets. The condition of the smallholder irrigation infrastructure in South Africa deteriorates due to negligence and hesitation of farmers to take part in its maintenance (Dirwai et al., 2019).

During the 1990s, the Department of Agriculture, Forestry and Fisheries (DAFF) introduced the Revitalisation of Smallholder Irrigation Schemes (RESIS and RESIS Recharge) programmes to restore SIS to full production. These programmes were intended to support poverty alleviation and improve the livelihoods of previously disadvantaged communities

(DAFF, 2012). Revitalisation involves not only the redesign and rehabilitation of existing irrigation infrastructure but also the integration of key development components such as business strategy development and marketing, human capital development and empowerment, organisational and social dynamics of water apportionment, finances, and the agricultural production system (DAFF, 2012). In Limpopo Province, approximately 180 irrigation schemes were supported through the RESIS and RESIS Recharge programmes (Van Koopen et al., 2017).

RESIS primarily focused on the rehabilitation of the irrigation infrastructure and engagement of Strategic Partners (SP) through joint ventures aimed at improving productivity and promoting the commercialisation of agricultural produce. In this context, rehabilitation refers to the reconstruction of dilapidated irrigation infrastructure, including the redesign and repair of water supply and irrigation distribution systems. In contrast, the RESIS Recharge programme emphasised the development of new irrigation infrastructure and similarly involved strategic partners through joint ventures. Despite the implementation of RESIS and RESIS Recharge, many SIS in Limpopo Province had collapsed again by 2015 (DAFF, 2015). This continued underperformance was largely attributed to persistent challenges such as poor infrastructure, lack of farmer participation in water management, limited knowledge of crop production and irrigation scheduling, and a lack of markets and credit services (DAFF, 2015). Furthermore, a lack of transparency regarding income and expenditure between farmers and Strategic Partners, as well as insufficient farmer involvement in operational decision-making, also contributed to the failure of the schemes (Ledwaba, 2013).

In general, the primary objective of SIS in South Africa and other countries in the region is poverty alleviation, improved food security, employment creation, curbing the migration of rural residents to urban areas, and modernization of smallholder farming (Chancellor, 2004). Chibisa et al. (2008) reported that 42% of farmers believed that SIS had the potential to effectively alleviate poverty. However, these farmers emphasised that such outcomes would depend on the availability of adequate input support programmes and sustainable market access. In contrast, 22% of the farmers in the same survey opined that SIS initiatives were incapable of alleviating poverty, grounding their rationale on the premise that irrigation schemes were only established to alleviate adverse effects of droughts and to enhance food security. These farmers unintentionally alluded to poverty reduction because addressing droughts would lead to more consistent agricultural production.

The significance of SIS in South Africa largely derives from the large number of people who depend on them for their livelihoods (Bembridge, 2000). Fluctuating seasons and unpredictable rainfall patterns that are closely linked to drought conditions, combined with rising demand for food to sustain expanding populations, have made the practice of irrigation farming an urgent requirement (Chibisa et al., 2008) in South Africa. In addition, SIS can serve as a successful means of attaining sustainable rural livelihoods (Chibisa et al., 2008). Taking into consideration the importance of SIS for the country, it is still of extreme importance that the government intervene to revitalise the collapsed irrigation schemes. However, it is important to first investigate the causes of the failure of the previously revitalised irrigation schemes. Knowledge of the factors that contributed to the failure will assist in the development of mitigation strategies to prevent the recurrence of the failures.

1.2 Research Problem

Most irrigation schemes revitalised by the Limpopo Department of Agriculture through the RESIS and RESIS Recharge programmes have either collapsed or continue to underperform (DAFF, 2015). The Mbahela Irrigation Scheme (MIS) is one such smallholder irrigation scheme (SIS) that was revitalised through the RESIS Recharge programme in 2008 but had already begun to underperform by 2012. The revitalisation initiative involved the installation of a floppy irrigation system (FIS) and the engagement of a Strategic Partner (SP) in 2009. The FIS was introduced to replace the traditional flood irrigation method due to the persistent water shortage challenges at the scheme. The SP, who had expertise in the use of FIS, was expected to provide technical support and train farmers for a period of three years.

The local government regarded the strategic partnership model as the most suitable approach to ensure the sustainability of the irrigation scheme. However, this approach did not yield the expected outcomes at MIS. The irrigation scheme began to decline again in 2012 following the departure of the SP. Farmers reverted to the traditional flood irrigation method despite the ongoing water shortage challenges. To date, the underlying causes of MIS's continued underperformance have not been thoroughly investigated. Therefore, the broad aim of the study was to investigate the factors contributing to the underperformance of the irrigation scheme with a view to recommending mitigation strategies and best practices that can promote full operation and long-term sustainability. Ensuring the effective functioning of MIS is critical given its role in in supporting socio-economic development, improving food security, alleviating poverty, and creating employment opportunities for the local communities.

1.3 Rationale of the Study

The Limpopo Department of Agriculture initiated the revitalisation of smallholder irrigation schemes that had collapsed during the late 1990s. However, limited information is available regarding the factors that have contributed to the continued underperformance of irrigation schemes the RESIS and RESIS Recharge revitalised irrigation schemes in the province. Due to financial constraints, the current study focused solely on the Mbahela Irrigation Scheme. . MIS was revitalised in 2008 through the introduction of a fully automated and computer-managed floppy irrigation system (FIS) and as well as the engagement of a Strategic Partner. Despite the substantial investment made by the state, farmers discontinued the use of the FIS in 2012. However, the reasons for abandoning the system were not comprehensively investigated. This study therefore provides an in-depth understanding of why the MIS farmers stopped using the FIS and reverted to flood irrigation, despite the persistent water shortage challenges. Furthermore, the study further explores why farmers stopped farming collectively and producing the same crop immediately after the departure of the SP. The study results are expected to inform policy and decision-makers, farmers, investors, NGOs, and government officials on critical factors affecting SIS and on the most suitable interventions for the development and management of SIS.

1.4 Research Objectives

1.4.1 Main Objective of the Study

The main objective of this study was to investigate the factors that contributed to the underperformance of MIS in the Vhembe District, Limpopo Province, which benefitted from the RESIS programme, with a view to helping with the development of mitigation strategies.

1.4.2 Specific Objectives of the Study

i. To investigate the socio-economic and bio-physical factors that contributed to the underperformance of MIS following the implementation of the RESIS programme

ii. To evaluate the role of the Strategic Partnership Programme in the underperformance of MIS after the RESIS programme

1.5 Layout of the Dissertation

This dissertation is structured into five chapters: Chapter 1: Introduction, Chapter 2: Literature Review, Chapter 3: Materials and Methods, Chapter 4: Results and Discussion, Chapter 5:

Conclusions, and Chapter 6: Recommendations. The last part of the dissertation is a list of references.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This chapter starts by reviewing the history of SIS in South Africa. This is followed by a review of socio-economic and biophysical factors that contribute to underperformance of SIS in South Africa, which heavily leans on Fanadzo and Ncube (2018), who reviewed the "Challenges and opportunities for revitalising smallholder irrigation schemes in South Africa." The chapter also reviews the historical overview of the RESIS programme in Limpopo Province. This detailed review of previous work laid the foundation for all the concepts and theories pertinent to this study.

2.2. The history of SIS in South Africa

In South Africa, SIS denotes multi-farmer irrigation initiatives, exceeding 5 ha in area, established in former homelands or resource-deficient regions (Van Averbeke, 2008). They were created to benefit local inhabitants, who are also expected to efficiently operate and maintain them. The history of SIS in South Africa is categorised into four eras: the peasant and mission diversion scheme era, the canal development era, the independent homeland era, and the irrigation revitalisation era (Van Averbeke & Mohammed, 2008). The first era, referred to as the peasant and mission diversion scheme, occurred during the 19th century. Irrigation development involved river diversions where groups of individual farmers extracted water from rivers for the purpose of irrigation.

The second era, which occurred from the 1930s to the 1960s, further improved the early SIS, whose water supply was based on river diversion, by developing canals. The thrust was to provide better livelihoods to previously disadvantaged people. In 1952, the Commission for Socio-Economic Development of the Bantu Areas (SEDBA) in the Union of South Africa had improved 122 SIS, encompassing 11 406 hectares managed by 7 538 plot proprietors. In many instances, the water conveyance and distribution systems were not lined (De Lange et al., 2000). After 1950, the government enhanced the existing SIS by erecting permanent weirs and lining the canals with concrete (Van Averbeke, 2008).

The third era, during the period from around 1970 to the 1990s, saw a significant increase in the number of SIS, especially in the Eastern Cape from 1975 to 1985 (Van Averbeke et al., 1998). Modern irrigation technologies, such as pressurised overhead irrigation systems, were introduced in the SIS to supplant the canal-based irrigation systems, which aligned with the global trend of modernising irrigation schemes (Faurès et al., 2007). Some notable SIS developed during this period include Ncora, Keiskammahoek, Tyefu, Shiloh, and Zanyokwe. The projects were capital-intensive (Van Averbeke et al., 1998; Bembridge, 1987) due to the construction of dams and the installation of modern water distribution and application systems (Denison & Manona, 2007a; Van Averbeke et al., 1998). For example, the expense of developing 473 hectares at the Tyefu Irrigation Scheme in 1976 was R12,000 per hectare (Bembridge, 1987), which corresponds to R282,189 per hectare when adjusted to 2010 values. The SIS relied on governmental funds for functionality (Laker, 2004; Van Averbeke et al., 1998). The government of South Africa handed over the responsibility to operate and maintain the SIS to the farmers during this period. The operational and maintenance expenses were substantial (Laker, 2004), and financial viability was never attained. As a result, most of the SIS collapsed, causing social unrest amongst the smallholder farming communities.

The fourth era started in 1990 with the purpose of revitalising the SIS that had collapsed during the third era. In 2010, SIS encompassed 47,667 hectares (Van der Stoep, 2011). The population of plot holders across the 302 SIS amounted to 34 158. Approximately 96.7% of the SIS sourced their irrigation water from rivers, through direct pumping, diversion via weirs, or dam storage. Groundwater accounted for 3.0%, municipal water 0.2%, and spring water 0.1%. Water was pumped on 48.5% of the SIS, and gravitational force was utilised on 34.6%, while 16.9% used a combination of pumping and gravity. Typically, surface irrigation was conducted using short furrows (Van Averbeke, 2008; Crosby et al., 2000; De Lange, 1994).

The SIS established before 1950 had ceased to exist in their original form by 2010 (Van Averbeke, 2008). The Taung Irrigation Scheme in North-West Province, established in 1939 (Bembridge, 1997), exemplifies a typical smallholder irrigation scheme (SIS) where the original canal system was supplanted with an overhead system. During the SEDBA in 1952, the lined SIS canals were anticipated to have lifespans of 20 to 40 years. Nonetheless, the majority of SIS have been operational for over 60 years and now require maintenance (Van Averbeke, 2008). Not all the 302 SIS were operational in 2010. Table 1 illustrates the operating status of the SIS by province for irrigation method.

South Africa focuses more on maintaining existing SIS rather than creating new ones (Fanadzo, 2012). In line with this, Limpopo Department of Agriculture initiated the RESIS programme in 2004 to revitalise SIS in former homelands and the newly created SIS on former commercial farms. The main objective was to enhance the capacity of SIS given the significant number of economically disadvantaged smallholder farmers. In general, most SIS in South Africa are located in areas where the main socio-economic context is a high level of poverty; hence, the programmes offered promising prospects for enhancing local livelihoods.

Table 1: South African smallholder irrigation schemes operational status by Province and history of the irrigation system

Province	**Number of operational schemes**				**Number of non-operational schemes**				
	Gravity- fed surface	**Pumped surface**	**Over head**	**Micro**	**Gravity fed surface**	**Pumped surface**	**Overhead**	**Micro**	**Total**
Limpopo	49	9	30	13	12	5	41	11	**170**
MP	3	0	4	0	1	0	11	0	**9**
Northwest	0	2	0	0	0	0	0	0	**2**
KZN	5	0	30	0	0	0	0	0	**35**
Free State	0	1	0	0	1	0	0	0	**2**
NC	0	2	0	0	0	1	0	0	**3**
EC	4	0	46	1	0	0	0	0	**67**
WC	6	0		0	0	0	0	0	**8**
Total	**67**	**14**	**111**	**14**	**14**	**6**	**59**	**11**	**296**

Note KZN: MP: Mpumalanga, KwaZulu-Natal, NC: Northern Cape, EC: Eastern Cape, WC: Western Cape

Revitalisation of SIS is a holistic development approach that aims for more effective outcomes as compared to mere restoration of the infrastructure. Hence, RESIS aimed at rebuilding the SIS and socially uplifting the surrounding communities because smallholder farmers require comprehensive assistance beyond the provision of irrigation schemes to make substantial improvements to their livelihoods (Fanadzo, 2012). Therefore, the RESIS programme focused on developing human capital at individual and organisational levels, access to marketing information and business strategy creation, and on repairing and redesigning existing infrastructure (Denison et al., 2007). The elements leading to the dysfunctional condition of SIS after the RESIS programme were not comprehensively investigated. However, several studies have assessed the factors that generally affect the performance of SIS in South Africa and beyond. These factors are now discussed in the following sections.

2.3 Socio-economic factors that contribute to underperformance of SIS

2.3.1 Low interest in farming

Fanadzo and Ncube (2018) pointed out that lack of interest in farming by young rural people was a risk to the smallholder agricultural sector in South Africa. They attributed the low utilisation of available smallholder irrigation schemes in KwaZulu-Natal and Limpopo Provinces to the lack of interest in farming. Fanadzo and Ncube (2018) also pointed out that women sometimes feel discouraged from farming because although they are the actual farmers, the title deeds to the land on which they farm are mostly issued in the names of men. They cited Machethe et al. (2004) and Tlou et al. (2006) to support their point.

2.3.2 Lack of recognition of the diversity of farmers in SIS

While rehabilitation of the irrigation infrastructure through the RESIS programme was an important focus, it is important to note that SIS are case-specific, complex and dynamic heterogeneous socio-biophysical entities (Fanadzo and Ncube, 2018). Their heterogeneity arises from many factors, such as farmer objectives and natural resource base, technologies, scheme and plot sizes, farmer profiles, and marketing opportunities (Fanadzo and Ncube, 2018). This diversity, therefore, means any intervention needs to respond to the unique needs, resources and agricultural contexts of the individual farmers constituting the SIS.

2.3.3 Limited farmer participation in planning and decision-making

Exclusion of farmers in planning stages of projects and the extent to which they take part in decision-making processes is always questionable (Fanadzo and Ncube, 2018), yet community participation is key in determining the community priorities before implementing interventions (Mollinga et al., 2007). While the current study did not manage to review the processes involved in identifying the choices made for the RESIS programmes, the focus on rehabilitation of the irrigation infrastructure and engagement of SP suggests a limited lack of participation by the SIS themselves. Therefore, decisions might have been made without due recognition of the roles of the farmers and their leadership as a collective. A more profound process to deal with, for example, historical inequality without ignoring the multiple social identities of all the farmers can enhance the success of interventions in the smallholder farming sector.

2.3.4 Limited access to water for irrigation

In their review of this factor, Fanadzo and Ncube (2018) indicated that lack of SIS success could partially be attributed to environmental challenges that include limited water availability, poor soil fertility, and negative effects of pests and diseases on crop production. In general, South Africa is a water-scarce country with a projected demand-supply deficit of 17% by 2030 (WWF, 2017). The country is largely semi-arid with a long-term annual precipitation of 480 mm yr^{-1} (Dennis & Dennis, 2012), which is much lower than the global average of 860 mm yr^{-1}. The precipitation varies greatly across the country, with 43% occurring on only 13% of the total land area of the country. Moreover, only 9% turns into surface runoff to feed inland dams and rivers (Dennis & Dennis, 2012), which makes water for irrigation a scarce resource.

2.3.5 Weak institutions and organisational structures

The institutional framework regulating SIS in South Africa experienced substantial alterations after the 1994 democratic transition. Multiple acts, including the Marketing Act of 1996, the National Water Act of 1998, the Land Bank Act of 2002, and the Communal Land Rights Act of 2004, were enacted and have substantial implications for smallholder agriculture. They required substantial modifications in institutions servicing SIS, especially parastatals like the Land Bank and the Agricultural Research Council, which had to adjust their operations to fulfil SIS's specialised demands. Smallholder farmers must be enabled to address the obstacles they encounter, including the lack of collective action. Farmers on SIS rely on one another due to their shared water distribution systems, necessitating collaborative efforts to fulfil their respective goals (Van Averbeke et al., 2011).

Regulations pertaining to institutional cooperation and frameworks are essential for the efficient and sustainable operation of collective initiatives. Irrigator communities and their voluntary leadership structures frequently encounter challenges in enforcing regulations (Van Averbeke et al., 2011). Farmers who prioritise individual ambitions over collective objectives often confront the irrigator community organisations (Letsoalo & Van Averbeke, 2006). Research on an SIS in the Eastern Cape and another in KwaZulu-Natal indicated that farmer groups were predominantly ineffective in fulfilling their duties, adversely impacting the productivity and overall efficacy of the schemes (Mnkeni et al., 2010). Consequently, any revitalisation of these schemes must primarily focus on strengthening farmer institutions and organisations.

2.3.6 Inadequate farmer support services and capacity building

Inadequate agricultural support services constitute a major impediment to the advancement of SIS in South Africa (Machethe, 2004). While the number of agricultural extension officers servicing smallholders in the country was generally adequate when compared against other countries sharing similar agricultural circumstances, most of them are not adequately trained (Fanadzo & Ncube, 2018). As a result, they have limited capacity to adequately support and train smallholder farmers in the technical skills required to manage irrigated crops, for example. Audinet and Haralambous (2005), cited in Fanadzo and Ncube (2018), indicated that some areas may have modern technologies, but such technologies do not always reach smallholder farmers because of inadequate extension services and insufficient distribution methods. In general, South African smallholder farmers have limited access to training programmes, which has resulted in insufficient production skills to improve yields (Fanadzo et al., 2010). New interventions may not be successful if the beneficiaries are not adequately supported.

2.3.7 Limited access to markets

Market access can be evaluated through three dimensions: physical access to markets (e.g., distances, costs); market structure (asymmetry in relationships among farmers, market intermediaries, and consumers); and the producers' proficiency, information, and organisation (e.g., market comprehension, pricing, negotiation) (IFAD, 2003). Support for SIS should be considered not merely in terms of land and water allocation but within a broader framework that includes access to markets, loans, and extension services (Magingxa & Kamara, 2003).

2.3.7.1 Physical access to market

Despite numerous measures implemented to enhance smallholder agricultural production in South Africa, farmers continue to face challenges in market access (Makhura & Mokoena, 2003). The FAO (2000) noted that the SIS in developing nations is ineffective because of inadequate access to markets and insufficient inputs. Smallholder farmers reported that they could not enhance their standard of living due to insufficient access to markets for selling their goods and obtaining inputs (Heinemann, 2002).

Research by Mangisoni (2006) noted the absence of collective action in the marketing environment and the high transaction costs as impediments to reaching formal markets. Farina and Reardon (2000) also identified product licensing, insufficient marketing intelligence, high marketing margins, and inadequate entrepreneurial skills as significant impediments for smallholder farmers seeking entry to formal markets. Consequently, many smallholder farmers sell their produce to middlemen at reduced rates in the periphery of their farms (Fatchamps & Vargas, 2005). These intermediaries subsequently sell the identical produce at much higher prices in the legitimate markets (Botlhoko, 2012; IITA, 2001).

2.3.7.2 Access and ability to use information on markets

According to Sikwela (2013) and Van Rooyen (2003), smallholder farmers have limited access to marketing information (such as prices) because they are in rural areas where information and communication technology knowledge and facilities are limited. In the current era, information regarding produce and input prices is mostly disseminated through the internet. Lack of information on the price and quality of produce puts smallholder farmers in a compromising situation concerning getting good prices, knowing when to sell the produce, and market access (Bienabe et al., 2004). Smallholder farmers lack resources such as business and negotiating experience and the collective organisation to give them the power to interact on equal terms with stronger market chain actors (Magingxa & Kamar, 2003).

2.3.7.3 Market saturation

When farmers produce identical crops at the same time in an environment where the number of buyers and traders is small, it leads to market saturation and low prices for that crop. Production of identical crops at the same time is a common practice in SIS because agricultural extension packages promote this practice for easy management of the production process without much consideration of the marketing opportunities for the crops. The participation of agribusinesses and processors capable of enhancing the value chain and mitigating farm losses (Amede, 2015) should be included in the intervention strategy for revitalising SIS.

2.3.8 Financial constraints

2.3.8.1 Lack of access to credit

Smallholder farmers in South African communal areas face limited access to factors of production, such as loans and knowledge. Financial intermediaries cannot support smallholder farmers due to the associated risks, expenses, and other challenges (Spio, 2002). The lack of access to credits impacts negatively on the sustainability of SIS because they do not have enough finances to cover their operations and other costs such as inputs. Smallholder farmers generally do not have enough collateral to secure credit (Jari & Fraser, 2009). Makhura (2002) indicated that cooperatives could help the development of SIS into a commercial agricultural sector through better access to credit facilities. Governments and other funding agencies prefer financing cooperatives because individuals bear higher risks than cooperatives (Sikwela, 2013). For example, smallholder farmers do not repay the loans (Baiphethi and Jacobs, 2009). There is also a general lack of knowledge among smallholder farmers on the preference of cooperatives for financial assistance (Sikwela, 2013).

2.3.8.2 Limited financial support from the government

Financial support to agriculture by the South African government has decreased over the years, culminating in the budget allocation for agriculture in 2016 being lower than in the 1980s in real terms (Fanadzo & Ncube, 2018) due to many possible reasons, including increasing competition for funding against other sectors. The diminishing budget allocations to agriculture translate to limited funding to SIS, which hinders the implementation of plans.

2.3.9 Poor agribusiness sector support

The SIS sector in South Africa is characterised by poor agribusiness sector support. As a result, smallholder commercial agriculture and local capabilities to augment the value of agricultural products through processing are limited. Combining processing of crop products with production enhances the stability of commodity markets by mitigating the risks linked to price volatility. Agribusiness support is also important for equipping farmers with information which is crucial for organising production schedules to meet specific opportunities in the market. This can guarantee that smallholders participate in forward delivery contracts with enhanced confidence.

2.4 Bio-physical factors that contribute to the underperformance of SIS

2.4.1 Poor condition of the infrastructure

Irrigation infrastructure (such as water storage, conveyance, system distribution, and field application facilities), roads, product storage, and farm boundaries are key elements in sustainable and profitable farming. The irrigation and other associated infrastructure should always be in good functional condition.

2.4.1.1 Irrigation infrastructure

The efficacy of irrigation infrastructure is affected by the state of the conveyance, distribution, and field application systems (Reinders, 2011). Conveyance denotes the transfer of water from the source to the agricultural land. System distribution pertains to the conveyance of water via the infield network of canals and/or pipelines to various locations on the irrigated terrain. Field application refers to the transfer of water from the distribution system to the root zone of plants. Van Koopen et al. (2017) emphasised that the availability of water resources, storage, conveyance, and application infrastructure are essential for the optimal utilisation of irrigation schemes.

2.4.1.2 Road networks

The majority of SIS in South Africa are located in remote areas characterised by poor road infrastructure, restricted market access, and a lack of value chain participants (Amede, 2015). The SIS frequently becomes inaccessible during the wet seasons, limiting farmers' access to production inputs and complicating the transportation of produce to markets. Poorly maintained roads can hinder extension officers from visiting farmers consistently (Fenyes et al., 2008).

2.4.1.3 Crop storage facilities

Lack of storage facilities leads to loss of produce, which discourages farmers from increasing production (Machete, 2004). Smallholder farmers participate highly in marketing their crops when they have access to storage facilities (Persson, 2009). Farmers with storage facilities have better chances of selling their crops when the price becomes favourable to them (Gitonga et al., 2015). Insufficient storage facilities lead to local price declines during harvest season when the most impoverished people require income the most (Burney & Naylor, 2012). Therefore, availability of storage facilities in good condition serves as an advantage for smallholder farmers to store their products and sell them at a later stage at higher prices.

2.5 The history of RESIS in Limpopo Province

Soon after attaining independence in 1994, South Africa embarked on initiatives to rectify historical imbalances, especially in the agricultural sector. Transformation in the agricultural sector was to be executed through land reform and revival of SIS, together with support to new SIS on former commercial farms (Xaba & Dlamini, 2015). The Comprehensive Agricultural Support Programme (CASP) was created to assist smallholder farmers enhance productivity, mitigate poverty, and generate employment (Hall & Aliber, 2010). It focused on six areas of intervention: advising and regulatory services, capacity building, information and training, market development, and financial services.

However, CASP did not achieve the intended results (Xaba and Dlamini, 2015; Jacobs et al., 2010; Idsardi et al., 2008) because it predominantly focused on rehabilitating on-farm infrastructure (Hall & Aliber, 2010; Xaba & Dlamini, 2015) with, for example, only 10% of its budget being allocated to training and capacity development (DAFF, 2007). The emphasis on infrastructure necessitated that beneficiaries needed to own their land, and this excluded most smallholder farmers from accessing the support because they generally do not own the land they use. Its reliance on extension services, which engage only a small fraction of smallholder farmers, also rendered it structurally incapable of reaching a substantial number of intended beneficiaries (Hall & Aliber, 2010).

RESIS (2001-2004), followed by RESIS Recharge (2005-2008), was created to address the challenges associated with CASP. The two programmes shifted from the traditional way of improving SIS, which focused on rehabilitating the on-farm infrastructure. Rehabilitation of irrigation infrastructure alone does not improve the livelihoods of the smallholder farmers (Fanadzo, 2012). The RESIS Recharge introduced the concept of strategic partnerships to SIS, with the main purpose of enhancing the transfer of skills and expertise from experienced, commercial-minded farmers to the smallholder farmers. The idea was to equip the smallholder farmers with skills to operate the SIS profitably and sustainably.

In terms of access to markets and community engagement, 70% of the 150 SIS that benefitted from the RESIS programmes were to establish direct linkages to markets, which enhanced economic stability for the farmers. Over 1 200 smallholder farmers participated in RESIS training programmes which focused on sustainable practices and water management (Department of Rural Development and Land Reform, 2023). These efforts improved the resilience of agricultural practices in Limpopo Province, promoting not only economic growth but also environmental sustainability in the face of climate challenges.

Despite the notable successes, most SIS that benefitted from the RESIS programmes soon deteriorated again. Mothapo et al. (2011) reported that 69% of SIS equipped with centre pivots ceased to operate due to the poor state of the irrigation infrastructure, farm boundaries, and farm tractors. A lot of the SIS were also vandalised after the departure of the strategic partners. However, there is no known comprehensive investigation of the factors that influenced the deterioration and underperformance of the SIS that benefitted from the RESIS programmes in Limpopo Province. Therefore, the current study gathered and analysed qualitative and quantitative data to better understand the factors in Limpopo Province using the Mbahela Irrigation Scheme as a case.

CHAPTER THREE: MATERIALS AND METHODS

3.1 Description of the Study Area

The study was conducted at the Mbahela Irrigation Scheme, located in Thulamela Local Municipality within the Vhembe District of Limpopo Province, South Africa (Figure 1). The scheme forms part of the Tshiombo Irrigation Area, situated at approximately 22°48'07.1" S and 30°27'12.6" E, and is about 37 km north of the Thulamela Local Municipality offices (Figure 2).

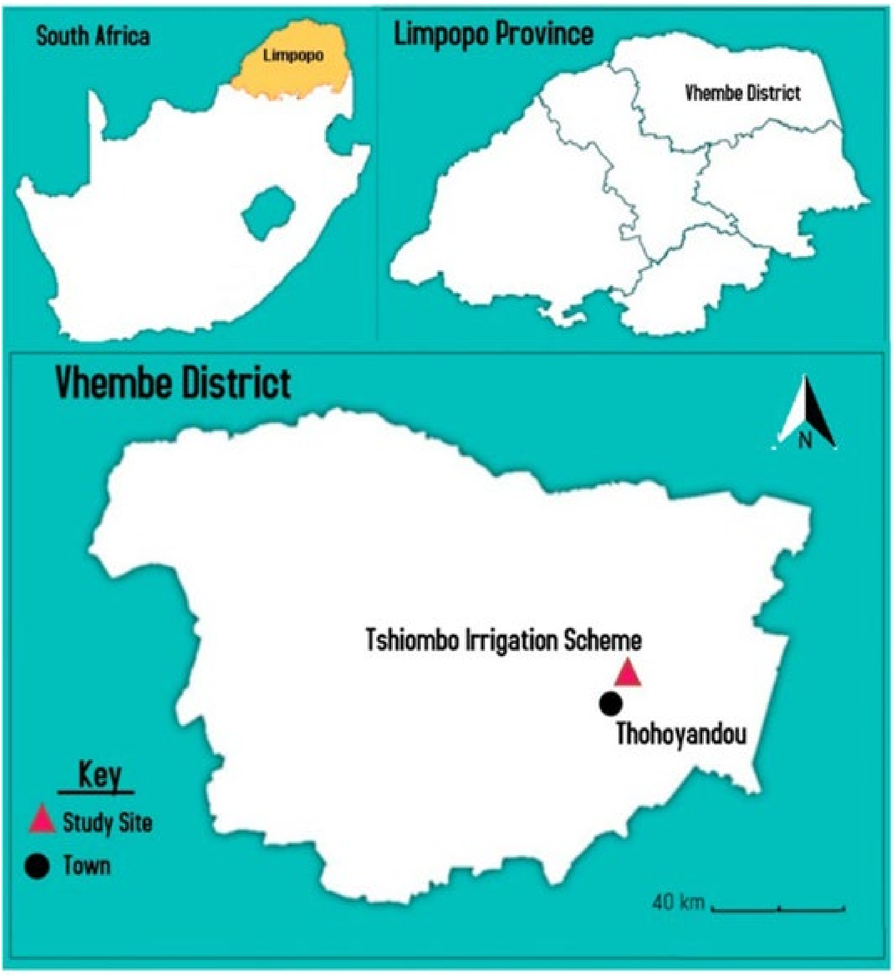

Figure 1: Map showing location of Limpopo Province in South Africa, Vhembe district in Limpopo Province, and Tshiombo Irrigation Scheme, where the Mbahela Irrigation Scheme is located (Source: Google Maps, 18 July 2024 at 08h25)

The agroecology of the area is characterised by arid and semi-arid climatic environments with an average annual rainfall of 560 mm and an average annual temperature of 27°C (Mwadzingeni et al., 2018). The Mbahela Irrigation Scheme falls under the Permission to

Occupy land tenure, which means it is communally owned. The irrigation scheme covers an area of approximately 100 ha and is registered as the Mbahela Agricultural Cooperative. It started operations in 1963 with 85 farmers, with each individual farmer owning a plot of minimum 1 ha size. It is characterised by different soil types, with the dominant ones being loamy soil (49.2% of the area), sandy soil (44.3%), and clayey soil (6.6%). The irrigation scheme used to get water from the Mutale River through a main canal to a dam, where it would then be pumped to the different plots. However, the dam is not operating anymore because the pump has been vandalised; hence, water flows straight from the river through the main canal to the plots with no temporary storage.

The irrigation scheme was revitalised through the RESIS Recharge programme in 2008. Before the RESIS Recharge programme, the irrigation scheme used a furrow system for infield water application. A floppy irrigation system (FIS) was adopted during the RESIS programme. The 100-ha irrigation scheme was put under a fully automated and computer-managed FIS. The irrigation scheme was partnered with a strategic partner with skill in the use of FIS, with the main expectation that the strategic partner would train the farmers on the use of the FIS and on commercial farming in general. The Mbahela Irrigation Scheme produced potatoes and maize during the tenure of the strategic partner. However, the farmers switched to using the furrow irrigation system and producing any type of crop, with each farmer deciding on what to produce without consulting other farmers after the departure of the strategic partner (Jiyane & Simalenga, 2019).

3.2 Data collection procedure

The study aimed to investigate the factors contributing to the underperformance of the Mbahela Irrigation Scheme. The term ‘underperformance’ in this study refers to a failure to perform as expected. The irrigation scheme failed to maintain the standard set during the RESIS programmes. To achieve this aim, the study employed a combination of surveys and field measurements.

3.2.1 Survey

A survey was carried out using a questionnaire to collect qualitative and quantitative data. The researcher administered the questionnaire in the Tshivenda language. The survey used a sample of 61 active individual plot owners. The interviews were conducted from the 21st to the 23rd of November 2023 and on the 2nd of December 2023 at the Mbahela Irrigation Scheme workshop. Sixteen plot owners were interviewed as individuals per day. The questionnaires aimed to collect data on socio-economic factors (e.g., markets and their accessibility, financial matters such as sources of funding and financial management, profit-sharing arrangements and access to financial records, operational management, strategic partnership matters such as the perception of farmers on strategic partnerships, the selection of strategic partners, channels of communication between the farmer and strategic partners, skills development through strategic partnerships, age, household income, education levels, household size) and bio-physical factors (e.g., infrastructure, crop selection). The information collected and analysed is for the time before and after the RESIS programmes.

Table 2 Dependent and independent variables used in the logistic regression model

DURING RESIS PROGRAMME			
	Variable Code	**Variable Name**	**Unit of Measure**
Y	FSDS	Farm status	1 = Operational, 0 = Not Operational
X_1	AIY	Age (years)	1 = < 30, 2 = 30-40, 3 = 41-50, 4 = 51-60, 5 = > 60
X_2	HLOE	Highest level of education	1 = no formal schooling; 2 = primary school; 3 = completed secondary school; 4= certificate level; 5 = diploma level; 6 = university level; 7 = professional college/trade certificate
X_3	FEDS	What was your farming experience during the strategic partnership?	1 = farming background, 0 = No farming background
X_4	FDSI	Were you fully dependent on the scheme as a source of income?	1 = Yes, 0 = No
X_5	DHWR	Did you have water rights?	1 = Yes, 0 = No
X_6	FCMS	Were the farmers in a cooperative management system?	1 = Yes, 0 = No
X_7	FFIS	Were farmers farming full-time on the irrigation scheme?	1 = Yes, 0 = No
X_8	CRGC	Did the members have a constitution or rules for the governance of the cooperative?	1 = Yes, 0 = No
X_9	DFRS	Were farmers receiving a salary?	1 = Yes, 0 = No
X_{10}	FRPF	Did the farmers receive farm produce for free?	1 = Yes, 0 = No
X_{11}	FPMC	Did the farmers play a role in the marketing of the crops?	1 = Yes, 0 = No
X_{12}	RIDC	Was the road infrastructure to the farm in good condition?	1 = Yes, 0 = No
X_{13}	CFSP	Was there communication between farmers and strategic partner?	1 = Yes, 0 = No
AFTER RESIS PROGRAMME			
Variable code		**Variable Name**	**Unit of Measure**
Dependent			

Y	FSAS	Farm status	1 = Operational, 0 = Not Operational
Independent			
X1	AIY	Age (years)	1 = < 30, 2 = 30-40, 3 = 41-50, 4 = 51-60, 5 = > 60
X2	HLOE	Highest level of education	1 = no formal schooling; 2 = primary school; 3 = completed secondary school; 4= certificate level; 5 = diploma level; 6 = university level; 7 = professional college/trade certificate
X3	FDSI	Are you fully dependent on the scheme as a source of income?	1 = Yes, 0 = No
X4	DHWR	Do you have water rights?	1 = Yes, 0 = No
X5	RCMS	Did the farmers remain in a cooperative management system?	1 = Yes, 0 = No
X6	CRGC	Do the members have a constitution or rules for the governance of the cooperative?	1 = Yes, 0 = No
X7	DFRS	Do farmers receive a salary?	1 = Yes, 0 = No
X8	RIDC	Is the farm road infrastructure in good condition?	1 = Yes, 0 = No
X9	AADR	Are there any dispute resolution mechanisms put in place?	1 = Yes, 0 = No
X10	RTAS	Have you received training after the strategic partnership?	1 = Yes, 0 = No
X11	PSCS	Do you participate in the selection of the crops grown per season?	1 = Yes, 0 = No
X12	ROIS	Do you currently have a role in the operation of irrigation system?	1 = Yes, 0 = No
X13	RMIS	Do you have a role in the management of irrigation scheme?	1 = Yes, 0 = No

Figure 2: Mbahela Irrigation Scheme; left: introducing the research study, right: individual farmer interview

3.2.2 Field measurements

The field measurements aimed at investigating canal network water losses and some bio-physical factors that influence the water losses. Low water conveyance efficiency is thought to have contributed to the underperformance of the irrigation scheme.

3.2.2.1 Description of the experimental layout

The measurements were conducted on three canal sections: a concrete-lined main canal with a rectangular shape, a lined field canal with a parabolic shape, and an unlined field canal with a parabolic shape. Canal dimensions (i.e., width, depth and length) and water flow properties (i.e., flow depth, top width of the flow surface and flow velocity) were measured to facilitate computations of flow characteristics such as cross-sectional area and discharge. The measurements were done simultaneously at the entrance and exit of a selected canal section to facilitate calculating water losses using the inlet-outlet approach after accounting for legitimate water withdrawals from the section. The Google Map in Figure 2 shows the canal positions where water flow measurements were conducted. Figure 3 is a schematic illustration of the experimental design, indicating canal sections that were used for the current study.

Figure 3: Google Map showing the positions where water flow measurements were done during the study at the Mbahela Irrigation Scheme

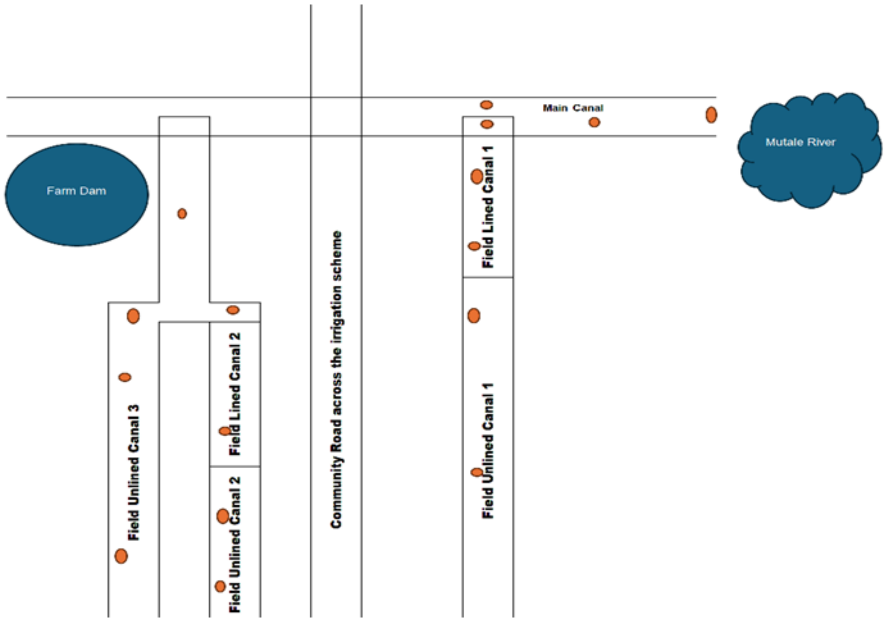

Figure 4: Schematic illustration of the canal sections at the Mbahela Irrigation Scheme that were used for the study

3.2.2.2 Characteristics of canal sections used

Two main canal sections were used for the study, with lengths of 2780 m and of 481 m. These two sections had an average depth of 2.29 m and an average width of 2.21 m. The sections were lined with concrete. In the field, two concrete-lined canal sections were used. One section had a length of 137 m, while the other had a length of 425 m. The average depth of the two concrete-lined field canals was 0.16 m, while the average width was 0.46 m. Another field canal which was not lined was also used for the current study. Three sections were used on this unlined field canal with lengths of 206, 239 and 361m. The average depth of the three unlined field canal sections was 0.13 m, whereas the average width was 0.15 m. GPS was used to fix the locations for water flow measurements.

3.2.2.3 Water flow measurements

Water flow velocity was measured using a Global Water Flow Probe for measuring water flow velocity in open, partially filled pipes and open channels with an accuracy of 0.1 m/s (Global Water Instrumentation, 2012). Flow characteristics such as the depth and width of flow were measured using a measuring tape. The aim was to be able to calculate the cross-sectional area of water flow at the measurement positions. Data were collected during three separate irrigation events: the first in mid-December 2023, and the second and third in January 2024.

Figure 5: Measuring water flow velocity using global water flow meter

3.2.2.4 Discharge and conveyance efficiency calculations

Water flow velocity and cross-sectional area of flow were used to compute discharge using Equation 1.

$$Q_i = V_i \times A_i \qquad \text{Equation 1}$$

Where Qi – refers to discharge (m^3/s)

V - refers to velocity (m/s)

A – refers to cross sectional area (m^2)

Water loss was computed using Equation 2 below:

$$Q_{loss} = 100 \times \frac{Q_{inflow} - Q_{outflow}}{Q_{inflow}} \qquad \text{Equation 2}$$

Where Q_{inflow}- refers to Quantity of water diverted from the water source (L/s)

$Q_{outflow}$ - refers to Quantity of water delivered to the farm (L/s)

The difference in discharge between the inlet and outlet of a canal section, after accounting for legitimate water abstractions, was considered the water loss. This water loss data was then used to compute the conveyance efficiency (CE), which reflects the canal's capacity to transmit water effectively. The conveyance efficiency was calculated using the following equation:

$$CEi = 100 - Q_{loss} \qquad \text{Equation 3}$$

Where CE_i – refers to Conveyance efficiency (%)

Q_{loss} – refers to different sections of the canal as calculated in equation number 2

The overall canal network conveyance efficiency was calculated as:

$$CE = CE_{main\ lined} \times CE_{field\ lined} \times CE_{field\ unlined} \qquad \text{Equation 4}$$

Where CE - refers to the overall efficiency

3.3 Statistical Analysis

Quantitative data collected through a questionnaire were analysed using descriptive statistics and a logistic regression model. Data from field measurements were analysed using both descriptive statistics and analysis of variance (ANOVA). Significant differences were tested using the t-test at a 95% level of significance.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents results from the survey and field measurements. It starts by presenting and discussing the key socio-economic and bio-physical factors identified as crucial for the performance of the Mbahela Irrigation Scheme. This is followed by a presentation and discussion of the logistic regression analysis results which quantify the influence of the factors on the underperformance of the irrigation scheme. The last part presents and discusses the results on water flow characteristics and losses and the bio-physical factors that influence water losses at the irrigation scheme.

4.2 Socio-economic factors that characterised the Mbahela Irrigation Scheme

At the time of this study, the Mbahela Irrigation Scheme comprised 85 individual plot owners; however, only 61 plot holders were available and participated in the interviews. the following section presents and discusses the key socio-economic factors affecting the scheme.

4.2.1 Farmers' demographics by age

Table 3 shows that women constituted the majority of farmers in the irrigation scheme, representing 56% during the RESIS programmes. Among the women, the largest age group (47%) was between 41 and 50 years old, while the majority of men (37%) were aged between 51 and 60 years old. Overall, approximately 41% of the farmers were older than 51 years, and only 11% were under 30 years of age. In terms of education, about 43% of the farmers had not attended formal schooling. Most farmers who completed secondary school education were within the 41 and 50-yearage group.

Table 3: Cross-tabulation of farmers' demographics during the RESIS programme

Variables	< 30	31 - 40	41 - 50	51 - 60	> 60	Total
Farmers gender						
Female	1 (1.6%)	3 (4.9%)	16 (26.2%)	13 (21.3%)	1 (1.6%)	34 (56%)
Male	6 (9.8%)	3 (4.9%)	7 (11.5%)	10 (16.4%)	1 (1.6%)	27 (44%)
Level of education						
No Formal Schooling	0 (0.0%)	0 (0.0%)	3 (4.9%)	3 (4.9%)	1 (1.6%)	7 (12%)
Primary School	5 (8.2%)	0 (0.0%)	6 (9.8%)	9 (14.8%)	1 (1.6%)	21 (34%)
Completed Secondary School	1 (1.6%)	6 (9.8%)	13 (21.3%)	11 (18.0%)	0 (0.0%)	31 (51%)
Certificate Level	1 (1.6%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (2%)
Diploma Level	0 (0.0%)	0 (0.0%)	1 (1.6%)	0 (0.0%)	0 (0.0%)	1 (2%)
Did you join the irrigation Scheme before RESIS Programme						
Yes	6 (9.8%)	6 (9.8%)	21 (34.4%)	23 (37.7%)	2 (3.3%)	58 (95%)
No	1 (1.6%)	0 (0.0%)	2 (3.3%)	0 (0.0%)	0 (0.0%)	3 (5%)
Farming Experience before joining the irrigation scheme						
Farming Background	6 (9.8%)	6 (9.8%)	22 (36.1%)	23 (37.7%)	2 (3.3%)	59 (98%)
No Farming Background	1 (1.6%)	0 (0.0%)	1 (1.6%)	0 (0.0%)	0 (0.0%)	2 (3%)
Responsibility in the irrigation scheme						
Labourer	3 (4.9%)	6 (9.8%)	15 (24.6%)	8 (13.1%)	2 (3.3%)	34 (56%)
Committee member	0 (0.0%)	0 (0.0%)	2 (3.3%)	3 (4.9%)	0 (0.0%)	5 (8%)
Security	1 (1.6%)	0 (0.0%)	1 (1.6%)	1 (1.6%)	0 (0.0%)	3 (5%)
Unemployed	3 (4.9%)	0 (0.0%)	5 (8.2%)	11 (18.0%)	0 (0.0%)	19 (31%)
Fully Dependent on the scheme as source of funds						
yes	4 (6.6%)	5 (8.2%)	15 (24.6%)	16 (26.2%)	2 (3.3%)	42 (69%)
No	3 (4.9%)	1 (1.6%)	8 (13.1%)	7 (11.5%)	0 (0.0%)	19 (31%)
Alternative Source of Income						
Salary	0 (0.0%)	1 (1.6%)	4 (6.6%)	0 (0.0%)	0 (0.0%)	5 (8%)
Business	1 (1.6%)	0 (0.0%)	1 (1.6%)	2 (3.3%)	0 (0.0%)	4 (7%)
Government Grant	1 (1.6%)	1 (1.6%)	2 (3.3%)	5 (8.2%)	0 (0.0%)	9 (15%)
Dividends	5 (8.2%)	4 (6.6%)	16 (26.2%)	16 (26.2%)	2 (3.3%)	43 (70%)

Table 4 shows that women comprised 56% of the workforce at the Mbahela Irrigation Scheme's workforce following the RESIS programme, while men accounted for 44%. Among the women, the largest age-group (47%) was between 41 and 50 years, whereas the majority of men (37%) were aged between 51 and 60 years. Overall, approximately 41% of the total irrigation scheme farmers were over 51 years, and only 11% were under 30 years of age. According to Mwadzingeni et al. (2020), farmers with an average age of 59 years are generally no longer economically active. Similarly, Dube (2018) reported that ageing has a diminishing effect on food security and irrigation schemes' performance.

Table 4: Cross-tabulation of farmers' demographics after the RESIS programme

Variables	Less than 30	31 - 40	41 - 50	51 - 60	above 60	Total
Farmers gender						
Female	0 (0.0%)	1 (1.6%)	4 (6.6%)	11 (18.0%)	18 (29.5%)	34 (56%)
Male	1 (1.6%)	5 (8.2%)	2 (3.3%)	5 (8.2%)	14 (23.0%)	27 (44%)
Level of education						
No Formal Schooling	0 (0.0%)	0 (0.0%)	0 (0.0%)	4 (6.6%)	3 (4.9%)	7 (12%)
Primary School	0 (0.0%)	2 (3.3%)	0 (0.0%)	1 (1.6%)	14 (23.0%)	17 (28%)
Completed Secondary School	1 (1.6%)	2 (3.3%)	5 (8.2%)	10 (16.4%)	15 (24.6%)	33 (54%)
Certificate Level	0 (0.0%)	1 (1.6%)	1 (1.6%)	0 (0.0%)	0 (0.0%)	2 (3%)
Diploma Level	0 (0.0%)	1 (1.6%)	0 (0.0%)	1 (1.6%)	0 (0.0%)	2 (3%)
Did you remain farming in the irrigation scheme after RESIS programme						
Yes	1 (1.6%)	5 (8.2%)	4 (6.6%)	10 (16.4%)	26 (42.6%)	46 (75%)
No	0 (0.0%)	1 (1.6%)	2 (3.3%)	6 (9.8%)	6 (9.8%)	15 (25%)
What was your farming experience after RESIS						
Farming Background	1 (1.6%)	6 (9.8%)	6 (9.8%)	16 (26.2%)	32 (52.5%)	61 (100%)
Responsibility in the irrigation scheme						
Ordinary member	1 (1.6%)	5 (8.2%)	6 (9.8%)	14 (23.0%)	25 (41.0%)	51 (84%)
Committee member	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	5 (8.2%)	5 (8%)
Stopped farming	0 (0.0%)	1 (1.6%)	0 (0.0%)	2 (3.3%)	2 (3.3%)	5 (8%)
Fully dependent on the scheme as your source of income						
No	0 (0.0%)	2 (3.3%)	2 (3.3%)	11 (18.0%)	32 (52.5%)	47 (77%)
Yes	1 (1.6%)	4 (6.6%)	4 (6.6%)	5 (8.2%)	0 (0.0%)	14 (23%)
Alternative source of income						
Salary	0 (0.0%)	0 (0.0%)	1 (1.6%)	1 (1.6%)	0 (0.0%)	2 (3%)
Business	0 (0.0%)	1 (1.6%)	0 (0.0%)	3 (4.9%)	0 (0.0%)	4 (7%)
Government grant	0 (0.0%)	1 (1.6%)	1 (1.6%)	7 (11.5%)	32 (52.5%)	41 (67%)
No alternative	1 (1.6%)	4 (6.6%)	4 (6.6%)	5 (8.2%)	0 (0.0%)	14 (23 %)

In terms of education, the study revealed that 43% of SIS farmers aged between 41 and 50, as well as 43% of SIS between 51 and 60 years, did not attend formal school. The majority, 42% of farmers who completed secondary school, were between the ages of 41 and 50 years. The results indicated a balance of literate and non-literate farmers within the irrigation scheme. The results further revealed that 24% of the irrigation scheme farmers aged below 30 years had completed primary school level during the RESIS Programme. Youth who were least educated participated in the irrigation scheme, with 24% having completed primary school, certificate level, and diploma level. About 11% of the total respondents did not attend formal schooling, whereas 51% had completed secondary school level, with at least 2% having completed certificate level and 2% diploma level. Most farmers who had completed higher education levels were found to be between the ages of 41 and 50 years. A slight increase was observed after the RESIS Programme, where 54% of the farmers completed school, 3% completed a diploma, and 3% completed a degree. There was a slight increase of 1% for farmers who did not have formal schooling.

Not all plot owners were involved in farming before the RESIS programme. About 5% started farming during the RESIS programme. The majority (95%) of farmers were found farming in their individual plots before the introduction of the RESIS programme to the irrigation scheme. About 97% of the farmers had farming experience during the RESIS programme, and they further had different responsibilities within the irrigation scheme. During the RESIS programme, all individual plots of MIS were combined into one farm managed by the strategic partner. The individual farmers were then appointed as labourers and guards of the irrigation scheme. Not all individual farmers were appointed; some of the farmers found themselves without jobs during the transition from individual farming to the RESIS programme, whereas some were employed on a seasonal basis. About 56% of individual plot owners were hired as labourers on a seasonal basis during the period of planting and harvesting. 31% were unemployed during the RESIS programme. Only 13% of the individual plot owners were employed on a full-time basis, where 5% were employed as security guards, and 8% were employed as committee members and were between the ages of 41 and 60 years.

The study results further revealed that 75% of the irrigation scheme farmers remained farming, and 25% stopped farming after the departure of the strategic partner due to different reasons, such as lack of funds to purchase farming inputs, lack of water, and lack of market. The majority (56%) of farmers who remained farming are above 60 years of age, followed by farmers who are between the ages of 51 and 60 years at 22%. According to the Government of South Africa (2005, 2004), cited in Maepa (2015), the RESIS programme was meant to improve the livelihood of rural communities where irrigation schemes are based through improved income for beneficiaries and improved agricultural productivity. According to Fanadzo and Ncube (2018), the government introduced the RESIS programme for the purpose of creating jobs for rural communities to reduce the unemployment rate and poverty within rural communities.

Although one of the roles of the strategic partner was job creation and provision of capacity building to individual farmers, the study indicated that the strategic partner did not employ all individual plot owners during the RESIS programme and further indicated that even the ones who were employed were working as seasonal workers. Only 31% of individual plot owners relied on the irrigation scheme as the only source of income; during the RESIS programme, the remaining 69% had alternative sources of income such as government grants, business, salaries, and dividends. Individual plot owners who relied on dividends were found to be 70%, whereas 15% relied on government grants.

A decrease in irrigation scheme farmers who relied on the irrigation scheme as the only source of income was observed after the RESIS programme, and that led to an increase in irrigation schemes relying on different alternative sources of income after the RESIS programme. Twenty-three percent (23%) of farmers were found to rely on the irrigation scheme as the only source of income, and 77% had a different alternative source of income. A huge increase, with 67% of irrigation scheme farmers relying on government grants, was observed compared to the RESIS programme period. This is because most farmers are above 60 years of age. Only 10% of the farmers' irrigation scheme relied on salaries, and others relied on privately owned businesses. Mwadzingeni et al. (2020) reported that farmers earning social grants are enjoying minimum incentives; hence they are no longer active enough, which might be the case in the MIS, where most farmers are no longer actively farming.

4.2.2 Farmer participation in crop selection

The study results presented in Table 5 revealed that only the strategic partner was responsible for selecting crops grown seasonally and purchasing farm inputs during the RESIS programme. While this arrangement may have ensured uniformity in production and possibly met market demands, it limited farmer participation in key decisions, which can undermine capacity-building goals. According to Mollinga et al. (2007) and Van Averbeke et al. (2011), farmer involvement in decision-making is crucial for ownership, skills transfer, and long-term sustainability of revitalisation programmes. The information generated through contact interviews with the farmers shows that the farmers have been producing a variety of agricultural products such as sugar beans and maize, which could have been in line with their interests and experience.

Table 5: Farmers' participation in crop selection and farm inputs

		Frequency	**Percentage**	**Frequency**	**Percentage**
		During RESIS Programme		After RESIS Programme	
Participation in the selection of the crops grown per season?	Yes	26	42.6	45	73.8
	No	35	57.4	16	26.2
Responsibility of purchasing farm inputs (seeds, fertiliser, chemicals)?	Strategic Partner	57	93.4		
	Farmers	4	6.6		

During the implementation of the RESIS programme, the strategic partner chose potatoes for them, which could have been difficult for farmers to produce given their experiences and interests. Excluding farmers from crop selection may have reduced their sense of ownership and motivation. It may also have prevented them from aligning production with their own knowledge, preferences, and local market opportunities. As a result, after the strategic partner's departure, farmers may have lacked the skills and confidence to manage crop planning independently, contributing to the scheme's decline. Moreover, farmers knew when and where to buy their input, meaning they probably had some form of relationship with input suppliers.

During the RESIS programme, the responsibility was completely shifted to the strategic partner, which could make farmers feel excluded from decision-making. As revealed in Table 4, most respondents (57.4%) indicated that the strategic partner was not involving them when it comes to the selection of crops to be grown, while 42.6% did participate. Most respondents (93.4%) reported that the strategic partner paid for inputs such as chemicals, seeds, and fertilisers.

One of the main support systems offered by the strategic partnership model is reflected in this. In the short term, this arrangement probably lessened farmers' financial stress and guaranteed prompt access to necessary inputs, which can be a major limitation in smallholder irrigation systems (Magingxa and Kamara, 2003). By providing inputs, the strategic partner might have preserved quality standards, increased output uniformity, and freed farmers from having to find and pay for inputs separately, allowing them to concentrate on crop management. Although advantageous during the partnership phase, this model might have unintentionally encouraged reliance, leaving farmers unprepared to finance and acquire inputs on their own when the strategic partner left.

Other revitalised irrigation programmes have shown similar trends, with farmers' limited financial resources and lack of established supplier ties leading to lower output levels when input support was removed (Ledwaba, 2013; Van Averbeke et al., 2011). Additionally, farmers' market exposure and bargaining strength may be diminished by an excessive dependence on a single partner for input provision, which may restrict their capacity to negotiate contracts, compare pricing, or look for other suppliers (Bembridge, 2000). Therefore, even though the strategic partner's input provision improved operational performance during the RESIS programme, it also emphasises how crucial it is to combine input support with capacity-building initiatives like supplier negotiations, cooperative bulk purchasing, and financial management training to guarantee the long-term viability of smallholder irrigation schemes after external support concludes.

The study further indicated changes in crop selection participation and financing of inputs, with a trend towards greater farmer involvement and responsibility after the RESIS programme, where irrigation scheme farmers are now individually responsible for selecting the type of crop to farm with and for purchasing farm inputs. While individual crop choice can increase autonomy, it can also fragment production, reduce economies of scale, complicate marketing, and result in market oversupply of certain crops. This shift away from coordinated production may explain part of the post-RESIS decline in commercial performance. Some farmers (26.2%) still engage in discussion with other farmers regarding the type of crop to grow seasonally, while 73.8% individually decide on the crop type to grow in their individual plots.

The study results revealed that farmers have shifted from potato production, which was their main enterprise during the RESIS programme, to cultivating other crops, with nuts being the predominant choice amongst most farmers. Farmers reported that potato production has become impractical due to limited capital to purchase production inputs, as well as inadequate access to formal markets. Currently, farmers in the irrigation scheme cultivate a variety of crops driven by individual interests. However, the diversity creates challenges when it comes to consolidation and marketing as one entity. As observed, the study results indicated that all farmers own 1ha of land, which is found to be below the national average plot size. According to Van Averbeke et al. (2011), cited in Mwadzingeni et al. (2020), the national average plot size owned by South African SIS is 1.513ha.

4.2.3 Communication and dispute resolution mechanisms

Table 6 below summarises the frequency of communication and dispute resolutions among the strategic partner and the farmers, which were prevalent during the implementation of the RESIS programme.

Table 6: Communication and dispute resolution mechanisms

		Frequency	Percentage	Frequency	Percentage
		During RESIS Programme		After RESIS Programme	
Communication between farmers and strategic partner	Yes	7	11.5		
	No	54	88.5	61	100
Dispute resolution mechanisms put in place	Yes	3	4.9	13	21.3
	No	58	95.1	48	78.7

The study results indicated that there was a lack of communication between irrigation scheme farmers and strategic partners. A small number (11.5%) reported that communication existed between farmers and the strategic partner. However, it was not direct, as it was conveyed by the committee members, not the strategic partner. The majority (88.5%) indicated that there was no communication at all. The study indicated that currently there is no communication between the strategic partner and the Mbahela irrigation scheme farmers. Communication that existed ended at the end of the RESIS programme. During the RESIS programme, most respondents (95.1%) stated a lack of resolution mechanisms, whereas 4.9% of respondents reported having such mechanisms that were developed by the irrigation scheme committee members. There was a slight increase in dispute resolution mechanisms, with 21.3% reporting their existence after the RESIS, while the majority (78.7%) still indicated that no such mechanisms were in place. The result indicates a potential area for further development in the cooperative relationship.

During the RESIS initiative, there was a widespread lack of contact between the strategic partner and irrigation scheme farmers, according to the results in Table 4. Just 11.5% of respondents said there was communication with the strategic partner, and even then, it was indirect and passed through committee members rather than directly involving farmers and partners. Most of the respondents said they had no direct involvement with the strategic partner. This implies that there might have been a legal agreement for the strategic partner to speak only to the management committee or cooperative leadership, who were then in charge of informing the rest of the membership. The goal of this strategy is frequently to preserve operational effectiveness and expedite communication (Bembridge, 2000).

However, this structure might have resulted in information bottlenecks if it hadn't been well-defined, closely watched, and reinforced by robust feedback mechanisms. It's possible that important messages between the strategic partner and regular farmers were misplaced, censored, or delayed (Mollinga et al., 2007). In actuality, the strategic partner may have been more concerned with satisfying production and market demands than cultivating direct connections with farmers, which may have been reflected in the dependence on indirect communication. This strategy might have been further supported by elements like time restrictions, hierarchical management styles, and the belief that technical and business choices belong in the leadership hierarchy.

Ineffective and indirect communication has serious repercussions. First, it can cause disengagement and a diminished sense of ownership over scheme activities by undermining confidence between farmers and the strategic partner (Van Averbeke et al., 2011). Second, the participatory principles necessary for sustainable agricultural development conflict with farmers' limited ability to influence decisions that directly impact their livelihoods in the absence of open and regular communication channels (Cleaver & Franks, 2008). Thirdly, farmers are less equipped to run the programme on their own after outside assistance is removed since there are fewer opportunities for mentorship, skills transfer, and capacity building when there is little direct contact with the strategic partner (Ledwaba, 2013).

Strategic partnership models should incorporate transparent and organised communication systems that include frequent in-person meetings between farmers and partners, unambiguous reporting procedures, and chances for reciprocal contact to ensure long-term viability. This would improve the operational resilience of revitalised irrigation schemes when the cooperation ends, foster confidence, and guarantee efficient skills transfer.

Figure 6 below presents the channels of communication employed during and after the implementation of RESIS by the SP and farmers.

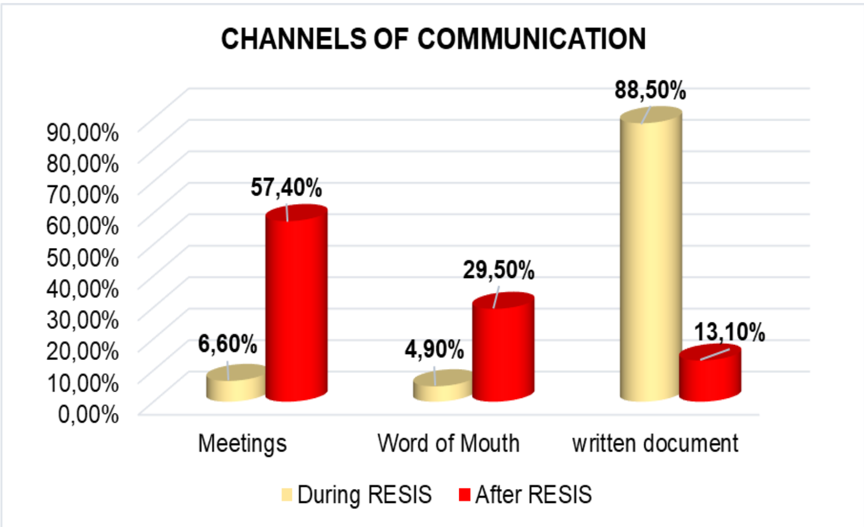

Figure 6: Communication channels used during and after the RESIS programme

The communication channels between the strategic partner and individual plot owners changed from the RESIS programme to the post-RESIS phase, as shown in Figure 6. The primary means of communication throughout the RESIS programme were indirect and relied on written materials like communiqués or memos that were sent by coordinators. This method is frequently employed in structured projects to keep records, formalise instructions, and guarantee that communications are understood by all parties involved (Bembridge, 2000). Nevertheless, it is also a top-down, one-way communication strategy that restricts chances for discussion, clarification, and farmer input. Farmers may become passive information consumers rather than active decision-makers as a result of such practices (Mollinga et al., 2007).

Farmers switched to direct in-person meetings as their main means of contact following the RESIS programme. With the ability to voice concerns, pose inquiries, and engage in collective decision-making, this shift points to a shift toward more interactive and participatory involvement. In general, face-to-face communication works better for establishing trust, clearing up misconceptions, and encouraging teamwork (Cleaver & Franks, 2008). In the absence of the strategic partner, farmers may need to coordinate more effectively, especially when it comes to planning production, marketing, and maintenance tasks. This could be reflected in the return of frequent meetings.

In terms of inclusion and farmer empowerment, the move to in-person meetings is a good thing, but it also shows that this kind of participatory communication was mostly lacking during the strategic partnership time. This disparity probably hindered the transfer of skills, decreased farmer control over scheme operations, and exacerbated operational difficulties following the partner's removal (Van Averbeke et al., 2011; Ledwaba, 2013). Future communication techniques for future revitalization programs should mix the formal advantages of written records with the participative advantages of direct engagement to ensure both information clarity and active farmer involvement.

4.2.4 Natural resources

The main natural resource factors considered in this study were the dominant soil types, the main source of water, and the state of water rights, are summarised in Table 5 for both the RESIS and post-RESIS periods at the Mbahela Irrigation Scheme. Secure water rights support fair distribution and long-term investment in irrigation operations, the dependability and routing of the water source influence conveyance performance and losses, and soil texture determines water-holding capacity and field application efficiency. A significant portion of respondents stated that they lacked legal water rights throughout both times; the primary water supply in our situation changed from storage in the dam during RESIS to direct abstraction from the Mutale River following RESIS, and loamy soils predominate (with sandy and clay soils present).

The biophysical and institutional background required to assess scheme performance elsewhere in the results is provided by these metrics. There is evidence that water-rights regimes have a significant impact on smallholder irrigators' incentives and willingness to pay for dependable service in Limpopo (Speelman et al., 2008; Speelman et al., 2010), and the focus on conveyance efficiency and proper matching of soils, sources, and distribution is in line with established guidelines for efficient irrigation from dam release to root-zone application (Reinders et al., 2010).

Table 7: Natural resources that were taken into consideration during the study

		Frequency	Percentage	Frequency	Percentage
		During RESIS Programme		After RESIS Programme	
Prevalent soil type	Sandy	27	44.3	27	44.3
	Clay	4	6.6	4	6.6
	Loamy	30	49.2	30	49.2
Water source	River			59	96.7
	Dam	61	100	2	3.3
Water rights	Yes	27	44.3	27	44.3
	No	34	55.7	34	55.7

4.2.4.1 Prevalent soil types

Since loam is typically regarded as the best soil type for agricultural productivity under irrigation, the Mbahela Irrigation Scheme's 49.2% loamy soil predominance is noteworthy. The ideal circumstances for root growth and nutrient uptake are created by the balanced texture of loamy soils, which blends the water-holding ability of clay with the good drainage and aeration of sand (Hillel, 2003). This indicates that if the water supply is steady and agronomic techniques are acceptable, a large portion of the plan is suitable for supporting a variety of crops and producing good yields from the standpoint of soil quality.

There are certain difficulties, nevertheless, because 44.3% of the soils are sandy. Sandy soils need more frequent watering because of their high infiltration rates and low water-holding capacity, which can cause rapid water loss through percolation (Van Averbeke et al., 2011).

This can increase manufacturing costs and put more strain on water resources. Although the small percentage of clay soils (6.6%) can hold water for longer, improper management might impede root penetration and produce drainage issues.

Overall, the scheme's diversity in soil types necessitates site-specific irrigation scheduling and management, even if the preponderance of loamy soil is advantageous for production potential. Water loss may be minimised, yields can be maximised, and efficiency can be increased by adjusting water application to the infiltration and retention properties of each soil type. The overall productivity of the project could be compromised if these variations are not taken into consideration, since it may worsen water stress in sandy regions or cause waterlogging in clay zones.

4.2.4.2 Water resources

The Mutale River is the primary source of water for the Mbahela Irrigation Scheme. The study showed that during the RESIS programme, the irrigation scheme relied on water stored in the farm dam and was delivered to the field through the irrigation system. A shift of water source was observed after the RESIS programme where the majority (96.7%) of respondents reported using water that came straight from the Mutale River through a canal conveyance system, with the minority of 3.3% still diverting water from the farm dam.

The Mbahela Irrigation Scheme's water source clearly changed before and after the RESIS initiative, according to the statistics. At first, the irrigation plan mostly used water that was kept in the farm dam, indicating that access to water was restricted to what could be gathered and kept locally. Seasonal restrictions, possible evaporation losses, and limited water supply during dry spells are only a few of the possible effects of this reliance on dam water.

Most of the farmers (96.7%) started using a canal conveyance system to obtain water straight from the Mutale River following the RESIS initiative. This change suggests that water is becoming more dependable and accessible. Farmers can obtain a steadier and more plentiful supply of water by taking it straight from the river. This should improve irrigation effectiveness, lessen reliance on stored water, and possibly enable more effective cropping cycle planning.

Due to factors including proximity, personal desire, or the inability of canal infrastructure to reach their plots, the small minority (3.3%) who still rely on the farm dam may do so. This change, taken as a whole, shows how the RESIS initiative has improved the management and infrastructure of water distribution. For farmers taking part in the programme, it probably results in increased productivity, increased drought resistance, and better livelihoods. It also emphasises how crucial dependable water supplies are to the long-term viability of small-scale irrigation projects.

4.2.4.3 Water Rights

The distribution of responses regarding water rights remains consistent during and after the RESIS programme, with 44.3% reporting having water rights and 55.7% indicating a lack of water rights. The study found that during the RESIS and post-RESIS periods, a sizable fraction of farmers in the Mbahela Irrigation Scheme lacked valid water rights. Since safe water rights are essential to efficient and long-term irrigation management, this is an important discovery. In South Africa, water rights—now known as water use authorisations under the National Water Act 36 of 1998—give people the legal right to take and use water. They are important because they guarantee fair distribution, encourage effective use, and make it possible to invest in irrigation infrastructure over the long run (Backeberg & Odendaal, 1998; Speelman et al., 2010).

Without official water rights, farmers are insecure about their water supply, leaving them open to disagreements, bureaucratic limitations, or even supply disruptions during shortages. Farmers may be deterred by this uncertainty from making maintenance investments, modernising infrastructure, or implementing water-efficient technologies (Speelman et al., 2008). Additionally, farmers' participation in official water user associations—which are frequently essential for coordinated scheduling, distribution system maintenance, and water allocation negotiations—may be restricted by the lack of legal recognition (Van Koppen et al., 2014).

The fact that this issue persisted following the RESIS programme indicates that institutional water governance was not sufficiently addressed during the revitalisation phase. Ignoring the organisational and legal aspects of water allocation can jeopardise the sustainability of a programme, even while physical infrastructure renovation is crucial. Secure water rights enhance farmers' bargaining power and their readiness to pay for scheme maintenance and operating expenses, according to research conducted in the Limpopo (Speelman et al., 2010).

Therefore, in future revitalisation initiatives, enhancing the security of water rights should be given equal priority with infrastructural improvements. This could entail training farmers on water law compliance and rights enforcement, helping them with the administrative process of acquiring authorisations, and incorporating them into recognised water user associations.

4.2.5 Governance structure and practices

Results in Table 8 illustrate the continuity and changes in governance structures, practices, and farmer satisfaction within the cooperative management system during and after the intervention through the RESIS programme.

Table 8: Status of cooperative management system during and after the RESIS programme

		Frequency	Percentage	Frequency	Percentage
		During RESIS Programme		After RESIS Programme	
Are farmers in a cooperative management system?	Yes	56	91.8	49	80.3
	No	5	8.2	12	19.7
Did the members have a constitution or rules for the governance of the cooperative?	Yes	37	60.7	35	57.4
	No	24	39.3	26	42.6
Did the members keep minutes of meetings?	Yes	38	62.3	43	70.5
	No	23	37.7	18	29.5
Were farmers receiving a salary?	Yes	25	41.0	6	9.8
	No	36	59.0	55	90.2
Did the farmers receive farm produces for free?	Yes	30	49.2	45	73.8
	No	31	50.8	16	26.2

The results in Table 8 indicate that most of the farmers (91.8%) were in a cooperative management system during the RESIS programme; however, a slight decrease was observed after the RESIS programme, with only 80.3% reporting to be in a cooperative management system. Although some farmers have reported being under a cooperative management system during the RESIS programme, 39.3% of respondents indicated that the cooperative did not have a constitution that governs the cooperative. 42.6% of respondents still indicated that the cooperative still lacks the constitution, whereas 57.4% reported the existence of the cooperative constitution. In terms of salaries, some 49.2% of the respondents reported that they were receiving salaries during the RESIS programme, whereas 50.8% indicated that they never received salaries. 50.8% of respondents have indicated that they did not receive farm produce for free, whereas 49.2% reported having received free produce during the RESIS programme. The produce that was provided free to farmers was the one that was not of good quality for the market.

For smallholder irrigation programmes to operate sustainably, effective governance mechanisms are essential. In this sense, governance refers to the formal and informal structures, regulations, decision-making procedures, and leadership configurations that direct the administration of scheme assets, plan member activities, and settle conflicts. Effective governance guarantees openness, responsibility, fair involvement, and compliance with established financial and production agreements (Cleaver & Franks, 2008; Van Averbeke et al., 2011).

The strategic partner's participation in the RESIS initiative significantly influenced the governance procedures in the Mbahela Irrigation Scheme. The strategic partner implemented operational strategies through the joint management committee, and decision-making authority was frequently centralised. A clear chain of command was established by this system, but direct farmer participation in some crucial decisions, like crop selection and marketing tactics, was also restricted. With differing degrees of adherence to constitutions, regulations, and group decision-making procedures, governance duties essentially passed to the cooperative's leadership and individual farmers following the RESIS program. Scheme performance is directly impacted by how well governance mechanisms work. While bad governance may lead to conflict, resource misuse, and ultimately a reduction in scheme operations, strong governance can foster collaboration, guarantee timely payment of contributions, and facilitate communal marketing (Bembridge, 2000).

Figure 7 indicates that the majority (62.3%) reported that the members of the cooperative kept minutes of the meetings during the RESIS programme, with improvement being observed after the RESIS, where 70.5% indicated that the current cooperative keeps minutes of the meetings.

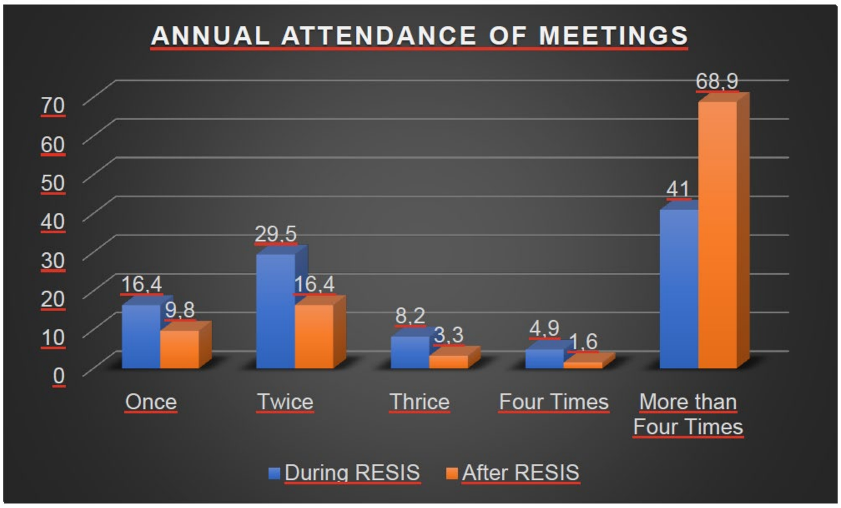

Figure 7 Frequency of meeting attendance

Attendance at meetings increased significantly following RESIS, as seen in Figure 7. During the RESIS period, meeting attendance was mainly concentrated in the categories "more than four times" (41.0%) and "twice per year" (29.5%). The "more than four times" category increased significantly to 68.9% following RESIS, whilst the "once" and "twice" categories fell to 9.8% and 16.4%, respectively. To put it briefly, after the strategic collaboration ended, farmers started holding regular meetings instead of just rare ones.

The change implies that farmers depended more on their own meetings to plan agricultural activities, exchange information, and settle daily conflicts when there was no resident strategic partner. This is in line with data found elsewhere in the dissertation that farmers reactivated internal forums (such as committees and general meetings) as their primary governance route because of a decline in direct partner–farmer connection. Regular gatherings can foster collaborative action, enhance rule enforcement, and increase social capital, all of which are essential components of efficient common-pool resource management in irrigation systems (Pretty, 2003; Ostrom, 1990).

More frequent attendance may be advantageous because it can expedite decision-making (such as planning turns, maintaining canals, and arranging input purchases), enhance accountability, and lessen coordination failures, all of which are long-emphasised outcomes in guidelines for smallholder irrigation revitalisation (Denison & Manona, 2007a; 2007b). However, to prevent elite capture, a common governance risk in farmer cooperatives, benefits rely on equitable participation and meeting quality (clear agendas, recorded minutes, follow-up on actions) (Francesconi & Ruben, 2008). To turn increased attendance into long-term operational benefits, meeting protocols (such as quorum rules, minute-taking, and action logs) should be strengthened.

4.2.5.1 Farmers’ satisfaction with the cooperative management system

Figure 8 captures a summary of farmers’ satisfaction with the cooperative management system.

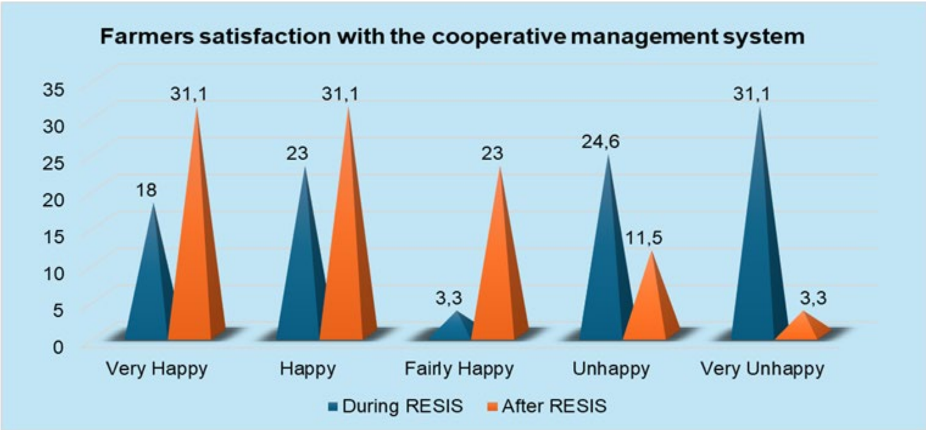

Figure 8: Farmers satisfaction with the cooperative management system

Figure 8 above highlights the satisfaction of farmers with the cooperative management system that was in place during and after the RESIS programme. Most of the respondents (31.3%) indicated that they were very unhappy with the cooperative management system that was in place during the RESIS programme; however, 31.1% indicated their satisfaction after the RESIS programme.

The findings point to a significant change in farmers' opinions on the cooperative management structure between before and after the RESIS initiative. A sizable percentage of farmers voiced their displeasure with the scheme; many said they were extremely unhappy with the way the cooperative was run. Poor governance, unclear constitutions, unfair benefit distribution, or inefficient cooperative decision-making could all be contributing factors to this discontent.

A comparable percentage of farmers expressed satisfaction with the management system following the RESIS program, which could point to some enhancements in member benefits, communication, or cooperative operations. The fact that satisfaction levels are not particularly high, however, suggests that there are still issues and that many farmers may still be frustrated with equity, participation, and governance.

All things considered, this suggests that although the RESIS program might have improved attitudes toward cooperative management, more work is required to fortify governance frameworks, enhance accountability, and guarantee that each member is treated equitably. Addressing these problems is essential for sustaining farmer involvement, fostering better teamwork, and raising the irrigation scheme's overall efficacy.

4.2.6 Capacity development

Figure 9 encapsulates a summary of training status provided to farmers during and after the implementation of RESIS programme.

Figure 9: Status of training provided to farmers during and after the RESIS programme

Figure 9 indicates the proportion of respondents who received training during and after the RESIS program. Only 19.7% of respondents had undergone different training, such as the production of okra and drip layout, while the majority (80.3%) did not attend any training during the RESIS programme. An increase in lack of training was observed after the RESIS programme, where only 16.4% of respondents reported having undergone training, while the majority (83.6%) had not. There is a slight decrease in the percentage of respondents who received training after the RESIS program compared to before. Respondents who attended the training after the RESIS programme indicated that the training was offered by the Department of Agriculture and Rural Development.

The irrigation system, which was previously installed, required a high level of knowledge and skill for the operation and maintenance; hence, a strategic partner with vast knowledge and skill in the use of the FIS was deployed to work with farmers for three years. Mentorship on commercial farming and training on the operation and maintenance of the FIS were two of the key aspects that the strategic partner had to focus on to ensure that the irrigation scheme continues to be commercially viable at the end of the three-year contracts. Lack of mentorship with regard to commercial farming and training on the use of FIS was observed in the study.

With only a tiny percentage of respondents having received training in crucial areas like crop productivity and irrigation system operation, the data show that farmers received little mentorship and training during and after the RESIS initiative. Given that the scheme's shoddy irrigation system necessitates technical expertise for correct operation and maintenance, this limited exposure is worrisome. Farmers' capacity to effectively use the irrigation system may be diminished by the absence of post-programme continuing training and mentoring, which could jeopardise output and the scheme's financial sustainability.

The reduction in training following the RESIS program indicates a gap in capacity-building and knowledge transfer, even though the strategic partner offered targeted support during the program. Farmers may struggle with crop management, maintenance, and commercial farming methods without ongoing training and mentoring. This could result in underuse of the irrigation system, lower yields, and lower income. These results imply that ongoing capacity-building, mentoring, and technical assistance are critical to the sustainability and commercial productivity of irrigation projects like Mbahela. Enhancing training initiatives would increase system effectiveness and provide farmers the ability to independently and successfully run the program.

4.2.7 Involvement of farmers in marketing

The results below indicate changes in market dynamics and farmers' involvement in marketing, market channels and transportation methods during and after the RESIS programme.

Figure 10: Demonstration of the market responsibility during and after the RESIS programme

It is important to comprehend the advantages and disadvantages of the strategic partnership model to know that the strategic partner was solely in charge of crop marketing during the RESIS program, with farmers not participating in any marketing-related activities. On the one hand, concentrating marketing under the strategic partner probably guaranteed access to existing customers, reliable quality assurance, and the ability to bargain for lower pricing through large purchases. According to Magingxa and Kamara (2003), smallholder farmers who do not have access to market networks, negotiating strength, or awareness of quality and grading criteria may find such arrangements especially advantageous in the near term.

This marketing arrangement also prevented farmers from acquiring the knowledge, expertise, or connections needed to compete on their own in the market. Numerous studies have demonstrated that excluding farmers from marketing responsibilities during revitalisation initiatives can lead to dependency, making it challenging for them to continue producing and generating income once outside assistance ceases (Ledwaba, 2013; Van Averbeke et al., 2011).

With 90.2% of farmers marketing alone and just 9.8% marketing together, the whole marketing burden was transferred to the farmers following the RESIS initiative. Individual marketing frequently leads to lower sales volumes, weaker bargaining positions, and increased exposure to price volatility, even though it gives farmers the ability to select buyers and possibly seize specialised opportunities. Collective marketing, on the other hand, can increase negotiating leverage with buyers and input suppliers, lower transaction costs, and improve economies of scale (Bienabe et al., 2004). A lost chance to use cooperative structures to improve market outcomes is indicated by the low percentage of farmers marketing cooperatively following RESIS.

The drop in scheme performance after RESIS may be explained by this shift from a centralised, partner-led marketing system to highly fragmented individual marketing. Farmers struggle to meet quality and volume standards, stabilise prices, and gain access to bigger, more profitable markets in the absence of collective marketing agreements. In order to prepare farmers to manage marketing functions independently and sustainably after external partners withdraw, it is crucial for future revitalisation efforts to combine initial marketing support with capacity-building initiatives that teach them buyer negotiation, quality control, market analysis, and cooperative marketing strategies. The study revealed that the strategic partner was entirely responsible for the marketing of crops, and farmers were not involved in any activities concerning marketing. Farmers started being responsible for the marketing of crops after the RESIS programme, where 90.2% of farmers marketed individually, whereas 9.8% marketed jointly.

4.2.7.1 Market Channels

The figure below represents the types of markets that were used by the irrigation scheme during and after the RESIS Programme

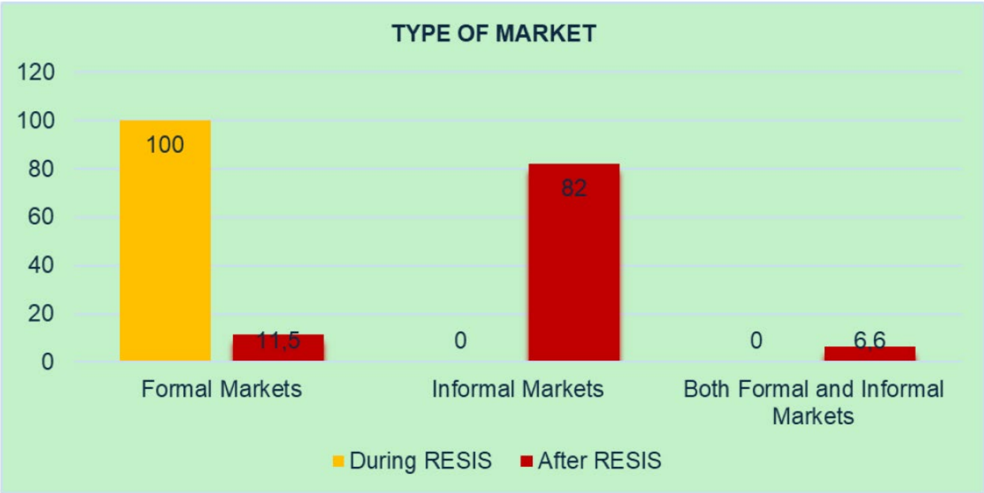

Figure 11: Types of markets used during and after RESIS programme

As shown in Figure 11, during the RESIS programme, farm produce was sold almost exclusively to established formal markets. After the program ended and most farmers started selling to any market outlet that was open, this drastically changed. According to the findings, 82% of farmers switched to informal marketplaces, mostly because of a lack of formal customers and a drop in food quality brought on by inadequate irrigation water. Just 6.6% were able to function in both market types, while a smaller percentage, 11.5%, continued to sell to formal marketplaces.

The long-term viability of the plan, farmer income, and market stability are all significantly impacted by this transition from formal to informal markets. Although formal marketplaces have more stringent quality and quantity standards, they also typically offer more stable prices, higher purchasing volumes, and predictable demand (Bienabe et al., 2004). Farmers are finding it more challenging to meet these demands because of the RESIS programme's decrease in water supply, which seems to have had an impact on both yields and produce quality. Many turned to unofficial marketplaces as a result, which are more flexible but frequently have lower and more erratic prices.

Additionally, selling one-on-one to unofficial markets might expose farmers to opportunistic buyers, lower their bargaining power, and raise transaction expenses. Since reduced returns lessen the incentive to invest in maintenance, inputs, or better production techniques, they can eventually erode the scheme's commercial viability (Van Averbeke et al., 2011). The tiny number of farmers remaining active in formal markets shows that only those with greater resources, water access, or agricultural management skills are able to maintain the essential standards.

This result emphasises how crucial it is to incorporate market access tactics into revitalisation initiatives. Along with guaranteeing dependable water supplies to maintain production standards, such programmes should concentrate on enhancing farmer capacity in quality control, collective marketing, and buyer bargaining in addition to the physical restoration of infrastructure. Without these steps, smallholder irrigation schemes' viability and profitability may be jeopardised as a result of the shift from formal to informal markets, which is fuelled by limitations in quality and resources.

4.2.7.2 Transportation of products to market

The strategic partner was responsible for the transportation of farm produce from the farm to the market during the RESIS programme. Farmers started being responsible for transporting farm produce from the farm to different markets after the RESIS programme. The findings show that 96.7% of farmers are now individually responsible for the transportation of crops to the market, while 3.3% transport crop produce jointly.

The results indicate that the farm was doing well during the RESIS programme and had access to formal markets. Currently, most farmers do not have formal markets, hence the poor performance of the farm. Farmers need to collaborate or partner and become one farm to produce one product for sustainability and to have access to formal markets and funding. Studies by Mungai et al. (2016), Cousins (2015), and Van Averbeke et al. (2011), cited in Mwadzingeni et al. (2020), further indicate that market access, land size, operational cost, and limited water allocation are constraints to the sustainability of SIS.

A vital link in the value chain, effective transportation of agricultural products from the farm to the market affects both product quality and profitability. The degree to which farmers can access lucrative markets and uphold competitive quality standards in smallholder irrigation schemes can be influenced by the accessibility, affordability, and dependability of transportation (Magingxa & Kamara, 2003).

There were significant differences in transportation arrangements between the RESIS and post-RESIS periods in MIS. The strategic partner usually oversaw and provided funding for transportation during the RESIS program, guaranteeing that produce arrived in official markets on time and in large quantities. By minimising delays, this approach helped farmers maintain quality, increased bargaining power through group delivery, and decreased transaction costs.

Farmers were now in charge of planning and funding their own transportation to markets when the strategic partner withdrew. Many relied on hired cars or small-scale transport, while others utilised their own vehicles for smaller quantities. This change brought with it a number of difficulties. Individual farmers' transportation expenses went up, especially for those who sold in tiny quantities to unofficial marketplaces. Furthermore, the frequency of market excursions increased, but the volume per trip decreased in the absence of coordinated bulk deliveries, which reduced economies of scale and might have raised per-unit transport costs (Van Averbeke et al., 2011).

Following RESIS, the absence of well-organised transportation networks not only increased prices but also had an impact on the quality and freshness of food, particularly for perishable crops. Reduced prices or even the loss of produce could result from delays in reaching purchasers. The trend towards informal channels noted in this study was further exacerbated for certain farmers by their inability to acquire timely and reasonably priced transportation, which further hindered their capacity to reach formal markets with rigorous delivery schedules.

These results highlight how crucial it is to incorporate transportation options into revitalisation plans. Collective transportation plans can lower expenses, increase market accessibility, and preserve product quality, possibly through farmer cooperatives. In the post-revitalisation phase, irrigation projects could be made more economically viable by forming partnerships with local carriers, investing in cooperative-owned vehicles, or facilitating transport subsidies throughout the shift from external to farmer-led management.

The results indicate that the farm was doing well during the RESIS programme and had access to formal markets. Currently, most farmers do not have formal markets, hence the poor performance of the farm. Farmers need to collaborate or partner and become one farm to produce one product for sustainability and to have access to formal markets and funding. Studies by Mungai et al. (2016), Cousins (2015), and Van Averbeke et al. (2011), cited in Mwadzingeni et al. (2020), indicate that market access, land size, operational cost, and limited water allocation are constraints to the sustainability of SIS.

4.2.7.3 Finances

The results below provide an insight into the agreement that was made between the strategic partner and the farmers in terms of profit sharing and the bank used for sales of farm produce during and after the RESIS programme.

Table 9: Farm finance arrangements during and after RESIS programme

		Frequency	Percentage	Frequency	Percentage
		During RESIS Programme		After RESIS Programme	
Are there contractual arrangements on the profit-sharing ratio?	Yes	15	24.6	2	3.3
	No	41	67.2	59	96.7
Are you able to access the financial records of the irrigation scheme?	Yes	7	11.5	28	45.9
	No	54	88.5	33	54.1
Is profit shared as per the contract agreement?	Yes	2	3.3		
	No	59	96.7	61	100.0

Contractual agreements for revitalised irrigation schemes must include farm finance arrangements since they dictate how inputs are financed, costs are recouped, and revenues are distributed. The strategic partner was responsible for procuring the necessary inputs, such as seeds, fertiliser, agrochemicals, and other production expenses during the RESIS programme at Mbahela Irrigation Scheme. Before any earnings were given to farmers, these expenses were recouped at the conclusion of each crop. This model put the strategic partner in a strong financial position, controlling both profit distribution and cost recovery, even though it also lessened the upfront capital requirements for farmers, which is crucial for smallholders with limited resources.

The results of the survey show that most farmers had a poor understanding of these contractual arrangements. The majority (67.2%) of respondents said they knew nothing about the terms of the agreement, and just 24.6% said they were aware of the profit-sharing ratios and related financial aspects. Additionally, 88.5% of respondents said they were unsure if the sums they got were correct, and 96.7% said earnings were not distributed in line with the contract. This issue was further compounded by restricted access to financial records, with only 11.5% of respondents having ever seen the scheme's financial statements.

According to Cleaver and Franks (2008), such opacity runs counter to the ideals of equitable and open contractual partnerships, which call for both parties to have equal access to information and the capacity to confirm financial transactions. Because members are unable to precisely ascertain if agreed agreements have been upheld, the absence of clarity and transparency also runs the danger of undermining trust between farmers and strategic partners.

Farmers' operational capability has been significantly impacted by the lack of financing from strategic partners since the RESIS programme terminated. Individual farmers today find it difficult to finance input purchases due to a lack of accessible, reasonably priced credit or group financing options, which has a direct impact on output and the capacity to satisfy market quality standards. A structural flaw in the initial contractual structure is shown by this transition: it did not increase farmers' ability to manage scheme funds after partnership or obtain independent financing.

Contractual arrangements pertaining to farm finance for upcoming revitalisation initiatives should be clear, available to all parties, and planned with an exit strategy that guarantees farmers may continue operating on their own. This could involve establishing cooperative savings or input funds, facilitating partnerships with credit providers, and providing financial literacy training. Such actions would increase irrigation schemes' long-term viability and lessen their financial risk after the collaboration.

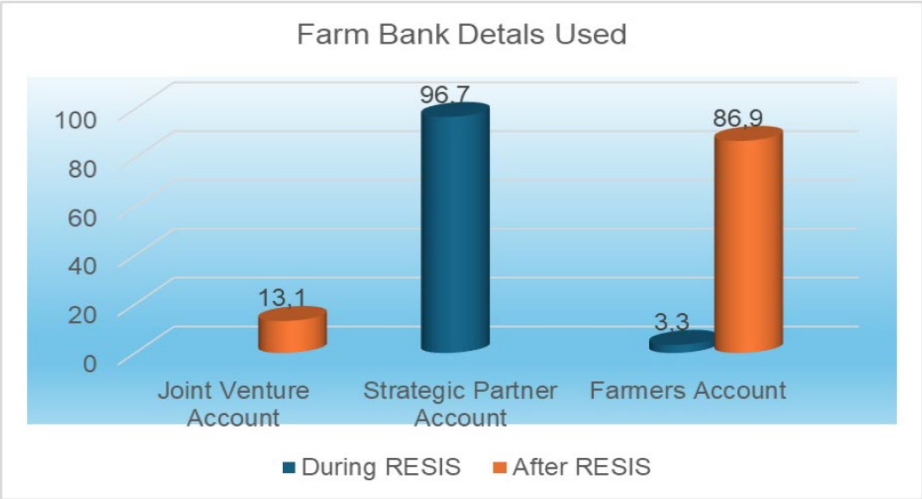

Figure 12: Farm banking details used during and after the RESIS programme

The findings shown in Figure 12 demonstrate a notable shift in the way financial transactions were managed during the RESIS and post-RESIS periods. A resounding 96.7% of participants in the RESIS programme stated that farm produce was sold using the strategic partner's banking information. Because of this arrangement, the strategic partner was in charge of managing the deduction of operating expenses and the distribution of profits once the money from crop sales was initially placed into an account under their control. While 13.1% reported using joint venture banking data (which would have overlapped with the strategic partner's management), just 3.3% reported using a farmer's account.

The strategic partner's centralised banking may have expedited transactions and guaranteed on-time payments to creditors and suppliers, but it also concentrated financial power in the hands of one person. The lack of openness in profit-sharing arrangements mentioned elsewhere in the paper was exacerbated by this structure, which also made it harder for farmers to monitor cash flows and sales income. Farmers' impressions of unequal benefit distribution and diminished faith in the partnership were probably strengthened by their inability to directly monitor contributions, withdrawals, and general account activity.

Following the conclusion of the RESIS programme, the majority of farmers began selling their produce using their personal banking information. A significant step toward achieving financial independence and direct control over farm income is represented by this move. Farmers who get payments directly are better equipped to handle money, monitor transactions, and make spending decisions free from the influence of middlemen. But this change also gives individual farmers more accountability for budgeting, maintaining records, and making sure input expenses are paid on time.

There are advantages and disadvantages to switching to individual banking arrangements. On the one hand, it empowers farmers by lowering their reliance on outside parties for financial management and providing them with direct access to income. However, individualised financial management can result in uneven reinvestment in production, fragmented market activity, and susceptibility to financial mismanagement in the absence of sufficient financial literacy, collaborative oversight, or collective bargaining tools.

Banking arrangements for future revitalisation projects should be created with efficiency, openness, and farmer empowerment in mind. Cooperative-controlled bank accounts with two signatures, frequent financial reporting to members, and financial management skill building are a few potential models. This strategy would guarantee that everyone has a clear view of income and expenses while maintaining some of the benefits of centralised financial coordination.

4.2.8 Strategic partnership

The result below provides an understanding of the process that was used to appoint a strategic partner and the relationship between the strategic partner and farmers during and after the RESIS programme.

Table 10: Selection and appointment of the strategic partner before the strategic partnership

		Frequency	Percentage
		During RESIS Programme	
Did you know the strategic partner before appointment?	No	61	100.0
Were farmers involved in the identification and selection of the strategic partner?	Yes	2	3.3
	No	59	96.7
Did the strategic partner involve farmers in decision-making?	Yes	4	6.6
	No	57	93.4
Were roles and responsibilities of the strategic partner and farmers clearly indicated?	Yes	28	45.9
	No	33	54.1

The results shown in Table 10 demonstrate that respondents were not very involved in the process of choosing and identifying the strategic partner. About 96% of respondents said that they were not participating, indicating that the majority had no role or influence in the decision-making process. Just 3.3% of respondents said they had participated, indicating very little commitment. It was also mentioned that the government chose and designated the strategic partner, demonstrating a top-down decision-making process. This centralisation implies that government officials chose partners primarily, with minimal involvement from stakeholders or the general public. A sense of exclusion or a lack of control over the process could result from respondents' perceptions of the strategic partner's legitimacy and efficacy being impacted by such low participation.

These findings suggest that the government played a major role in choosing the strategic partner, with little involvement from the participants. This could have consequences for accountability, participation, and the partnership's overall performance. There is a glaring absence of farmer participation in irrigation scheme decision-making. According to the findings, it is clear that the management strategy was primarily top-down because 93% of respondents said the strategic partner did not include them in decision-making. Farmers' sense of ownership and dedication to the scheme's success may be diminished by their exclusion from decision-making processes, since people are less inclined to actively participate or accept responsibility when they are not included in important choices.

The survey also reveals a substantial knowledge gap about personal accountability. Just 45.9% of respondents knew what was expected of them, while the majority of 54.1% said they were unsure of their precise tasks within the irrigation plan. Because farmers might not know how to effectively manage their plots, communicate with the strategic partner, or carry out their responsibilities that support the scheme's overall management, this ambiguity can lead to operational inefficiencies. Due to unclear expectations and accountability, it may also result in disputes or miscommunications between farmers and the strategic partner.

These findings imply that communication and governance issues plague the irrigation programme. The scheme's sustainability and productivity may be impacted by the combination of low farmer involvement in decision-making and a vague division of duties, which undercuts collaborative management. Enhancing farmer involvement and clearly defining roles and responsibilities could improve coordination, accountability, and the overall viability of the irrigation scheme.

4.3 Bio-physical factors that characterised the Mbahela Irrigation Scheme

4.3.1 Irrigation systems

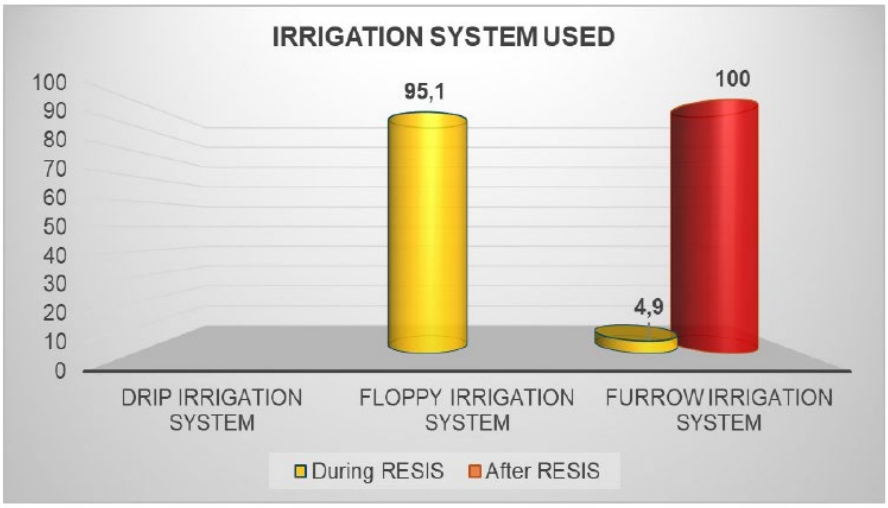

Figure 13: Types of irrigation systems used by the irrigation scheme

Figure 13 reveals that respondents' irrigation habits changed significantly both during and after the RESIS program. 95.1% of respondents reported using the floppy irrigation system, making it the most used method during the RESIS program. Just 4.9% of respondents reported that they were still using the furrow irrigation technology at that time. This implies that the floppy irrigation system, which might have been seen to be more effective, economical, or appropriate for the current agricultural conditions, was actively encouraged or supported by the RESIS programme.

However, following the RESIS initiative, there was a notable change in irrigation techniques. The study results demonstrated a full shift away from the floppy irrigation system. This shift could be the result of multiple underlying causes. First, it can imply that, although initially implemented under the programme’s direction, the floppy irrigation system was not long-term viable for farmers because of issues with upkeep, water availability, equipment costs, or crop and soil appropriateness. Second, farmers may have favoured a technique they were more accustomed to or considered more dependable for their everyday operations if they switched back to the furrow irrigation system.

The result draws attention to a crucial aspect of agricultural interventions: initial adoption of a marketed technology does not always imply continued use. Experience, resource availability, and pragmatic considerations all play a role in farmers' decisions. To achieve sustained uptake and success, the programme’s transition from a floppy irrigation system to a furrow irrigation system highlights the necessity of extension support, continuous training, and assessment of the appropriateness of introduced technology.

This result shows the practical realities that influence farmers' decisions after the RESIS programme, as well as the programme’s influence in introducing new irrigation techniques. It emphasises how crucial it is to promote agricultural technologies while taking sustainability, farmer preferences, and contextual considerations into account.

Table 11: Farmers satisfaction regarding irrigation systems during and after RESIS programme

		Frequency	Percentage	Frequency	Percentage
		During RESIS Programme		After RESIS Programme	
Were you satisfied with the irrigation systems used?	Yes	45	73.8	10	16.1
	No	16	26.2	51	82.3
Did you have a role in the operation and maintenance of irrigation system?	Yes	2	3.3	19	30.6
	No	59	96.7	42	67.7

According to the statistics, 73.8% of farmers expressed satisfaction with the floppy irrigation system's initial reception during the RESIS initiative. This implies that the new or modern irrigation system was well received, most likely because it offered advantages over conventional techniques, including better water distribution, increased efficiency, and the possibility for larger crop yields. An understanding of the innovation and its potential to increase irrigation scheme production is shown in the initial satisfaction.

However, following the programme, 82.3% of farmers showed no interest in the floppy irrigation method, indicating a considerable reduction in interest. This decrease can be attributed to farmers' limited participation in system upkeep and operation. Since the strategic partner had hired outside staff to handle irrigation system management, the majority of respondents (96.7%) were not in charge of this task. Just 3.3% of respondents said they were directly involved in operation and maintenance. Farmers' knowledge and comfort with the technology were probably diminished by this lack of practical experience, which made it challenging for them to continue using it on their own when the programme was over.

The results emphasise the importance of beneficiary ownership and active participation in the sustainability of contemporary agricultural technologies. Farmers may quickly lose their initial delight with technology if they are not involved in its management or upkeep, and they may turn back to more conventional techniques that they can use on their own. According to these findings, farmers must be actively involved in the operation of contemporary irrigation systems, such as the floppy irrigation system, and trained to operate them themselves in order for them to be successfully adopted over the long run. This will guarantee continuity and continuous interest after the RESIS program period is over.

Figure 14 presents the preferred irrigation systems during and after the RESIS programme period.

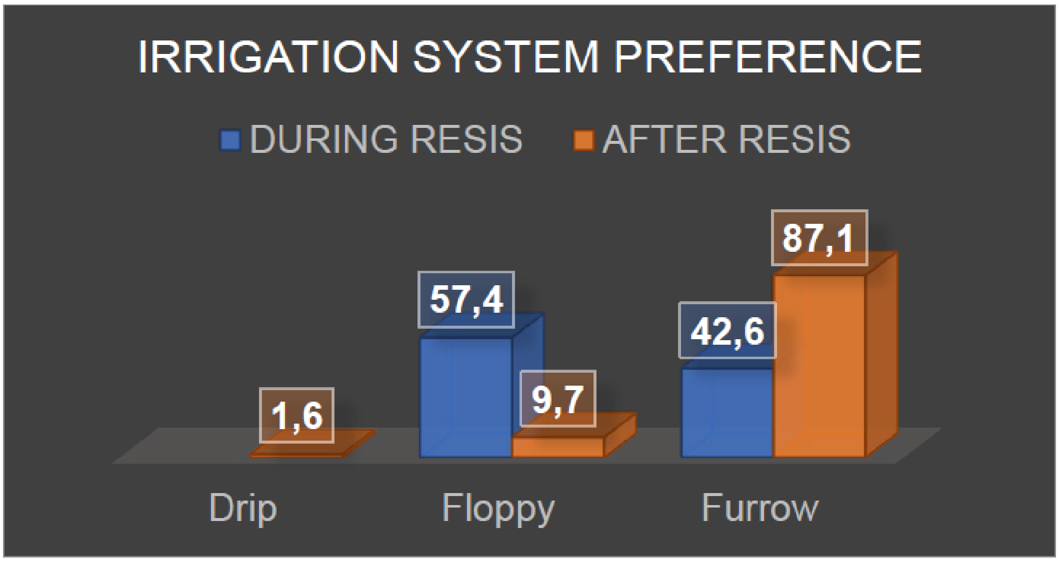

Figure 14: Irrigation systems preferred by farmers during and after the RESIS programme

The results in Figure 14 indicate that 57.4% of the farmers favoured the floppy irrigation system, while 42.6% preferred the furrow irrigation system during the RESIS programme. The majority (87.1%) now prefer the use of the furrow irrigation system due to its low operation and maintenance costs, while smaller percentages favour the floppy irrigation system (9.7%) or drip irrigation system (1.6%).

Senyolo et al. (2018) reported that old-age farmers are not enthusiastic about adopting new technologies. The same results were observed in the study where the Mbahela Irrigation Scheme farmers were reluctant to adapt to the FIS; hence, they reverted to using their traditional method of irrigation, which is furrow irrigation, immediately after the RESIS programme. Mango et al. (2018) have also observed that older farmers find it difficult to adapt to new technologies.

4.4 Effects of the socio-economic and bio-physical factors on scheme sustainability

Tables 12 and 13 below present the logistic regression outcomes, highlighting the factors that are likely to influence the farm's performance during and after the implementation of RESIS programme. The results of these analyses are discussed in the Sections 4.4.1 to 4.4.18 following the tables.

Table 12: Logistic Regression Analysis for the factors during RESIS programme

Factors that are likely to affect farm status during RESIS Programme		
Variables	**Coefficient (B)**	**Standard Error (S.E)**
Age (years)	-1.05	8 565
Highest level of education	5.47	6 385
What was your farming experience before joining the scheme?	12.58	69 182
Were you fully dependent on the scheme as a source of income?	25.73	12 752
Did you have water rights?	-23.08	15 594
Were the farmers in a cooperative management system?	6,.62	65 242
Were farmers farming full-time on the irrigation scheme?	-12.57	19 146
Did the members have a constitution or rules for the governance of the cooperative?	-19.02	14 223
Were farmers receiving a salary?	11.61	18 286
Did the farmers receive farm produce for free?	-0.34	14 149
Did the farmers play a role in the marketing of the crops?	-3.55	65 051
Was the road infrastructure to the farm in good condition?	10.20	28 506
Was there communication between farmers and strategic partner?	15.95	12 053

Table 13: Logistic Regression Analysis for the factors after the RESIS programme

Factors that are likely to affect farm status after RESIS Programme		
Variables	**Coefficient (B)**	**Standard Error (S.E)**
Age (years)	-0.56	0.70
Highest level of education	-0.10	0.62
Are you fully dependent on the scheme as a source of income?	0.69	1.43
Do you have water rights?	-0.76	0.93
Did the farmers remain in a cooperative management system?	21.65	11 437
Do the members have a constitution or rules for the governance of the cooperative?	-0.65	1.29
Do farmers receive a salary?	-0.21	1.46
Is the farm road infrastructure in good condition?	-0.31	1.18
Are there any dispute resolution mechanisms put in place?	-0.10	24 613
Have you received training after the strategic partnership?	-1.12	1.23
Do you participate in the selection of the crops grown per season?	-21.06	11 437
Do you currently have a role in the operation of the irrigation system?	0.90	1.15
Do you have a role in the management of the irrigation scheme?	0.35	1.45

4.4.1 Effects of farmer age on scheme sustainability

A significant socioeconomic determinant that affects farmers' risk tolerance, decision-making, and adoption of agricultural technologies is age. Additionally, it affects the long-term viability of irrigation projects because younger farmers might be more adaptable and able to handle physically taxing jobs, whereas older farmers might have more valuable farming experience but be less likely to embrace new methods or technologies (Rao & Qaim, 2011).

The logistic regression analysis revealed that age was differently associated with farm operational status during and after the RESIS programme The age coefficient during the RESIS period was -1.05, meaning that the probability of a farm remaining operational decreased as farmers' ages grew. This implies that older farmers might have been less inclined to follow new production and management systems, less involved in scheme activities, or less able to adjust to the strategic partner's organized arrangements. These trends align with research on smallholder irrigation in South Africa, which shows that elderly farmers tend to become less involved in community agricultural systems (Van Averbeke et al., 2011).

On the other hand, following the RESIS programme, the age coefficient was +0.56, indicating that a higher age was linked to a higher chance of farms continuing to operate. Older farmers' greater dedication to farming as their main source of income, local understanding of production methods, and accumulation of farming experience may all contribute to this beneficial link. Compared to younger farmers, some of whom would have looked for other sources of income outside farming, older farmers might have been more resilient and better equipped to handle the difficulties of self-management in the absence of the strategic partner.

This change emphasises how age plays a dynamic role in the sustainability of the system. Younger farmers might adjust more easily to externally driven, formalised partnerships, but in farmer-led environments, the experience and dedication of older farmers become crucial for continuity. These results emphasise how important it is for all age groups to participate equally. By making irrigated farming more attractive (for example, through training, technology use, and financial access), revitalisation programmes should seek to draw in and keep younger farmers while simultaneously utilising the experience and leadership of more seasoned farmers to maintain stability and continuity.

The results further suggest that older farmers might have faced challenges adapting to or fully engaging with the irrigation scheme during the RESIS programme. This could be due to factors like resistance to new practices or physical limitations. The irrigation scheme used the traditional method of irrigation (furrow irrigation system) before the RESIS programme. A new modern irrigation system (FIS) was introduced to the scheme; however, it was removed immediately after the departure of the strategic partner. From the interview questions, the concerned farmers indicated that they did not prefer a FIS over the one they were using before (furrow irrigation system) due to lack of knowledge and the high cost of electricity.

During the RESIS initiative, a modern floppy irrigation system was added to the Mbahela Irrigation Scheme with the goals of increasing crop yields, decreasing labour needs, and improving water-use efficiency. Since floppy systems offer consistent water distribution and can be controlled more precisely than traditional furrow irrigation, they are typically regarded as more sophisticated (FAO, 2012). The quick removal of this system following the strategic partner's departure, however, draws attention to significant obstacles to the uptake and sustainability of innovative technologies in smallholder irrigation systems.

According to the interviews, farmers cited ignorance and the high cost of electricity as their primary objections to the floppy system. The absence of technical expertise indicates insufficient training and a lack of farmer participation in the technology's development and application. Farmers may view new technologies as complicated, dangerous, or incompatible with their current methods if they are not properly trained and given practical experience. This is consistent with earlier research that demonstrates a high correlation between perceived simplicity of use and farmer capacity-building when it comes to the use of technology in smallholder farming (Rogers, 2003).

The difficulty of economic sustainability is highlighted by the second aspect, which is the high cost of electricity. Floppy irrigation systems need energy inputs for pumping and operation, in contrast to furrow irrigation, which mostly depends on gravity flow. The potential productivity gains may be outweighed by the higher operating expenses for farmers with limited resources, particularly in situations where there is limited access to reasonably priced energy. This result is consistent with other studies conducted in South Africa, which indicates that the adoption of contemporary irrigation technology has been significantly hampered by the high cost of energy (Van Averbeke et al., 2011).

The rejection of the floppy system serves as an example of a more general lesson: technological interventions in revitalisation programmes need to be not only technically competent but also economically feasible, socially acceptable, and supported by sufficient training and farmer involvement. The RESIS initiative prioritised technological improvement without giving enough thought to farmers' preferences, capabilities, and long-term affordability, as evidenced by the underperformance of the integration of the floppy irrigation system. Farmers should be involved in the selection of irrigation systems, taught in their use and maintenance, and provided with cost-management techniques as part of a participatory approach to technology adoption for future revitalisation initiatives. Without these safeguards, even well-meaning technological advancements run the risk of being shelved as soon as outside funding is removed.

Gutem and Andersen (2016) posit that younger farmers are generally more open to innovation and quicker to adopt modern agricultural methods. Older farmers may prefer traditional methods, which may not align with the technical requirements of a revitalised irrigation scheme. Additionally, Mwangi (2015) argues that age can influence the physical ability of farmers to maintain rigorous farming practices required for high-yield irrigation agriculture. A positive coefficient observed after the RESIS programme suggests that an increase in a farmer's age plays a positive role in farm status enhancement.

From the above Tables 12 and 13, a very high standard error of 8 565 was observed during the RESIS programme, while a low standard error of 0.7 was observed after the RESIS programme. This very high standard error observed during the RESIS programme indicates a lack of consistency in this impact across participants, although it does not mean the results are not robust. This suggests that while age might influence the irrigation scheme condition, the effects vary widely, possibly due to differences in individual circumstances, traits, personalities, or even experience.

The low standard error associated with "after the RESIS programme" results implies accuracy in the findings, supporting the idea that an increase in age can increase the status of the farm because the farmers will be more experienced with farming activities after the implementation of the RESIS programme compared to during the implementation of the RESIS programme. During the RESIS, farmers would be trying to synthesise and regurgitate what is being introduced to them by the strategic partner, and they will be learning how to manoeuvre around all the activities associated with the new irrigation system.

4.4.2 Effects of level of education on scheme sustainability

A coefficient of 5.47 was observed during the RESIS programme. This positive coefficient outcome indicates that education plays a supportive role in irrigation scheme success because as the educational level increases, the status of the farm also improves. Educated farmers may be better at managing resources, understanding irrigation practices, and adapting to new methodologies, all of which are essential for sustaining an irrigation scheme. A coefficient of -0.10 was observed after the RESIS programme. The results predict that a decrease in the educational level will result in a decline in farm status.

According to the difference in coefficients, there was a considerable shift in the influence of education in scheme performance between the two periods. Higher education was beneficial during the RESIS programme, as evidenced by the large positive coefficient. This is because educated farmers were better able to comprehend contractual agreements, adhere to management requirements, and interact with the formal systems that the strategic partner had introduced. This result is in line with research that demonstrates how education improves farmers' ability to accept innovations, understand technical data, and communicate with outside organisations (Asfaw & Admassie, 2004; Feder, Just & Zilberman, 1985).

However, the coefficient went slightly negative after the RESIS programme, indicating that the benefit of formal schooling had diminished. Operations relied increasingly on local knowledge, cooperative participation, and practical agricultural skills when the programme was taken over by farmers. In this situation, farmers with more practical farming experience and community connections were frequently better positioned to maintain farm operations, but even highly educated farmers did not always do better. Comparable trends have been observed in other smallholder irrigation programmes, where social organisation and firsthand knowledge might occasionally outweigh the advantages of formal instruction in guaranteeing sustainability (Van Averbeke et al., 2011).

A standard error of 6 385 was observed during the RESIS programme, which is extremely high. In econometric terms, the high standard error reflects high variability, implying that while education generally helps, the degree of its influence may differ significantly among participants. A very low standard error of 0.26 was observed after the RESIS programme, meaning that as educational level decreases amongst the farmers, the status of the farm is likely to deteriorate. According to Magesa (2016), higher educational levels are linked with better managerial skills, knowledge of modern agricultural practices, and a greater capacity to understand and respond to market demands. Moreover, the study conducted by FAO (2017) revealed that educated farmers are better at adopting sustainable practices and using resources efficiently. For instance, Ncube (2018) reiterates that education enables farmers to comprehend complex irrigation management practices, make informed decisions, and implement effective strategies for, inter alia, pest and water management.

4.4.3 Effects of farming experience on scheme sustainability

A coefficient of 12.58 was observed during the RESIS programme as presented in Table 12. The result means that the higher the experience of farmers, the better the condition of the farm. Farmers with more experience are likely better equipped to handle challenges within the scheme. Experienced farmers might contribute positively by applying practical knowledge and problem-solving skills. A standard error of 6 919 was observed during the RESIS programme, as shown in Table 13. This suggests that while experience might be relevant to the study, it is not a consistent predictor of success. This variability could be due to variability in the types of farming experience (for example, the type of crop and the scale of farming) that might or might not align with the needs of an irrigation scheme. Experience can provide practical knowledge, which is crucial for effective irrigation and crop management, making farmers more resilient to challenges such as water scarcity and soil degradation (Shah, 2014). However, literature also suggests that experience without innovation may limit adaptation to new technologies, highlighting the need for a balance between traditional knowledge and modern practices (Mutiro & Lautze, 2015).

4.4.4 Effects of reliance on scheme as a source of income on scheme sustainability

A coefficient of 25.73 was observed during the RESIS programme, and a coefficient of 0.69 was observed after the RESIS programme. A positive coefficient observed shows that relying on the scheme for income may push farmers to make it succeed. However, it could also increase the pressure on the scheme to perform, as failures would directly impact livelihoods. A high positive coefficient for income dependence suggests that farmers relying solely on the scheme may have strong incentives to see it succeed. However, this reliance also places significant pressure on the scheme's resources and infrastructure. Literature on rural livelihoods shows that dependence on a single income source increases vulnerability to economic and environmental shocks, leading to unsustainable farming practices when schemes cannot meet demand (Ellis, 2000; Scoones, 2009). Magingxa and Kamara (2003) propose that when farmers depend heavily on one scheme, any disruptions (such as water shortages) can lead to financial instability, impacting both farmers' livelihoods and the scheme's sustainability.

A high standard error of 12 752 was observed during the RESIS programme, accompanied by a low standard error of 1.43 after the RESIS programme. The high standard error observed during the RESIS programme indicates that the impact of income dependence is not uniform but does not imply that it is irrelevant to the study. Some farmers might have additional income sources, while others are solely reliant on the scheme, leading to diverse outcomes. The low standard error anticipates that depending on the irrigation scheme as the only source of income will contribute positively to the success of the irrigation scheme. Farmers will put more effort into the success of the farm and improve its condition to ensure its sustainability, as they will benefit monetarily and otherwise.

4.4.5 Effects of water rights on scheme sustainability

A coefficient of -23.08 was observed during the RESIS programme, while a coefficient of -0.76 was observed after the RESIS programme. The negative coefficient indicates that unclear or a lack of water rights significantly contributes to the scheme's underperformance. The positive coefficient observed after the RESIS programme indicates that an increase in water rights amongst the individual plot owners will increase the status of the farm. When farmers do not have secure access to water, conflicts or scarcity issues can arise, disrupting the scheme's operations. A standard error of 15 594 was observed during the RESIS programme, while a standard error of 0.93 was observed after the RESIS programme. The high standard error observed during the RESIS programme shows that while water rights are important, the extent of their impact may vary. The low standard error observed after the RESIS programme shows that having water rights will improve the condition of the farm because farmers will no longer fight over water.

For some farmers, lack of rights might be a critical issue, whereas others might face fewer challenges. Secure water rights are essential for the equitable distribution of water, particularly in shared irrigation schemes (Meinzen-Dick & Pradhan, 2002). Lack of clarity or disputes over water rights can lead to conflicts, inefficiencies, and over-extraction of resources, contributing to scheme degradation. Studies show that secure water rights encourage farmers to invest more confidently in irrigation and infrastructure, enhancing productivity (Shah, 2009).

4.4.6 Effects of the cooperative management system on scheme sustainability

A coefficient of 6.36 was observed during the RESIS programme, whereas a coefficient of 21.65 was observed after RESIS. A positive coefficient suggests that cooperative management systems have the potential to support scheme success by fostering collective decision-making and shared responsibilities. A standard error of 65 242 was observed during the RESIS programme, while a standard error of 11 437 was observed after the RESIS programme. These high standard errors reflect that this benefit is inconsistent but not unexplainable nor irrelevant.

The effectiveness of cooperative management might vary based on group dynamics, leadership, and individual commitment levels. Francesconi and Ruben (2008) submit that cooperatives can foster collective responsibility, improve resource management, and create economies of scale for smallholder farmers. On the other hand, Ortmann and King (2007) argue that successful cooperatives require effective leadership, clear governance structures, and active member participation. In the absence of these, cooperatives may suffer from mismanagement, free-riding, and internal conflicts, leading to inefficiencies in scheme operation.

4.4.7 Effects of full-time farming on the irrigation scheme sustainability

A coefficient of -12.57 was observed during the RESIS programme. The negative coefficient suggests that farmers who were fully committed to the scheme were more likely to encounter more challenges, potentially due to financial or operational over-reliance on the scheme. A high standard error of 19 146 indicates that the impact of full-time engagement was not consistent across all farmers; while some full-time farmers may have thrived, others struggled depending on factors such as resource availability and the efficiency of the scheme. Full-time engagement might indicate over-reliance, potentially leading to economic stress when the scheme underperforms. Literature on sustainable livelihoods stresses the importance of income diversification in reducing vulnerability, particularly in rural areas (Chambers & Conway, 1992). Farmers who depend solely on one irrigation scheme may lack resilience to disruptions, such as water shortages or poor crop yields, which can threaten their livelihoods.

4.4.8 Effects of governance structure and practices on scheme sustainability

A coefficient of -19.02 was observed during the RESIS programme, while a coefficient of -0.65 was observed after the RESIS programme. A negative coefficient suggests that a lack of formal governance structures can lead to disorganisation and conflicts, contributing to scheme underperformance. Well-defined rules and constitutions provide structure, helping manage resources and resolve disputes. A standard error of 14 223 was observed during the RESIS programme, while a very low standard error of 1.29 was observed after the RESIS programme.

The high standard error observed during the RESIS programme implies that while governance is generally beneficial, its influence can vary but is important. Some farmers might adhere to informal rules, while others need formal structures to function effectively. According to Koppenjan and Klijn (2004), effective governance structures are crucial in resource management, conflict resolution, and enforcement of accountability. Muchara et al.'s (2014) study on SIS indicates that clear constitutions and governance frameworks can help prevent conflicts, streamline decision-making, and enhance efficiency. Without these structures, schemes are prone to mismanagement and inefficient resource allocation.

4.4.9 Effects of farmer's salary on scheme sustainability

A coefficient of 11.61 was observed during the RESIS programme, while a coefficient of -0.21 was observed after the RESIS programme. A positive coefficient observed during the RESIS programme indicates that paying salaries to farmers might increase commitment to the irrigation scheme and the increase in farm status. A negative coefficient observed after the RESIS programme indicates that a lack of salaries might decrease the condition of the farm. A salary provides financial security, reducing pressure on farming yields alone. A standard error of 18 286 was observed during the RESIS programme, while a standard error of 1.46 was observed after the RESIS programme.

The high standard error observed during the RESIS programme indicates that not all participants benefitted equally from receiving a salary, possibly due to variations in salary adequacy or differing individual financial needs. Salaries offer financial stability, enabling farmers to invest in productivity-enhancing practices (Birner & Resnick, 2010). However, salary reliance could also introduce dependency, potentially reducing entrepreneurial motivation and innovation. Studies from Ghana and Uganda show mixed outcomes; while salaries encourage short-term engagement, they may not foster long-term sustainability if not accompanied by skill development (World Bank, 2008).

4.4.10 Effects of receiving inputs for free on scheme sustainability

A coefficient of -0.34 was observed during the RESIS programme. The result might suggest that receiving free inputs can reduce farmer engagement or investment, as they may lack incentives to increase productivity, which will then result in the decline of farm status. A standard error of 4 149 was observed during the RESIS programme. This high standard error indicates variability, suggesting that the impact of receiving free produce is not consistent across participants. According to behavioural economics, free resources can lead to a sense of entitlement, reducing farmers' motivation to work diligently (Thaler & Sunstein, 2008). Moreover, Pender and Fafchamps (2006) note that in schemes where produce is provided freely, farmers may lack the incentive to optimise productivity, leading to overall inefficiency.

4.4.11 Effects of involving farmers in marketing on scheme sustainability

The study observed a coefficient of -3.55 during the RESIS programme. This result suggests that the limited involvement of farmers in marketing might challenge scheme sustainability. When farmers are less engaged in marketing, they may lack motivation or insight into improving productivity. A standard error of 65 051 was observed during RESIS. The very high standard error suggests that involvement in marketing varies greatly in importance for different farmers. Studies show that farmers involved in marketing can respond better to market demands and price fluctuations, maximising their profitability (Dorward et al., 2004). Lack of involvement can isolate farmers from market knowledge, reducing their ability to optimise production and meet demand effectively (Barrett et al., 2011).

4.4.12 Effects of road infrastructure condition on scheme sustainability

A positive coefficient of 10.20 was observed during the RESIS programme, while a negative coefficient (-0.31) was observed after the RESIS programme. A positive coefficient suggests that good road infrastructure supports scheme success by improving access to markets, resources, and services. A negative coefficient observed after the RESIS programme suggests that poor road infrastructure results in the decline of farm status. A standard error of 28 506 was observed during the RESIS programme, while a standard error of 1.18 was observed after the RESIS programme. The high standard error reflects variability, suggesting that not all farmers may experience the same benefit from infrastructure, possibly due to differences in farm locations or infrastructure quality. The positive coefficient indicates that good infrastructure positively impacts scheme success, supporting access to markets, inputs, and services (Hine & Ellis, 2001). Poor infrastructure in rural areas often limits farmers' access to essential resources, reducing productivity and profitability. In the case of the Mbahela Scheme, good infrastructure could ease the transportation of goods and resources, fostering scheme sustainability (Fan & Chan-Kang, 2005).

4.4.13 Effects of farmers-strategic partners communication on scheme sustainability

During the RESIS programme, a coefficient of 15.95 was observed for communication with the Strategic Partner, indicating a positive association with the success of the irrigation scheme. Effective communication can provide support, knowledge sharing, and resources, fostering scheme sustainability. A standard error of 12 053 was observed during the RESIS programme. Despite the high standard error, communication between farmers and the strategic partner remains one of the more influential factors. The variability might result from differences in communication quality and partner responsiveness. Partnerships can provide access to funding, technical expertise, and market linkages, all of which are essential for the sustainability of the scheme (Bebbington & Kopp, 2000). Research shows that when farmers communicate regularly with partners, they can leverage resources and support more effectively, improving the likelihood of scheme success (Pretty et al., 2003).

4.4.14 Effects of dispute resolution mechanisms on scheme sustainability

The negative coefficient (-0.10) observed after the RESIS programme highlights the detrimental impact of inadequate dispute resolution mechanisms on the farm's status. Disputes within irrigation schemes often arise from water allocation issues, land use conflicts, or disagreements over maintenance responsibilities. Meinzen-Dick and Nkonya (2005) emphasise that unresolved disputes lead to inefficiencies, inequitable resource distribution, and reduced stakeholder collaboration. The high standard error (24 613) suggests variability in the way disputes were managed across the scheme, indicating a lack of consistency in applying conflict resolution strategies. This finding underscores the need for accessible and inclusive dispute resolution frameworks. Establishing community-based mechanisms, such as conflict resolution committees or mediation forums, could ensure timely and fair resolution of disputes, fostering a cooperative environment crucial for the sustainability of irrigation schemes.

4.4.15 Effects of capacity development on scheme sustainability

The significant negative coefficient (-1.12) indicates that the absence of robust capacity-building efforts correlates strongly with a decline in the farm's status. Capacity building is critical in equipping farmers with the skills and knowledge required to adopt modern agricultural practices and operate advanced irrigation technologies effectively. Fanadzo and Ncube (2018) argue that without continuous training and support, smallholder farmers cannot optimise resource use, leading to diminished productivity. The low standard error (1.28) points to the reliability of this finding, suggesting that the lack of capacity-building initiatives was a consistent issue across the scheme. The RESIS programme may not have adequately addressed farmers' need for training in technology use, water management, or market engagement. Moving forward, integrating regular training workshops tailored to farmers' specific challenges and leveraging extension services to provide on-the-ground support can significantly improve outcomes.

4.4.16 Effects of farmer participation in crop selection on scheme sustainability

The highly negative coefficient (-21.06) highlights the importance of involving the farmers in selecting crops grown on a seasonal basis. When farmers are excluded from these decisions, the farm’s status deteriorates significantly, as evidenced by this result. Participatory decision-making aligns crop production with farmers' preferences, market demands, and environmental conditions. Pretty (2003) highlights that participatory approaches enhance farmer ownership, encourage cooperation, and improve productivity. The high standard error (11 437) reflects variability in farmers' participation levels, indicating that not all farmers were equally involved in crop selection under the RESIS programme. This variability may have led to disjointed planning and suboptimal use of resources. Promoting collective crop selection processes could ensure that crops are both market-relevant and resource-efficient while fostering greater buy-in from all farmers involved in the scheme.

4.4.17 Effects of farmer roles in irrigation system operations on scheme sustainability

The irrigation scheme's operational status was significantly impacted by farmers' involvement in management operations, as indicated by the positive coefficient of 0.35. This supports the idea that farmers have a sense of ownership that inspires them to safeguard, preserve, and enhance the system when they are actively involved in decision-making and oversight. Therefore, farmer participation goes beyond mere symbolic engagement; it directly contributes to the productivity of farming operations and the sustainability of irrigation infrastructure.

Van Koppen et al. (2009) emphasise that participatory management enhances long-term scheme performance, strengthens maintenance practices, and decreases inefficiencies. This finding is consistent with their findings. Farmers make sure that decisions represent their own needs and objectives by participating in planning, budgeting, and day-to-day operations. This promotes accountability and group responsibility. The robustness of this association is further supported by the model's comparatively low standard error (1.453), which indicates that the beneficial effects of management engagement are constant throughout the sample.

These findings also show that while the RESIS programme acknowledged the value of farmer participation in management, it fell short in establishing robust, farmer-led governance frameworks. By instituting farmer participation in crucial tasks like resource allocation, performance monitoring, and dispute resolution, well-structured management committees could strengthen this effect. In addition to giving farmers more authority, these committees would offer a forum for open communication and group decision-making, two essentials for maintaining irrigation projects when outside partners leave. The findings emphasise how critical it is to transition from management that is controlled by outside forces to governance that is focused on farmers. In addition to improving operational effectiveness, enhancing farmers' involvement in management is crucial for the long-term viability of revitalised irrigation projects.

4.4.18 Effects of farmer roles in scheme management on scheme sustainability

The positive coefficient (0.35) reveals that farmers' participation in management activities benefits the farm's overall status. When farmers participate in managing irrigation schemes, they develop a sense of ownership and responsibility, which motivates them to ensure the system's sustainability. The study by van Koppen et al. (2009) notes that participatory management improves maintenance practices, reduces operational inefficiencies, and strengthens long-term viability. The low standard error (1.45) suggests consistency in this variable's positive impact across the scheme. The RESIS programme appears to have recognised the value of farmer involvement in management, but its effectiveness could be further enhanced by establishing farmer-led management committees. These committees could oversee budgeting, resource allocation, and performance monitoring, ensuring that management decisions are aligned with farmers' priorities and fostering a stronger sense of collective ownership.

4.5 Consolidation of logistic regression analysis results

The logistic regression findings reveal why the Mbahela Irrigation Scheme struggled to perform during and after the RESIS programme. The results point to a combination of socio-economic, governance, and infrastructural weaknesses that undermined sustainability despite the initial promise of revitalisation. During the RESIS programme, several positive factors, such as higher education levels, farming experience, dependence on the scheme for income, cooperative management, provision of salaries, good road infrastructure, and communication with the strategic partner, were associated with improved scheme performance. However, these benefits were not uniform across all farmers, as suggested by the high standard errors. This inconsistency highlights that while some individuals gained from these arrangements, others did not, largely because farmer participation was uneven, and not all farmers had equal access to benefits, information, or roles in the partnership.

At the same time, detrimental factors during RESIS, such as lack of water rights, weak governance, absence of full-time engagement, provision of free produce, and limited involvement in marketing, directly undermined farmer ownership and motivation. For example, the absence of water rights and governance structures meant that farmers had little control over key resources or decisions, reinforcing dependency on the strategic partner. Similarly, excluding farmers from marketing roles reduced their ability to gain market skills and negotiate fair prices, leaving them unprepared to take over once the partner withdrew. These patterns explain why the scheme's performance declined so sharply after RESIS ended: farmers lacked both the institutional framework and the capabilities needed for independent management.

After the RESIS programme, the regression results show a new set of challenges. Factors such as age, education, water rights, governance, salary provision, infrastructure, dispute resolution mechanisms, training, and participation in crop selection all had negative coefficients. This shift illustrates how the absence of external support exposed underlying weaknesses. For instance, without proper governance and transparent financial management, farmers were unable to coordinate effectively. The lack of training and exclusion from crop selection meant that farmers could not innovate or respond to changing market demands. Moreover, the absence of secure water rights and weak infrastructure continued to limit productivity. Together, these challenges explain why the scheme could not sustain operations in the post-RESIS era.

The overall interpretation is that while RESIS temporarily improved scheme performance through external inputs, financing, and partner-led management, it failed to build the internal capacity, governance systems, and resource control necessary for long-term sustainability. Once the strategic partner withdrew, farmers were left with structural weaknesses that translated into poor scheme performance. These findings directly address the aim of the study: to understand the causes of poor performance in the Mbahela Irrigation Scheme. The results demonstrate that poor performance is not due to a single factor but arises from the interplay of weak governance, lack of secure resource rights, insufficient farmer participation, and inadequate infrastructure. Addressing these issues requires an integrated approach that strengthens governance, secures water rights, builds farmer capacity in management and marketing, and ensures infrastructure support. Only by tackling these systemic challenges can revitalisation efforts translate into lasting improvements for smallholder farmers.

4.6 Water reticulation at the irrigation scheme

4.6.1 Water abstraction and distribution

At the time of the current study, Mbahela Irrigation Scheme sourced its water directly from the Mutale River. Water was conveyed to the farms through a canal network without any intermediate storage system and was applied to the farms using a furrow irrigation method.

Figure 15: Main canal that transmits water from Mutale River to the Mbahela Irrigation Scheme

4.6.2 Water flow velocity, discharge and water loss

Table 14 below presents the simple statistics (mean, minimum, maximum, SEM: Standard Error of Mean, and CV: Coefficient of Variation) for the canal flow characteristics (D_{ave}: average flow depth, W_{ave}: average width of the water surface, A_{ave}: average cross-sectional area of flow, V_{ave}: average flow velocity, Q_{ave}: average discharge, and Q_{loss}: water loss rate) at Mbahela Irrigation Scheme during the study. The different water flow characteristics are compared among the main, field-lined and field-unlined canals to determine the significance of differences ($p<0.05$).

Table 14: Simple statistics for water flow characteristics and water losses

	Canal Type	n	Mean	Min	Max	SEM	CV%
D_{ave} (m)	Main Lined	6	2.29	2.05	2.50	0.08	9
	Field Lined	12	0.16	0.09	0.21	0.01	21
	Field Unlined	24	0.13	0.11	0.20	0.01	20
W_{ave} (m)	Main Lined	6	2.21	2.18	2.25	0.02	2
	Field Lined	12	0.46	0.28	0.69	0.03	23
	Field Unlined	24	0.51	0.40	0.64	0.02	15
A_{ave} (m^2)	Main Lined	6	5.07	4.45	5.63	0.22	16
	Field Lined	12	0.07	0.03	0.11	0.01	34
	Field Unlined	24	0.07	0.04	0.11	0.00	29
V_{ave} (m/s)	Main Lined	6	0.53	0.35	0.70	0.06	27
	Field Lined	12	1.11	0.73	1.50	0.09	28
	Field Unlined	24	0.69	0.49	0.93	0.03	19
Q_{ave} (m^3/s)	Main Lined	6	2.87	1.55	4.16	0.46	39
	Field Lined	12	0.08	0.04	0.16	0.01	49
	Field Unlined	24	0.05	0.03	0.09	0.00	41
Q_{loss} (m^3/s)	Main Lined	6	2.77	2.25	3.94	0.27	24
	Field Lined	12	21.09	2.81	32.32	3.15	52
	Field Unlined	24	27.64	3.09	69.53	3.75	66

4.6.2.1 Flow depth, width and cross-sectional area

The results in Table 14 above confirm the general practice that main canal flows are always deeper than in secondary and tertiary canals. In the current study, the average flow depth for the main canal was significantly greater ($p<0.05$) at 2.05±0.08 m (mean ± SEM) than in the field canals. It was interesting to note that the average flow depth in the field-lined (0.16±0.01 m) was significantly greater than in the field-unlined canal (0.13±0.01 m) despite a similarity in their cross-sectional dimensions. The top width of flow (wave) also showed a greater average value (2.21±0.02 m) in the main canal than in the field canals. Unlike in the case of the flow depth, there was no significant difference in the average top width of flow between the field line and unlined canals, with respective values of 0.46±0.3 m and 0.51±0.02 m. Consequently, the average cross-sectional area of flow was significantly greater in the main canal (5.07±0.22 m^2) than in the field canals. Like the case of top width of flow, there was no significant difference between the field line (0.07±0.01 m^2) and the field unlined canal (0.07±0.00 m^2).

In general, these flow characteristics are influenced by the canal parameters, especially the dimensions and slope, which are in turn determined by the area commanded. For instance, a canal that supplies water to a large area is likely to have bigger dimensions than a canal delivering water to a small area. However, flow depth (and consequently the cross-sectional area of flow) can sometimes be controlled to manage water losses from a canal (Mutema & Dhavu, 2022). Nevertheless, the effect of flow depth on canal water loss is still affected by many other factors, including the condition of the lining material and the prevalence of debris and vegetation in the canal (Mutema et al., 2025).

4.6.2.2 Flow velocity

The flow velocity results in Table 14 are illustrated in the form of bar charts in Figure 16 to enhance visual appreciation of the differences. The field-lined canal handle significantly ($p<0.05$) greater flow velocity (1.11±0.09 m/s) than the field-unlined and main canal. The field-unlined can handle greater average flow velocity (0.69±0.03 m/s) than the main canal (0.53±0.06 m/s), which was lined by concrete. While the threshold flow velocities for the canals, under the existing conditions, were not investigated during the study, the general perception is to use lower flow velocities in unlined canals to minimise chances of scouring and erosion of the canal walls and bed. Canal flow velocity is mainly controlled by controlling the flow stream size; however, other factors also play a role e.g., slope of the canal bed, the prevalence of debris and vegetation on the canal, as well as the existence of check dams on the canal (Mutema et al., 2025).

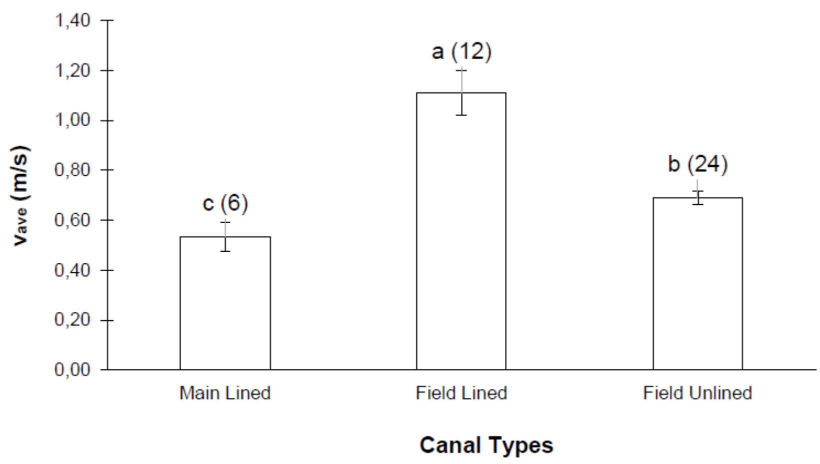

Figure 16: Velocity of water flow in canals during the study. Different letters show significant differences. Numbers in brackets are the sample sizes used for the analysis

4.6.2.3 Discharge

Canal discharge values in Table 14 are also compared in Figure 17. The results show significant differences in discharge between the main, field-lined, and field-unlined canals. The main canal handled an average flow rate (discharge) of 2.87±0.46 m^3/s, which was significantly greater than 0.08±0.01 m^3/s and 0.05±0.00 m^3/s for the field-lined and unlined canals, respectively. The average discharge for the field-lined canal was significantly greater than for the field-unlined canal ($p<0.05$).

These results show that despite the lowest average flow velocity, the main canal still handled the greatest discharge, which is important because it is the source of water supply to all the other canals in the canal network. This great discharge is due to its bigger dimensions, which result in a big cross-sectional area of flow. Handling big discharges at low velocities is important for the sustainability of the infrastructure, because the low velocities keep scouring and erosion of the lining material low, which means the canal remains in good functional condition for a long time. In contrast, the situation of high flow velocity for a small discharge in the field-unlined canal does not promote sustainability. As already alluded to, high flow velocities promote scouring; therefore, it is costly to operate the unlined canals at the irrigation scheme due to the need for frequent maintenance.

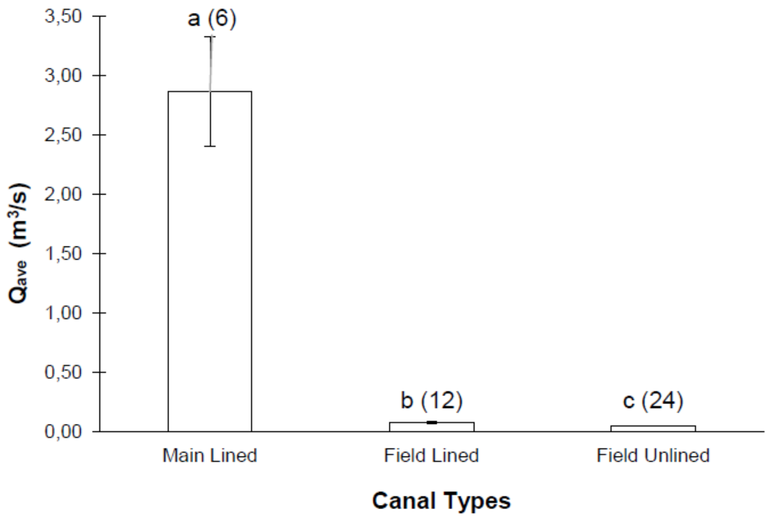

Figure 17: Discharge in canals during the study. Different letters show significant differences. Numbers in brackets are the sample sizes used for the analysis.

4.6.3.4 Water losses

Like the cases for flow velocity and discharge, water loss rates are also compared in the form of bar charts (Figure 18). The comparisons are on an equal canal length basis (per 100 m). The results show an increase of water losses from the main canal (2.77±0.27%) to the field-lined canal (21.09±3.15%) and to the field-unlined canal (27.64±3.75%). Water loss was much smaller in the main canal than the field canals. Despite visual evidence of the greater water losses in the field-unlined than the field-lined canal, the difference was not significant due to high variations in water losses on the two canals. Their respective coefficients of variation were 52 and 66%, compared to 24% for the main canal.

These results conform to the reported results for the Vaalharts Irrigation Scheme (Mutema et al., 2025); however, the study at the Vaalharts Irrigation Scheme did not involve unlined canals. The low water losses in the main canal were explained in terms of superior maintenance of the infrastructure and favourable flow conditions (Mutema et al., 2025). While the person responsible for maintaining the main canal at the Mbahela Irrigation Scheme was not identified, the Vaalharts Water is responsible for that at the Vaalharts Irrigation Scheme. Farmers are expected to be responsible for the welfare of field canals which are in contact with their farms. However, they often lack the skills and time to maintain the canals because their main work is to produce crops. Field canals are also in poorer condition than main canals due to their frequent interaction with human and vehicular movement, which makes them more vulnerable to water losses (Mutema et al., 2025; Mutema & Dhavu, 2022). Higher water loss from field unlined than field lined canals was expected. In general, unlined canals experience high seepage water losses than lined canals (Eltarabily et al., 2023).

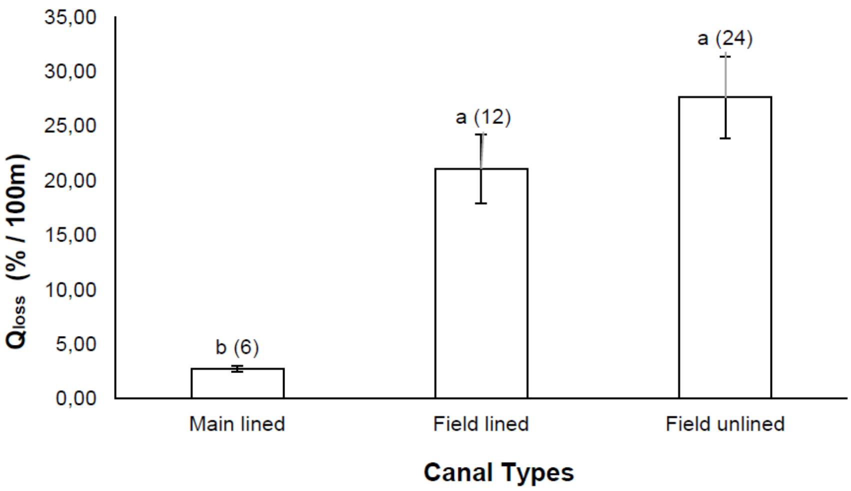

Figure 18: Water loss in canal during the study. Different letters show significant differences. Numbers in brackets are the sample sizes used for the analysis.

4.6.4 Canal network conveyance efficiency

The water loss results (Table 14, Figure 18) were used to compute canal conveyance efficiencies (Table 15). The computed canal network conveyance efficiency is 48.89%, which means 51.11% of the water abstracted from the Mutale River with the intention of irrigating the farms on the Mbahela Irrigation Scheme does not reach the farms. The canal network water loss rate of over 51% is too high and unacceptable for a water-constrained country facing a water demand-supply deficit of at least 17% by the year 2030 (WWF, 2017). This water loss rate at the Mbahela Irrigation Scheme is more than two times greater than at other irrigation schemes in the country, such as the Vaalharts Irrigation Scheme, reported to have a water loss rate of around 21% (Mutema et al., 2025). High irrigation water losses make farming very costly because irrigation is paid for in South Africa. Therefore, this undermines the sustainability of irrigation schemes, particularly the smallholder sector to which the Mbahela Irrigation Scheme belongs. High irrigation water losses may also have negative effects on the environment at large through, for example, creating waterlogged and high-salinity conditions.

Table 15: Water losses and conveyance efficiency after the RESIS programme

Canal Type	Q_{loss} (%)	CE_i (%)
Main lined	2.77	97
Field lined	21.09	79
Field unlined	27.64	72

4.6.5 Correlations between flow characteristics and water losses

The correlations in Table 16 quantify the influences of the different flow characteristics (D: depth, V: velocity, Q: discharge, A: area, PW: wetted parameters, and R: hydraulic radius) on water loss (Q_{loss}) from the canal network at the Mbahela Irrigation Scheme. This analysis allows for the examination of the strengths of the relationships between different canal flow characteristics and water losses. The Pallant (2016) assumptions for correlations (small/weak: $r \approx 0.10$-0.29, medium/moderate: $r \approx 0.30$-0.49, and large/strong: $r \approx 0.50$-1.00) were adopted for the current study.

Therefore, the results show that all the flow characteristics considered had very strong and negative effects on water loss from the main canal, which means increases in their values would decrease the water loss. In contrast, flow velocity (V) and discharge (Q) had significantly positive effects on water losses from the field canals. Flow velocity had greater influence on field-lined canal (r=0.69) than the field-unlined canal (r=0.55). In contrast, discharge had a moderate (r=0.49) effect on water loss from field-unlined canal and a weak (r=0.24) effect in the field-lined canal. The other flow parameters (depth, cross-sectional area, wetted perimeter, and hydraulic radius) did not have significant effects on water losses from field canals.

These correlation results inform that different canal types in an irrigation scheme require different operational strategies when it comes to combating water losses. For example, low water losses from the main canal are attained when the canal is used at maximum capacity i.e., maximum depth, which gives the maximum cross-section of flow and high velocity, which gives rise to high discharge rates. To make this possible, the main canal needs to be lined by concrete, as is the case at most South African irrigation schemes. Unlike the main canal, field canal flow velocity needs to be appropriately regulated because water loss increases with both flow velocity and discharge. The results also call for careful design of field canals, especially the canal bed slope. In line with Manning's formula, the canal bed gradient has a positive flow velocity which will in turn influence the discharge. Therefore, the sustainability of SIS that rely on canals for water distribution requires careful management of flow velocities in the field canals.

Table 16: Correlations between flow characteristics and water loss in canals after the RESIS

Flow Characteristics	Main canal Q_{loss}	Field lined canal Q_{loss}	Field unlined canal Q_{loss}
D	-0.91*	0.13	0.18
V	-0.88*	0.69*	0.55*
Q	-0.87*	0.24*	0.49*
A	-0.90*	-0.03	0.14
PW	-0.90*	-0.05	0.18
R	-0.90*	-0.07	0.04

Note: *at $p<0.05$

D= depth; V = velocity; Q = discharge; A = area; PW = wetted parameters; R = hydraulic radius

CHAPTER FIVE: CONCLUSIONS

This study aimed to investigate the determinants affecting the efficacy of the Mbahela Irrigation Scheme during and subsequent to the RESIS initiative. The investigation indicated that the scheme's inadequate performance results from a confluence of socio-economic, governance, and infrastructural deficiencies.

Throughout the RESIS initiative, scheme success was bolstered by external funding, strategic partner oversight, and access to formal markets. Beneficial factors were education, agricultural expertise, reliance on the programme for income, cooperative management frameworks, and dependable infrastructure. Nonetheless, these gains were inequitably allocated, as evidenced by elevated standard errors in the logistic regression outcomes, indicating that not all farmers equally benefited from the cooperation. Moreover, farmers were marginalised from essential roles such as marketing, financial management, and decision-making. This exclusion fostered dependency and hindered capacity development, rendering farmers ill-equipped for autonomous scheme management.

The loss of the strategic partner revealed numerous flaws. Factors including insufficient water rights, inadequate governance, limited training, deficient infrastructure, exclusion from crop selection, and financial opacity adversely impacted scheme operations. Farmers transitioned from formal to informal markets owing to substandard output and insufficient collective bargaining strength, while individual accountability for input finance and transportation escalated costs and diminished profitability.

The results indicate that the subpar performance of the irrigation scheme is attributable not to farmer reluctance but to structural impediments: restricted access to resources, ineffective governance frameworks, insufficient transparency in financial dealings, inadequate training, and excessive dependence on external collaborators. The RESIS approach effectively revitalised infrastructure in the near term but did not establish sustainable farmer capacity and governance structures for the long run.

In conclusion, for irrigation initiatives such as Mbahela to thrive, revitalisation programmes must extend beyond mere infrastructure restoration and external funding. They should also incorporate farmer empowerment, transparent governance, secure access to natural resources, and robust market linkages. An integrated and holistic approach is therefore essential to ensure that irrigation schemes deliver sustainable and long-term benefits to smallholder farmers.

CHAPTER SIX: RECOMMENDATIONS

The findings of this study indicate that the poor performance of the Mbahela Irrigation Scheme can be attributed to weak governance structures, inadequate financial transparency, unstable resource access, feeble market connections, and excessive reliance on foreign partners during the RESIS programme. To mitigate these challenges, the following recommendations are proposed. These recommendations are organised into three tiers—policy, scheme management, and farmer-level, highlighting the need for a coordinated, multi-tiered approach to ensure the long-term sustainability of irrigation schemes.

6.1 Recommendations at the Policy Level

6.1.1 Ensure Water Entitlements

The lack of official and enforceable water rights emerged as a significant detrimental aspect following the RESIS programme. In the absence of reliable water supplies, farmers are unable to strategise production or adhere to quality benchmarks. The government should prioritise the legal distribution and registration of water rights for irrigation schemes to safeguard farmers from external meddling and disputes over water allocation. This would also promote investment in irrigation, since farmers would have confidence in their sustained access to water.

6.1.2 Facilitate Infrastructure Investment

The reduction in scheme performance following RESIS was partially attributable to the degradation of infrastructure, notably irrigation systems, roadways, and energy provision. Inadequate highways restricted market access, while elevated energy expenses rendered methods such as floppy irrigation unviable. Government and development organisations must allocate resources towards enhancing irrigation infrastructure and rural roadways, while simultaneously investigating economical, renewable energy alternatives to diminish dependence on expensive electricity. Dependable infrastructure would diminish output losses, enhance access to formal markets, and augment farm profitability.

6.1.3 Enhance Financial Accessibility

During RESIS, the strategic partner financed the inputs. Following the partner's departure, farmers encountered difficulties in acquiring inputs, resulting in diminished yields and quality of produce. The government ought to implement finance structures conducive to smallholders, such as low-interest loans, input subsidies, or revolving credit systems administered by cooperatives. Access to financing would empower farmers to timely invest in seeds, fertilisers, and agrochemicals, thereby disrupting the cycle of dependency and underproduction.

6.1.4 Enhance Extension and Training Services

The study indicated that insufficient training, particularly post-RESIS, constrained farmers' capacity to oversee irrigation, finances, and marketing. Government extension agencies must deliver ongoing training customised to the requirements of irrigated farmers. This should encompass technical instruction in irrigation methodologies, financial literacy seminars, and the cultivation of marketing competencies. Consistent agricultural education would enhance competence and confidence, guaranteeing enduring sustainability independent of external assistance.

6.2 Recommendations for Scheme Management and Governance

6.2.1 Implement Transparent Governance Frameworks

The results indicated extensive discontent with governance during RESIS, especially with financial openness and profit distribution. Irrigation systems should formulate explicit constitutions that delineate roles, financial protocols, and decision-making procedures. Mandatory regular reporting of income, expenditures, and profit allocation is essential. Transparency would foster confidence among farmers and mitigate disagreements, so enhancing the cooperative's validity.

6.2.2 Advocate for Cooperative Marketing and Transportation Systems

After RESIS, most farmers sold their products individually to informal outlets, so diminishing their negotiating power and decreasing profitability. Cooperatives ought to facilitate bulk marketing to formal purchasers, enabling farmers to obtain superior pricing and consistent markets. Likewise, collaborative transportation systems should be structured to save costs, preserve product quality, and eliminate redundant expenditures. Collaborative efforts in marketing and transportation would enhance profitability and competitiveness.

6.2.3 Institutionalise Agricultural Producer-Involvement in Governance

The results of the logistic regression indicated that farmer involvement in management positively influenced scheme performance. Management committees, elected by farmers, ought to oversee budgeting, planning, and resource distribution. Empowering farmers with decision-making authority helps cultivate ownership and accountability within schemes. This participatory strategy would equip farmers to independently run schemes, hence diminishing dependence on external entities.

6.2.4 Guarantee Fiscal Transparency and Accountability

A significant deficiency identified during the RESIS programme was the limited access farmers had to financial records and documents. To address this, cooperatives should administer finances via jointly owned accounts that require dual signatories to avert misappropriation. Regular audits and financial reports should be disseminated to all members in accessible formats. This would enhance confidence in financial management and guarantee that farmers receive equitable compensation for their contributions.

6.3 Recommendations for Farmers

6.3.1 Enhance Collaborative Engagement

The study revealed that some farmers withdrew from cooperative formations following RESIS, resulting in fragmentation within the scheme. Farmers should therefore be encouraged and motivated to engage actively in cooperative meetings, decision-making processes, and collaborative activities. Active engagement enables farmers to impact government, disseminate knowledge, and enhance collective bargaining power in markets.

6.3.2 Embrace Sustainable Agricultural Practices

Farmers should take responsibility for maintaining irrigation infrastructure and using available resources judiciously. Fundamental practices, such as regular canal maintenance, regulated water consumption, and reinvestment of a portion of earnings into infrastructure, can contribute to the sustainability of the plan. Sustainable techniques would diminish expenses, enhance production, and extend the longevity of irrigation infrastructure.

6.3.3 Participate in Training Opportunities

Given that inadequate training was identified as a major challenge after the RESIS programme, farmers should commit themselves to participating in extension sessions, workshops, and capacity-building programmes. Engagement in training would enhance their technical, financial, and marketing competencies, allowing them to operate farms more effectively and autonomously.

6.3.4 Establish Connections with Purchasers and Markets

Farmers should proactively establish linkages with legitimate purchasers, agro-processors, and retail chains to reduce reliance on informal markets. This can be accomplished this by consolidating their produce, negotiating together, and adhering to quality standards. Robust market networks are likely to yield stable prices, increased volumes, and reliable income streams.

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