

**Institutional innovations for improved water security in smallholder irrigation schemes
in KwaZulu-Natal and Eastern Cape Provinces, South Africa**

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in Economics

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DEDICATION

To my family.


DECLARATION: PLAGIARISM

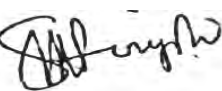
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As the candidate's supervisors, we agree to the submission of this thesis:

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Professor Gavin Fraser (Supervisor)

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Dr S Sinyolo (Co-supervisor)

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Dr J Marire (Co-supervisor)

DECLARATION 2: PUBLICATIONS

This thesis comprises three manuscripts, two of which have been published, while one has been submitted for review. Sandile Phakathi conceptualised all the papers. The data collection, cleaning, analysis, and write up was solely performed by Sandile Phakathi. The supervisors contributed guidance and insightful comments.

Chapter 4

Phakathi, S., Sinyolo, S., Fraser, G. C. G., & Marire, J. (2021). Heterogeneous welfare effects of farmer groups in smallholder irrigation schemes in South Africa. *African Journal of Agricultural and Resource Economics Volume, 16*(1), 27-45.

Chapter 5

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Chapter 6

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LIST OF ABBREVIATIONS

ATE - Average Treatment Effect
ATT - Average Treatment effect on the Treated
CMA - Catchment Management Agency
CPR – Common-Pool Resources
CPRM - Common Property Resource Management
CWR - Crop Water Requirement
DAFF - Department of Agriculture, Forestry and Fisheries
DED - Department of Economic Development
DWA - Department of Water Affairs and Forestry
EC - Eastern Cape
FAO - Food and Agricultural Organisation of the United Nations
FGD - Focus Group Discussion
GDP - Gross Domestic Product
GWP - Global Water Partnership programme
KZN - KwaZulu-Natal
IAD - Institutional Analysis and Development
IDA - Institutional Development Analysis
IMT - Irrigation Management Transfer
IWRM- Integrated Water Resource Management
IWR - Irrigation Water Requirements
KMO - Keiser-Meyer-Olkin
NDP - National Development Plan
NE - Neoclassical Economics
NGO - Non-Governmental Organisation
NIE - New Institutional Economics
NWA - National Water Act
OECD - Organisation for Economic Co-operation and Development
OLS - Ordinary Least Squares
PCA - Principal Component Analysis
PSM - Propensity Score Matching
SA - South Africa
SIS - Smallholder Irrigation Scheme
SSA - Sub-Saharan Africa
StatsSA - Statistics South Africa
VIF - Variance Inflation Factor
WRC - Water Research Commission of South Africa
WUA - Water User Association

ABSTRACT

Smallholder irrigation schemes are regarded as a key strategy to eliminate poverty and increase food security in rural areas in South Africa. While the South African government has invested heavily in rural development schemes, most irrigation schemes face a myriad of challenges, including deficient infrastructure, weak institutional arrangements and water insecurity. Weak institutions have been identified as a major bottleneck in the performance of smallholder irrigation schemes in developing countries, including South Africa. Two main reasons have been identified for this challenge. Firstly, the agency of the irrigators was ignored during the design of the schemes. Treating farmers as passive rather than active agents resulted in institutional arrangements that were not context-specific, as well as weak farmer commitment to the ownership and management of the schemes, leading to system breakdown. Despite being noble in intention or design, institutions designed by outsiders often fail due to a lack of legitimacy. Secondly, institutions have failed to evolve to cope with dynamic challenges and opportunities in the sector. Stability over a reasonable period is required for institutions to effectively perform their crucial role of establishing reasonable expectations in dealings among people. Institutional innovations are required to keep up with the changing nature of development.

In particular, farmer-led institutional innovations have been touted as key to improving the management of water resources in irrigation schemes. Farmer-led institutional innovation refers to a process, in which farmers themselves initiate, establish, and improve institutions based on their context-specific challenges or opportunities. Farmers' groups are regarded as an important institutional arrangement to reduce transaction costs, improve social networks, and increase livelihood outcomes. However, little is known about the internal dynamics of these farmer groups, how they operate, and whether or not they are inclusive and innovative, as well as what makes certain groups more successful than others. Furthermore, there is a paucity of research on whether these farmer groups embrace institutional innovations to improve water security and strengthen their design principles that are crucial for collective action. It is against this background that this study aimed to examine the internal group dynamics within the farmer groups; determine whether smallholder farmers are capable of implementing institutional innovations that are novel, useful and legitimate; determine the nature of these innovations (incremental or radical) and their role in improving water security. The main theories that

underpinned the study were induced institutional innovation theory, collective action theory, random utility theory and Ostrom's eight design principles. Multistage sampling was used to collect data from 28 farmer groups and 401 irrigators in smallholder irrigation schemes in KwaZulu-Natal (Tugela Ferry and Mooi River) and the Eastern Cape (Qamata and Zanyokwe). Data were gathered by means of focus group discussions, key informant interviews and household surveys. Several empirical tools were employed to analyse the data (descriptive statistics, thematic analysis, logit model, propensity score matching, PCA and OLS).

The study found that group membership was associated with higher levels of water access, adoption of inorganic fertiliser, incomes and assets. Group members had an additional four days' access to water in a month and applied at least 130 kg/ha more inorganic fertiliser than non-group members. Group members also had a higher household income per capita and more assets than non-group members. However, the results revealed a heterogeneous effect among group members, with the benefits varying according to members' socio-economic characteristics as well as internal group dynamics. The results suggest that organising farmers into groups should be promoted to improve farmers' access to productive assets such as water, technology adoption and welfare outcomes. However, the study findings also indicate that smaller groups should be promoted, programmes targeted at empowering women should be prioritised, and that it is imperative to invest in improving farmers' human capital through various training initiatives.

The results indicated that farmers could develop and implement institutional innovations that are novel, useful and legitimate. Of the 28 groups, 21 (75%) had implemented institutional innovations in the past three years. Examples of innovations include, among others, the introduction of a secret voting system to improve marginalised people's participation in decision-making processes, designing daily rotation rosters to reduce conflict, using an attendance register for participation in group activities, and rewarding members according to their participation levels. Most of these innovations were designed to improve the graduated sanction mechanism (22.2%), enhance the penalty system for non-compliance; improve collective action arrangements (27.8%); monitor attendance of group meetings (18.5%); democratise decision making; and ensure equitable water distribution. However, they mainly focused on addressing challenges rather than exploiting opportunities and were largely incremental (94%), involving an adjustment or reinterpretation of rules and regulations. Furthermore, the innovative groups were small in size and were dominated by male farmers.

Based on these results, it is recommended that the government should build on the irrigators' agency to improve the effectiveness and legitimacy of institutional arrangements in irrigation schemes. The findings also suggest that small groups should be actively promoted, while tailored training should be offered based on the groups' specific needs to improve institutional innovations in the smallholder irrigation sector in South Africa.

A positive association was established between belonging to an innovative group and water security, highlighting the importance of institutional innovations in water security. The propensity score matching indicated that water secure irrigators produced an additional 569-622 kg of maize and earned additional income of R2 037.81. The study's findings suggest that organising farmers into groups is a promising strategy to improve farmers livelihoods and water security. The government and private donors should thus continue to promote the formation and organisation of farmers into groups. The innovative agency of the irrigators should be acknowledged and harnessed to strengthen institutional innovations. The focus should be on strengthening the institutions designed by farmers themselves, as these are locally contextualised and socially embedded, and hence legitimate. It is recommended that small groups should be actively promoted, while tailored training should be offered based on groups' specific needs to improve institutional innovations in the smallholder irrigation sector in South Africa.

CHAPTER 1: INTRODUCTION

1.1 Background to the study

The agricultural sector plays an important role globally, as it is regarded as the second-largest source of employment after the service sector (FAO, 2020). In 2019, this sector employed 27% (884 million people) of the global workforce (a quarter of the world's labour force). In the same year, 225 million people were employed in agriculture in Africa, comprising half of the continent's employment, while 598 million people worked in this sector in Asia. Agriculture contributed 4% of global Gross Domestic Product (GDP) in 2019, a figure that has remained stable since 2000 (FAO, 2020). According to the Food and Agricultural Organisation of the United Nations (FAO) (2020), the value added by Asia remains high at \$2.2 trillion, followed by the United States (\$480 billion), Africa (\$397), Europe (\$328 billion) and Oceania (\$45 billion) (FAO, 2020). More than 50% of women in Africa are employed in the agricultural sector, and 82% of poor households living in rural areas depend on farming for an income (Beegle et al., 2016; Davis et al., 2017). Agriculture-led growth has a more significant impact on poverty reduction than non-agriculture-led growth in Africa because most poor people earn their livelihoods through farming, especially in the smallholder sector (Moyo, 2015; Aliber & Hart, 2009; World bank 2008; Sihlobo & Kirsten, 2021).

Based on the two hectares' threshold, there are approximately 500 million smallholder farms globally, of which 9% are in sub-Saharan Africa (SSA) (IFPRI, 2016; Lowder et al., 2016). Smallholder farmers produce around 28-31% of total worldwide crop production (Ricciardia et al., 2018). In SSA, smallholders contributed 18-25% of GDP and hired 40-65% of the labour force from 2007 to 2017 (World Bank, 2017). Thus, the smallholder farming sector is the backbone of the agricultural sector in this region. In turn, the agricultural sector is vital to achieving the Sustainable Development Goals in developing countries, particularly Goals one and two, which aim to end poverty and hunger, achieve food security, improve nutrition, and promote sustainable agriculture (DED, 2011; UN, 2015).

In South Africa, agricultural sector is recorded as the 8th largest employers (Sihlobo & Kirsten, 2021). There are 40 122 commercial farms and more than 300 000 smallholder farms in rural areas (BFAP, 2021). It is estimated that 2.3 million people are involved in agricultural

production in the country (BFAP, 2021). In 2020, the agricultural sector contributed 2.3% to GDP despite the impact of Covid-19. Smallholders' location in rural areas renders them important role players in achieving the Sustainable Development Goals through reducing poverty and food insecurity, and creating employment both directly and indirectly through forward and backward linkages (Chipfupa & Wale, 2018; Lipton et al., 2003; van Averbeke et al., 2011). South Africa's National Development Plan (NDP) 2030 identifies agriculture as the primary economic strategy for inclusive rural development. According to the NDP, agriculture has the potential to create close to a million jobs, which would make a significant contribution to the employment target (The Presidency, 2012). Both the Department of Agriculture, Forestry and Fisheries (DAFF) (2012) and the Department of Economic Development (DED) (2010) aim to increase food security, job opportunities, and agriculture's contribution to GDP by expanding the commercially-oriented smallholder farming sector.

To achieve SDGs, investing in irrigation farming is crucial because South Africa is a water scarce country and is classified among the top 40 driest nations, with only 40% of the country receiving more than 500 mm of rainfall annually (FAO, 2021). However, only 8% of the land is under irrigated agriculture, implying that farming is highly reliant on rain-fed agriculture, which is susceptible to droughts, decreasing the yield and leading to the under-utilisation of agricultural land (DEA, 2017; Ortega-Cisneros et al., 2021). Climate change has exacerbated water scarcity and is a significant threat to sustainable agricultural development (DAFF, 2019; FAO, 2021). Thus, achieving the Sustainable Development Goals requires the expansion of irrigated agriculture (DAFF, 2019). In rural areas, policymakers have identified smallholder irrigation schemes as a more effective vehicle to increase food production because rain-fed agriculture is inherently risky (DEA, 2017; Ortega-Cisneros et al., 2021; Lipton et al., 2003; Wiggins, 2005, 2010; Namara et al., 2010; van Averbeke et al., 2011; Cousins., 2013; Sinyolo et al., 2014). The country's irrigation farming contributes 25-30% to national agricultural production and accounts for 90% of high-value crops such as fruits and vegetables (Bonthuys, 2018; Van Niekerk et al., 2018).

Smallholder irrigation in South Africa occupies 3% of the 1.3 million hectares of land under irrigation (Fanadzo & Ncube, 2018; Van Averbeke et al., 2011) and around 250 000 to 300 000 farmers with an average of 1.5 hectares of land benefit from smallholder irrigation schemes

(Denison et al., 2016). These schemes are a source of employment as they boost agricultural productivity in the wake of water scarcity (Denison et al., 2016). The NDP 2030 vision aims to expand irrigated agriculture under smallholder farms by at least 500 000 hectares through water use efficiency and the development of new schemes to create job opportunities and expand agricultural production in the former homelands. Irrigation farming can improve yields by between 100 and 400% (Rockstrom et al., 2009). Therefore, investing in irrigation schemes in water scarce countries is crucial to improve productivity, incomes, and food security. Evidence from the green revolution in Asia indicated that farmers could produce throughout the year when irrigation was combined with improved inputs and crop varieties. Studies across the world in both developing and developed countries have shown that irrigation has a positive effect on incomes, asset accumulation, food security, the adoption of agricultural technologies and overall poverty reduction (Hussain et al., 2006; Namara et al., 2008; Kuwornu & Owusu, 2012; Dillion, 2011; Bacha et al., 2011; Yokwe, 2009; Moyo & Machethe, 2016; Sinyolo et al., 2014; Li et al., 2020; Tesfay, 2021).

While irrigation is considered important, several studies (e.g., Brewis et al., 2019; Sinyolo et al., 2014; Muller et al., 2009; Hussain & Hanjra, 2004) have shown that irrigation access is more effective as a poverty reduction mechanism when the irrigators are water secure. Irrigation water security is defined as the relationship between hydrological and governance conditions that is vital for each irrigator to sustain an agricultural livelihood for subsistence or commercial farming (Klumper et al., 2017). Access to irrigation is necessary but not sufficient to improve the welfare of irrigating farmers. Secure and reliable access to irrigation water incentivises a farmer to innovate and use new technologies which increase farming capacity, leading to improved productivity (Sinyolo et al., 2014; Wiggins, 2005; Hussain & Hanjra, 2004). In turn, this boosts production and returns from farming, improving commercialisation opportunities (Hussain & Hanjra, 2004).

The NDP 2030 vision notes that credible programmes, stronger institutions, and efficient use of water resources are required to expand smallholder irrigation schemes and create new job opportunities. In particular, stronger institutions at scheme level are crucial for the efficient management of water resources. Institutions refer to rules, norms and regulations designed to facilitate coordination among stakeholders and reduce uncertainty, transactional costs and free-riding (North, 1993; Ostrom, 2008). They are crucial in the establishment of individual rights

to resources and providing mandates and stability in the complex and ambiguous world of economic relations (Menard & Shirley, 2005).

Irrigation management strategies have evolved in line with the need to improve institutional arrangements in smallholder irrigation schemes. The South African government has decentralised irrigation management systems through programmes such as “Participatory Irrigation Management, Farmer Managed Irrigation System and Irrigation Management Transfer”, with the latter having been introduced in the current era (Muchara et al., 2014; Perret, 2002). These programmes aim to assign full responsibility to farmers to manage and run the schemes. Moreover, current water policies in the form of the National Water Act, No. 39 of 1998 (RSA, 1997, 1998), and the National Water Resource Strategy were adopted to enable marginalised people to participate in water management decisions, unlike former centralised bureaucratic policies such as Irrigation Conservation, the Water Act of 1910, and the 1956 Water Act (Backeberg, 1997; Perret, 2002; Tempelhoff, 2017).

The National Water Resource Strategy resulted in the formation of Catchment Management Agencies (CMAs) for holistic management of water at provincial level and Water User Associations (WUAs) for management at local level. Farmers are prominent actors in WUAs at scheme level, and are responsible for managing water resources. A WUA is a cooperative association of water users that oversees water-related activities and the “management of local water infrastructure, e.g. irrigation water supply in the schemes, to supply water to entitled water users and to implement management decisions agreed upon between the members” (Pegram & Mazibuko, 2003:23). These policy changes aimed to enhance marginalised poor people’s participation in the water management system.

1.2. Research problem

Smallholder irrigation schemes in South Africa have performed below expectations despite decentralised irrigation management systems and substantial government investment in irrigation infrastructure. According to van Averbeké et al. (2011), of the 302 smallholder irrigation schemes in South Africa in 2010, 164 (54%) were underperforming due to poor managerial capabilities among farmers, weak and outdated institutions, and water shortages required to sustainably manage the schemes (Dirwai et al., 2019; Muchara et al., 2014; van

Averbeke et al., 2011; Perret, 2002). A growing body of literature asserts that, among other factors, weak institutions are a major bottleneck in the performance of smallholder irrigation schemes in developing countries, including South Africa (Dirwai et al., 2019; Mnkeni et al., 2010; Muchara et al., 2014; Vandersypen et al., 2006).

Among other things, research has identified two main reasons for poor institutions in smallholder irrigation schemes. Firstly, irrigators' agency was ignored during their design; and secondly, institutions have failed to evolve to cope with the dynamic nature of the challenges and opportunities in the sector (Muchara et al., 2014; Mnkeni et al., 2010; van Averbeke et al., 2011; Yokwe, 2009). According to these studies, irrigators were treated as passive recipients rather than active partners during the rehabilitation of irrigation schemes through programmes such as Irrigation Management Transfer (IMT), Participatory Irrigation Management and support for Farmer Managed Irrigation Systems. Top-down, command and control type interventions limited farmer participation (Dirwai et al., 2019; Muchara et al., 2014; Shiferaw et al., 2009). This resulted in institutional arrangements that were not context-specific, as well as weak farmer commitment to ownership and management of the schemes, leading to system breakdown. As Raffaelli and Glynn (2015) observed, institutions designed by outsiders often fail due to a lack of legitimacy, despite being noble in intention or design. They perform better when designed and implemented in a socially and politically acceptable manner with the involvement of all relevant parties to enhance legitimacy (Raffaelli & Glynn, 2015).

In order to perform their crucial role of establishing reasonable expectations in dealings among people effectively, institutions should be stable over a reasonable period of time (Ruttan, 2005). However, institutional innovations are required to keep pace with the changing nature of development (Gatzweiler & von Braun, 2016; Ruttan, 2005; Spielman et al., 2011). Institutional innovation refers to the design and implementation of new or significantly improved rules, norms, processes and procedures that differ significantly from an organisation's previous ones. It should be led by farmers in order to create an enabling societal environment that motivates people to use their capabilities to the fullest extent (Gatzweiler & von Braun, 2016; Raffaelli & Glynn, 2015).

Farmer-led institutional innovation refers to a process where farmers initiate, establish, and improve institutions based on their context-specific challenges or opportunities (de Bont & Veldwisch, 2020). Farmers are rational agents who understand their local context and are

capable of negotiating, designing, adapting, and implementing innovations that relate to their local realities and can enhance their ability to adapt to rapidly changing environments (Ostrom, 2008; Reij & Waters-Bayer, 2001; Tambo, 2018; Tran et al., 2019). The current literature on inclusive innovation (Cozzens & Sutz, 2014; Fressoli et al., 2014; Gupta, 2012) highlights the importance of not only ensuring that marginalised or poor people benefit from the outcomes of innovation, but also ensuring their participation in innovation processes. Thus, rather than innovations for the poor, it is about innovations with the poor (Gupta, 2012).

This study employs the Induced institutional innovation theory, which postulates that challenges, opportunities and competition over natural water resource (irrigation water), induces farmers to collectively design and implement institutional innovations to strengthen institutional arrangement. Farmers are rational agents who are capable of implementing, and solving their context specific challenges through collective action because improving water management in an era of water scarcity, it is crucial to improve water management. A dynamic approach to improving water management at the local level requires an understanding of collective action and innovation as a context-specific process involving a multitude of actors with specific interests and agendas. Smallholder farmers exist in an environment of multiple property regimes and frequently contested claims in natural resource management. The ability to act collectively is an important determinant of local adaptation (Van Rooyen et al., 2017; Adger et al., 2003). Responding to opportunities and overcoming local challenges requires farmers to be agents of change by adapting local knowledge and selectively integrating ‘scientific’ knowledge to develop new and better ways of managing resources (Sanginga, 2009). The study uses case studies of the rural irrigation farmers in the Mooi-River and Tugela Ferry irrigation schemes, in KwaZulu-Natal and Zanyokwe and Qamata irrigation schemes of the Eastern Cape Province.

1.3. Research Objectives

The specific objectives of the study were to:

1. Examine internal group dynamics and assess the heterogenous impact of farmer groups on water access, fertiliser use, household income and asset holdings.

2. Investigate the nature of farmer-led institutional innovations and determine the factors that enhance or inhibit these innovations.

3. To assess the effect of institutional innovation on water security, and evaluate the impact of water security on household welfare.

1.4 Justification for the study

Documenting farmer-led institutional innovations is an important step towards recognising farmers as major producers and users of innovations. However, there is a paucity of research on institutional innovations led by farmers in the agricultural sector. The focus of a growing strand of literature on farmer-led innovations has been more on technologically oriented innovations (new crop varieties, soil conservation practices, new planting methods, and irrigation and drainage technologies) (Tran et al., 2019; Jouni et al., 2018; Tambo, 2018; Levidow et al., 2014). While some studies have been conducted on institutional innovations (Mose et al., 2015; Muchara & Mbatha, 2016; Tambo, 2018; Vandersypen et al., 2006), most overlooked the importance of legitimacy in institutional innovations, focusing instead on usefulness and novelty (Raffaelli & Glynn, 2015). For example, Mose et al.'s (2015) study focused on institutional innovations to improve access to information and markets through the establishment of private extension officers and the implementation of a computerised programme to manage production.

Tambo's (2018) research on farmer-generated innovations reported mainly technically-oriented innovations, with very few institutional innovations. Vandersypen et al. (2006) investigated the implementation of a rotation roster for irrigation access and canal cleaning as an example of institutional innovations in Niger irrigation schemes. The study found that farmers' inability to monitor and enforce rules resulted in their institutions remaining immature. In South Africa, Muchara and Mbatha (2016) showed how, through small informal groups, farmers were able to improve input procurement, market access, and information flow in the Mooi River irrigation scheme. The study pointed to the need for strong institutions to enforce rules, regulations, and incentives to motivate more farmers to participate in reducing transactional costs and recommended that farmers should take the lead in crafting their institutions. Studies on water governance in smallholder irrigation schemes, such as those by Dirwai et al. (2019) and Muchara et al. (2014), also focused on broad issues such as how

governance affects infrastructure, with limited attention to how farmers have solved their institutional challenges.

Given the fact that smallholder farming is highly heterogeneous, rather than only focusing on generic technical solutions to agricultural water issues, local capacity should be harnessed to identify problems and develop innovative solutions specific to the local context (Lorentzen, 2013). This does not mean that government should stop supporting farmers (*“Laissez-faire”*) to improve their institutional arrangements, but that farmers should be the main agents of change and rules should not be imposed on them. It is against this background that this study aimed to explore farmer-led institutional innovations and their impact on water security, and examine individual farmer welfare outcomes in the context of poor, vulnerable and disempowered communities characterised by extreme poverty and water inequality. Improving the management of limited water resources is crucial because in South Africa, poor communities, such as smallholder farmers, face the most significant risk of water insecurity. Gaining or retaining access to water for livelihood activities such as farming depends on wealth, social status, or political connections (Wilchens, 2015). These challenges call for institutional innovations within smallholder irrigation schemes for the smooth management of water resources, leading to a sustainable and resilient agrarian community (Cofie & Amede, 2015).

This study sought to contribute to the literature by conceptualising and operationalising institutional innovation in the context of smallholder irrigation schemes. Documentation of farmer-led institutional innovation remains scarce; hence, this study focused on documenting institutional innovations in four irrigation schemes in the Eastern Cape (EC) and KwaZulu-Natal (KZN) provinces. The four schemes were chosen because they have existed for a sufficient period of time (at least 29 years) to understand the dynamics of institutional innovations since their management was transferred to farmers. Moreover, these schemes have been identified as major examples of irrigation management failure (Dirwai et al., 2019; Muchara et al., 2014; van Averbeke et al., 2011; Yokwe, 2009). The study also makes a methodological contribution in the form of the procedures employed to collect and verify farmer-led institutional innovation. To the best of my knowledge, few empirical studies, if any, have contextualised institutional innovations with an emphasis on legitimacy, which highlights the importance of all actors in designing institutions (Raffaelli & Glynn, 2015).

Moreover, the study examined whether institutional innovations are important to improve water security by examining the linkages between water security and institutional innovation. It aimed to evaluate the probability of a farmer being water secure when he/she is a member of an innovative group. Improving water security is key to increasing agricultural productivity in the light of water scarcity. However, while there is consensus on the need to improve water security, debate continues on how it should be measured, especially at the scheme or household level (Brewis et al., 2020, Boateng et al., 2018, Jensen & Wu, 2018). A wide range of indicators and measurements are employed depending on whether water security is evaluated at a national, regional, city or local scale (Falkenmark, 1989; Gleick, 2003; Lawrence et al., 2002; Sullivan & Meigh, 2003; OECD, 2002; Cullis & Van-Koppen; 2007; Koop & van Leeuwen et al., 2015; Sinyolo et al., 2014; Young et al., 2019).

Dickson et al. (2016) emphasise that water quantity at community level remains a crucial challenge; hence, case studies focusing on rural areas might need to measure sufficient quantities. This study contributes to the literature by measuring the quantity of water applied by farmers in one production cycle using the Marsh-McBirney Model 2000 to calculate the flow velocity area in the canal to derive the discharge rate. Velocity in m^3s^{-1} was multiplied by the time taken to irrigate in hours in a day and the number of days a farmer had access to water to derive the estimated actual water quantity applied in one production cycle in m^3 . The CROPWAT 8 model was used to determine whether a farmer met the crop water requirement. For robustness checks, a water security perception index was generated using principal component analysis (PCA). This was followed by an analysis of the relationship between belonging to an innovative group and individual irrigator water security status. To the best of the researcher's knowledge, no study has empirically linked institutional innovations to water security in the smallholder irrigation sector.

Institutional innovations were investigated at the farmer group level because farmers in these schemes share the same water source. Moreover, farmer groups are important in South Africa as the government and development agencies prefer working with groups in order to reduce transaction costs (Sinyolo & Mudhara, 2018). It is imperative for policymakers to establish where interventions can best be made to understand why and how a group of farmers

collectively chooses to make changes in their everyday operational and constitutional rules (Ostrom & Benjamin, 1993).

Participating in farmer groups offers several advantages to poor farmers. Group membership results in reduced transaction costs, as it enables the sharing of information, inputs and transportation costs (Fischer & Qaim, 2012; Abebaw & Haile, 2013; Sinyolo & Mudhara, 2018a). Furthermore, farmers in groups often buy in bulk, resulting in economies of scale and improved bargaining power. These advantages lead to a greater likelihood of the use of inorganic fertiliser, among other inputs, improved access to water, higher productivity and better output prices, which in turn result in higher household incomes and asset accumulation (Nilsson, 2001; Fischer & Qaim, 2012; Abebaw & Haile, 2013; Sinyolo & Mudhara, 2018a; Bachke, 2019).

Several empirical studies have reported the positive effect of farmer groups on various outcomes in the smallholder sector. While there is a plethora of literature on collective action among farmer groups (Barham & Chitemi, 2009; Gezahegn et al., 2019; Muchara et al., 2014; Sinyolo & Mudhara, 2018), these studies rarely examine the internal dynamics of such groups. A few studies (e.g., Barham & Chitemi, 2009; Sebhatu et al., 2021) discuss group characteristics and internal dynamics and how these affect groups' influence. However, they often focus on whether a farmer belongs to a group without investigating the characteristics of different groups. No two farmer groups are the same as they are likely to differ in size, and in their members' social characteristics, available capital assets, and internal dynamics, which affect a group's strength and success (Barham & Chitemi, 2009). Therefore, there is a need to identify the factors that hinder or promote successful institutional innovations and collective action. This study also contributes to the body of literature by evaluating the heterogeneous effect of group membership on various outcomes such as access to water and fertiliser, asset holdings and household income.

1.5. Research outline

The thesis structure is PhD by papers, and it is organised into seven chapters. The first chapter presented the background to the study, the problem statement, the research objectives and the justification for the study. Chapter 2 presents a brief literature review, which extends the

introduction to provide further insight. It includes an overview of smallholder agriculture, the history of smallholder irrigation schemes, water governance policies in South Africa and the challenges hindering the performance of smallholder schemes. The literature review that identifies the gaps in water security, institutional innovations, and farmer groups is presented separately in Chapters 4, 5 and 6, as the thesis is semi-structured as PhD by paper. Chapter 3 discusses the study area, the research paradigm, the sampling framework and data collection instruments. The analytical methods (econometric models) for data analysis are presented in each chapter (4, 5, and 6).

The first empirical section is presented in Chapter 4 on the heterogeneous welfare effects of farmer groups in smallholder irrigation schemes in South Africa. This chapter assesses the impact of farmer groups on four welfare outcomes - water access, fertiliser use, household incomes and assets ownership. The chapter begins with an introduction, followed by the theoretical framework, results and discussion, and a summary. A condensed version of Chapter 4 was published in the *African Journal of Agricultural and Resource Economics*.

Chapter 5 presents the second set of empirical results on farmer-led institutional innovations in managing smallholder irrigation schemes in KZN and EC provinces. It builds on the problem statement and justification for the study discussed in the introduction. A condensed version of this chapter was published in *Agricultural Water Management*.

Chapter 6 on institutional innovations for improved water security is the final empirical chapter. A condensed version of this chapter has been considered for publication (currently under second review) in the *International Journal of Water Resources Development*.

The last chapter, Chapter 7 summarises the study and presents the conclusion, policy recommendations, the study's limitations and possible directions for further research.

CHAPTER 2: LITERATURE REVIEW

2.0. Introduction

This chapter presents an overview of the agricultural sector and the smallholder irrigation sector in particular, with a focus on smallholder irrigation schemes. It begins with an overview of the agricultural sector and its contribution to the economy. This is followed by the definition of smallholder farmers and a discussion on the importance of smallholder irrigation schemes in the livelihoods of rural poor people, as well as water policies, governance and institutional issues. The theoretical importance of collective action and social capital in managing smallholder irrigation schemes is outlined, followed by various schools of thought's perspectives on institutional change. It is important to note that in the empirical chapters (4, 5, 6) literature review is provided for each chapter, highlighting the gap in the literature and the study's contribution which might not be presented in Chapter 2. This chapter therefore focuses on the broad context of the smallholder sector in South Africa.

2.1. An overview of the agricultural sector in South Africa

Globally, about five billion hectares of land are under agriculture, accounting for 38% of the world's surface (FAO, 2020). Generally, the agricultural sector is divided into large-scale and small-scale farmers (farmers with less than two hectares of land) (Ricciardia et al., 2018; Samberg et al., 2016). Approximately a third of the land is for crop production, with two-thirds for livestock grazing (FAO, 2020). Asia has the largest share of land under agricultural production at 34%, with the United States at 25% and Africa at 24%, followed by Oceania (10%) and Europe (9%). Worldwide, about 21% of the land is under irrigation farming. The green revolution in Asia during the 1960s significantly improved agricultural production and 70% of the world's land equipped for irrigation is currently in Asia. Only 16% of the United States' land is under irrigation, followed by Europe (8%), Africa (5%) and Oceania at just 1% (FAO, 2020). The average cropland area per capita in 2016-2017 in Asia was 0.13 hectares, with Africa recording 0.22 hectares. Oceania recorded the highest level of 1.21 hectares per capita. Furthermore, the number of people dependent on the agricultural sector globally has increased. In 2012, globally, about 1.3 billion people were directly involved in farming, while

in 2018, it was reported that globally, the agricultural sector provided livelihoods for 2.5 billion people (FAO, 2020; Sridharan et al., 2018).

South Africa has a total command area of 122.5 million hectares, with only 14 million under agricultural production (DAFF, 2019; StatsSA, 2016). The South African agricultural sector produces various products such as oilseeds, sugar, fruits, wine, vegetables, and all essential grains such as maize and sorghum except for rice, under both rain-fed and irrigated agriculture (DAFF, 2019; BFAP, 2021). Livestock production includes cattle, goats, hogs, sheep and poultry. Eighty per cent of the country's agricultural land is suitable for livestock production, which contributes around 40% of agricultural incomes (Oduniyi et al., 2020; Rojas-Downing et al., 2018). Cattle farming is the leading livestock production sector, and commercial farmers hold a 60% share in livestock farming (DAFF, 2019). The agricultural sector employs 5.4% of the total labour force compared to 27% and 71% employed in industry and the service sector, respectively. Agriculture's contribution to GDP declined from more than 10% in 1960 to just above 2% due to the country's economic transformation from relying on primary industries to the manufacturing and service sectors. In 2010, 2016, and 2020 the agricultural sector contributed 2.2%, 2.7% and 2.3%, respectively, to GDP. Nonetheless, the sector remains crucial to decrease poverty and food insecurity, particularly in rural areas.

2.2. Defining smallholder farmers

The agricultural sector is mainly categorised into commercial large-scale, emerging and smallholder farmers (DAFF, 2015). Commercial, large-scale farmers mainly comprise well-established and integrated white farmers with all the assets required to make agricultural farming successful (Aliber & Mdoda, 2015; FAO, 2020; Chipfupa & Wale, 2018). Smallholder farms are highly heterogeneous and diverse in terms of farm size, income, purpose (either for subsistence or commercial), access to capital assets and market access (FAO, 2020; Chipfupa & Wale, 2018; Lowder et al., 2016; Fanadzo and Ncube, 2018; Ricciardia et al., 2018; Fanadzo & Ncube, 2018; DAFF, 2012; van Averbeke et al., 2011).

Globally, smallholder farms are defined based on land size as farms of less than two hectares (World Bank, 2003; Eastwood et al., 2010; Ricciardia et al., 2018; Samberg et al., 2016). The International Food Policy Research Institute (IFPRI) (2016) estimates that, globally, there are

500-540 million smallholder farmers globally (Lowder et al., 2016). The majority (78%) are in Asia and SSA (62%), with Latin America home to only 17% of small farms (Lowder et al., 2014). A recent study by Ricciardia et al. (2018) reported that smallholder farmers produce about 28-31% of total crop production. However, categorising farmers based on land size is problematic because it does not consider the economic valuation of the farm enterprise based on the land quality, market access, and access to the capital assets required to make farming a success (Rapsomanikis, 2015; Nkonya et al., 2011). Access to these resources determines the degree of commercialisation (Fanadzo & Ncube, 2018; von Braun & Mirzabaev, 2015; DAFF, 2012; van Averbeké et al., 2011). For example, one hectare of land under irrigation producing high-value crops and located close to urban markets may generate more income than a farm of five hectares cultivating crops under rain-fed farming (Nkonya et al., 2011). The definition of a smallholder farmer cannot be rigid, or one-size-fits-all because it varies depending on the context, country and ecological characteristics (Rapsomanikis, 2015).

In South Africa, the term smallholder farm is used interchangeably with small-scale farm. Smallholders are primarily defined as black farmers who mainly live in the former homelands. Homelands were territories set aside for the black population by the apartheid regime, which demarcated them according to the 1913 and 1936 Native Land Acts (Aliber & Mdoda, 2015; Lahiff & Cousins, 2005). These Acts restricted land ownership by black farmers, resulting in them owning 7-13% of the land, despite being in the majority (more than 70%) (Lahiff & Cousins, 2005). Apartheid also influenced the classification of these farmers in South Africa, as they are grouped according to race (Aliber & Mdoda, 2015; Fanadzo & Ncube, 2018). The exact number of smallholder farmers in South Africa is not known; as a result, the DAFF (2018) implemented a project known as the farmers' registry to verify the number. The project started in 2018 and was expected to end in 2021; however, progress has been slow due to the Covid-19 pandemic. Aliber and Hart (2009) estimated that there were four million black smallholder farmers in South Africa, cultivating 13% of agricultural land. Smallholder farming is mainly dominated by women and elderly farmers (Pienaar & Traub, 2015).

Smallholders farmers have limited capital assets or resource endowments compared to commercial farmers, and most cultivate crops for subsistence purposes to improve household food security (Fanadzo & Ncube, 2018). They cultivate small plots ranging from 0.1 to 2 hectares of land and are highly dependent on family labour. Most of these farmers use outdated technologies for production, limiting their performance and growth (Ricciardia et al., 2018;

Samberg et al., 2016). They face numerous challenges that limit their performance and capacity to reduce poverty and unemployment. Since most smallholder farmers are situated in rural areas, they lack access to proper roads, hampering access to input and output markets. This results in high transaction costs, as infrastructure development and communication services are relatively poor in most rural areas, making it difficult to access market information and to be integrated into the market (Aliber & Mdoda, 2015; Aliber & Hall, 2012; Phakathi & Wale, 2018; World Bank, 2005; Sinyolo et al., 2018; Muchara et al., 2016). Emerging farmers are regarded as a middle group between commercial and smallholder farmers. They have better access to advanced farming technologies than smallholder farmers (DAFF, 2012; Phakathi & Wale, 2018; Sinyolo, 2016; van Schalkwyk et al., 2012).

2.3. A brief history of smallholder irrigation schemes in South Africa

Smallholder irrigation schemes are formal public irrigation projects that were established by the apartheid government in rural areas for black farmers due to extremely hot weather conditions and high unemployment (Van Averbeke, 2012). The history of irrigation in the country's smallholder sector can be divided into four epochs. The first is known as the "*Peasant and Mission Diversion Scheme Era*", which took place during the 19th century. During this time, technological devices such as pipes were developed to divert water from rivers to irrigate crops (DAFF, 2015). Management of these schemes was highly centralised, with a top-down approach. Towards the end of the 19th century, they became dysfunctional. The "*Smallholder Canal Scheme Era*" emerged following World War Two (DAFF, 2015; De Lange, 1994). The government established canal schemes to support black households to secure a livelihood. In 1955, about 122 canal smallholder irrigation schemes were established covering about 11 406 hectares of land. The average plot size ranged from 1.28 to 1.78 ha of land per household.

The period 1970 to 1990 was the "*Independent Homeland Era*" when the government established additional schemes (64 covering 13 000 ha) to decrease food insecurity, unemployment and poverty in the former homelands (Van Averbeke & Mohamed, 2006). These schemes were distinguished by the use of up-to-date systems such as overhead irrigation systems. Moreover, government "parastatals" were formed to manage these schemes on behalf of farmers using a centralised decision-making system. It employed command and control type policies which excluded farmers from decision-making processes. In the 1990s, management

of the schemes was handed over to farmers through the programme known as the "*Irrigation Management Transfer and Revitalisation Era*" (Dirwai et al., 2019; DAFF, 2015; Muchara et al., 2014; Fanadzo & Ncube, 2018). During this period, 62 schemes covering 2 400 ha were established, and advanced technologies such as sprinklers and pump irrigation systems were introduced (Van Averbeke & Mohamed, 2006). However, many schemes collapsed due to the high transaction costs of maintaining them, and weak or poor institutional management, among other reasons.

Around 1994, the South African government planned and partially executed the revitalisation of some of these schemes. It was planned that 250 hectares would be rehabilitated each year; however, due to financial constraints, progress has been slow as one hectare was estimated to cost about R200 000 (Bembridge, 2000; DAFF, 2015; Denison & Manona, 2006; De Lange, 1994). As at 2011 (the latest available data), the number of smallholder irrigation schemes was reported to be about 302 (Van Averbeke et al., 2011). Limpopo, EC and KZN provinces have the largest number of irrigation schemes in South Africa. Statistics show that Limpopo had 170 schemes, with only 101 operational, while 69 were non-operational as at 2011, while in the EC, 67 schemes were documented in 2011, with 50 active and 16 non-active. Only 35 schemes were recorded in KZN, all of which were operational (Van Averbeke et al., 2011).

The social organisation of irrigation management has changed rapidly in order to improve the smallholder irrigation schemes' institutional arrangements. The government has decentralised irrigation management systems through programmes such as "Irrigation Management Transfer, Participatory Irrigation Management, and Farmer Managed Irrigation System" (Chaudhry, 2017; Perret, 2002). Despite these programmes, management and performance of the irrigation schemes remains poor. Fanadzo (2012), Machethe (2004) and Muchara et al. (2014) attribute poor infrastructural maintenance to the rushed process of IMT, which created challenges in terms of farmers' ability to manage and maintain the schemes. Political reforms in South Africa to redress apartheid inequalities further contributed to the high failure of IMT because less attention was paid to capacitating farmers to effectively manage the schemes (Senanayake et al., 2015). In Africa, this process was not as gradual and smooth as in Asia. Excessive transaction costs, coupled with insufficient government support and low human capital in managing irrigation, led to system breakdown.

In Asia, government efforts to recover the capital cost from farmers to reinforce ownership of smallholder schemes promoted the success of these schemes (Barker & Molle, 2004; Facon, 2013; Mukherji et al., 2012). African governments have not recovered capital costs because smallholder irrigation schemes are regarded as welfare projects rather than investment ones, and it is felt that farmers are too poor to contribute to capital costs (Koopman et al., 2001; Mundra & Garg, 2013). Hirsch (2013) is of the view that this welfarist approach is unsustainable and not '*pro-poor*' because it compromises farmers' commitment to the management and ownership of the schemes; this has exacerbated the dependency syndrome among farmers and perpetuated water insecurity because of poor scheme management (Phakathi & Wale, 2018). Improving water security remain crucial in reducing poverty.

2.4. Defining water security

Water security, as a concept, is broad, multidimensional, and differs from discipline to discipline. There are many definitions that vary in terms of scope (broad versus narrow) and discipline (academic versus applied) (Scott et al., 2013; Bakker, 2012, OECD, 2011). The main challenge is to operationalize the concept into a manner that allow robust analysis that is of utility to public policy (Jepson & Vandewalle, 2016). Water security was first conceptualised in the early 1990s when the Middle East and other regions were confronted with water scarcity and political conflict (Staddon & James 2014). Figure 2.1 highlights the major changes by thematic attributes that have taken place in the conceptualisation of water security from 1996 to 2013.

In 1996, during the United Nations World Food Summit, the Food and Agricultural Organization (FAO, 1996) adopted the term water security in the context of food security. The key attributes of the FAO's definition included access, quantity, quality, health, economy, time and preferences. The Global Water Partnership (GWP) (2000) subsequently adopted the term and conceptualised water security as "a deliberate action [in which] every person has access to enough safe water at an affordable cost to lead a clean, healthy and productive life while ensuring that the natural environment is protected and enhanced" (GWP, 2000:26). The key attributes added by the GWP were sustainable development, ecosystems, and hazards (Gerlak et al., 2018). In 2007, Grey and Sadoff (Gerlak et al., 2018) added the aspect of livelihoods in their definition and defined water security as "the availability of an acceptable quantity and

quality of water for health, livelihoods, ecosystems and production, coupled with an acceptable level of water-related risks to people, environments and economies” (Grey & Sadoff, 2007:9). This has become one of the most cited definitions.

Source/Attribute	FAO	GWP	Grey & Sadoff	UNEP	Norman et al.	OECD	Bakker	UN-Water	Scott et al.	Total
Year	(1996)	(2000)	(2007)	(2009)	(2010)	(2011)	(2012)	(2013)	(2013)	
Quantity	X	X	X		X	X	X	X	X	8
Quality	X	X	X	X	X	X	X	X	X	9
Health	X		X		X		X	X		5
Economic Growth	X		X	X		X		X		5
Access	X	X			X	X				4
Time	X									1
Preference	X									1
Ecosystems		X	X	X	X	X	X	X	X	8
Sustainable		X			X	X		X	X	5
Risk/hazards		X	X				X	X		4
Livelihoods			X				X	X		3
Sanitation				X						1
Food/energy				X						1
Industrial resources				X						1
Transport				X						1
Watershed					X					1
Policy						X				1
Peace/national security							X	X		2
Global Change									X	1
Resilience									X	1
Uncertainty									X	1
Total	7	6	7	7	7	7	7	10	9	78

Figure 2.1: Water security definitions compared by thematic attribute

Source: Gerlak et al. (2018)

In 2009, the United Nations Environment Programme (UNEP) incorporated the food-energy-nexus and resources in the conceptualisation of water security. Norman et al. (2010) added the issue of watershed scale, followed by the OECD in 2011. Peace and national security aspects were later introduced by Bakker (2012) and Cook and Bakker (2012). Scott et al. (2013)

included global change, resilience, and uncertainty in conceptualising water security. Gerlak et al. (2018) noted that the most common attribute in all these definitions is “access”. The question that arises is access to what? Scholars have argued that access to water is not sufficient for a household to enjoy a comfortable livelihood; adequate access to secure water is required (Sinyolo et al., 2014). The UN (2015) acknowledged this by adopting Sustainable Development Goal 6 which aims to address water insecurity across different regions in a coordinated manner. The UN conceptualisation of water security consist of ten thematic attributes, as a way to broaden the term.

Figure 6.1 shows that the conceptualisation of water security is dynamic and has changed over time; between 1996 and 2013, the broadening of the concept and the introduction of new terms in the definition of water security. The water security concept, in general, has three key thematic attributes; sustainability, quantity and quality (Jepson et al., 2017; Scott et al., 2013; Bakker, 2012). Access to sufficient, reliable and quality water is vital for a household to maintain a sustainable livelihood (Siddiqia et al., 2018; Cook & Bakker, 2012; Molle & Molling, 2003). There is debate in the literature on how the water security concept should be framed. Studies such as Gerlak and Mukhtarov (2015) & Gober *et al.* (2015) argue for a broad and dynamic definition because it can freely allow various stakeholders to find common ground on improving water management and come up with solutions that will be specific to a sector's needs. Cook & Bakker (2012) further argue for an integrative and broad conceptualisation of water security as it can play a vital role in advancing water governance. On the other hand, Jepson and Vandewalle (2016) argue for a narrow definition because the ultimate goal is to operationalise the concept to allow robust analysis that can be materialised to public policy.

A comprehensive definition of water security should not be limited to water availability issues (quantity and quality) but should go beyond and address the challenges of accessing water. Issues that involve individual rights to water access to national sovereignty rights are crucial in analysing water security, particularly at the individual level (Sinyolo *et al.*, 2014). Sinyolo *et al.* (2014:485) define water security in the context of smallholder as "access by the irrigating households to sufficient and reliable water to meet their agricultural needs and their ability to assert their water rights against other parties”. This definition has been adopted by other scholars such as Muchara et al. (2014), Sharangura & Mudhara (2016) in the context of smallholder irrigation schemes. Furthermore, Klumper et al. (2017) defined irrigation water security as the relationship between hydrological and governance conditions that is vital for

each irrigator to sustain an agricultural livelihood for subsistence or commercial farming. These definitions acknowledge that water security is beyond physical water access but incorporates governance and institutional issues. However, this definition lacks some critical aspect to water security at the smallholder level, such as flexible access to irrigation water because most smallholder farmers are women, so balancing household chores and farming needs to be taken into consideration. Therefore, flexible access to irrigation water is one of the most critical attributes in determining water security and needs to be incorporated in the empirical studies as it has been overlooked and not tested empirically by other studies (Sharangura & Mudhara, 2016; Sinyolo *et al.*, 2014 & 2018) in the irrigation farming sector. Chapter 6 will present the study contribution toward issues water security measurements. The next section presents the importance of irrigation farming as a key strategy for reducing poverty, especially in rural areas.

2.5. The importance of irrigation farming

Irrigated agriculture produces 40% of food worldwide under a third of global harvested land and consumes 70% of total global blue waters (FAO, 2020; Ringler, 2017). In Asia, 24.4% of the population is employed in irrigated agriculture, while in SSA, the figure stands at just over 52% (Ringler, 2021). In Asia, irrigation played a significant role in transforming and intensifying agricultural production as 68% of potential irrigated area in Asia is developed compared to only 39% in Africa and 28% in SSA (FAO, 2020; Ringler, 2021). The green revolution resulted in significant growth of the irrigated sector in Asia. South Asia has the world's largest irrigated area (97 411/1 000ha), followed by East Asia (73 009/1 000 ha). In South Africa, irrigation farming contributes 25-30% to national agricultural production while accounting for 90% of the production of high-value crops such as fruits and vegetables (Van Niekerk *et al.*, 2018; Fanadzo & Ncube, 2018). Smallholder irrigation only represents 3% of the 1.3 million hectares under irrigation in the country (Fanadzo & Ncube, 2018; Van Averbeke *et al.*, 2011). Irrigated agriculture uses about 62% of total water, while urban use accounts for 23%, and mining, power generation and industry consume the remaining 15% (StatsSA, 2019).

Although it consumes large quantities of water, irrigated agriculture is crucial because it can improve yields by between 100 and 400% (Rockstrom *et al.*, 2009). Studies in both developing and developed countries have shown that irrigation has a positive effect on incomes, asset accumulation, food security, the adoption of agricultural technologies and overall poverty

reduction (Hussain et al., 2006; Namara et al., 2008; Kuwornu & Owusu, 2012; Dillion, 2011; Bacha et al., 2011; Yokwe, 2009; Moyo & Machethe, 2016; Sinyolo et al., 2014; Li et al., 2020; Tesfay, 2021). Irrigation farming has the potential to increase food production and rural employment and reduce food prices and food insecurity (Dillon, 2011; Bacha et al., 2011; Yokwe, 2009; Moyo & Machethe, 2016; Sinyolo et al., 2014; Li et al., 2020; Tesfay, 2021; Ringler, 2021).

Hussain et al. (2006) found that the poverty headcount ratio was 29% among irrigators in Pakistan compared to 37% among rain-fed farmers. Yokwe (2009) concluded that the Zanyokwe and Thabina irrigation schemes in South Africa realised higher gross margins per hectare than rain-fed farming. Dillion (2011) found that irrigation improved household consumption by 24-30% in northern Mali, while Sinyolo et al. (2014) calculated that South African smallholder irrigation households spend R2 000 more on consumption per adult equivalent. Using panel data, Tesfay (2021) concluded that irrigated agriculture increased Ethiopian households' assets by 0.77 and led to a 3.79 and 3.75% rise in household consumption and crop income, respectively. In China, it was found that access to irrigation increased farm income by 14% (Li et al., 2020). Increased public investment and the green revolution pioneered the massive development of irrigation farming in Asia, while in SSA, there is a less political will to invest in infrastructure in rural areas where these irrigation projects are located (IEA, 2019; IFPRI, 2019).

South Africa is ranked as the 40th driest country in the world with an average of 500 mm of rainfall per annum (FAO, 2021). Coupled with intensifying climate change and the high percentage of people employed in the agricultural sector, this makes it crucial to invest in irrigation farming to improve food production. Lipton et al. (2010) argue that it is not possible to reduce poverty to acceptable levels all the while SSA relies heavily on rain-fed agriculture. However, expanding irrigated farming in South Africa remains a challenge because most water resources have already been allocated (Van Niekerk et al., 2018). An estimated 1.5 million hectares of potential land could be under irrigated production (Annandale et al., 2011, FAO, 1995; DWAF, 2004). However, the NDP (NDP, 2012) states that 500 000 ha could be expanded and irrigated by improving existing schemes' water use efficiency. In the EC, statistics show that about 7 604 potential hectares of land could be irrigated, and 10 000 ha in KZN. In Limpopo, expansion is not possible because all water resources have been allocated (DAFF, 2015).

Scholars such as Gomo et al. (2014); Muchara et al. (2014); Phakathi and Wale (2018), and Dirwai et al. (2019) argue that most water resources are wasted in smallholder irrigation schemes because of leaking infrastructure and poor institutional arrangements that result in mismanagement of water resources at the local scheme level. These factors expose farmers to water insecurity. Therefore, improving water use efficiency in existing schemes is the only option to expand irrigated areas. Moreover, improving the water security of existing schemes is imperative. Several studies (e.g., Brewis et al., 2019; Muller et al., 2009; Hussain & Hanjra, 2004) have shown that irrigation access is more effective as a poverty reduction mechanism when irrigators are water secure. According to these studies, access to irrigation is a necessary but not sufficient condition to improve the livelihoods of irrigating households. Access to reliable and secure irrigation water enables a farmer to adopt new technologies and intensify cultivation, leading to increased productivity (Sinyolo et al., 2014; Wiggins, 2005; Hussain & Hanjra, 2004). This results in higher overall production and greater returns from farming which improve opportunities for commercialisation (Hussain & Hanjra, 2004).

The importance of irrigation farming cannot be underestimated, particularly during a period of unreliable rainfall. However, every project has costs and benefits. Constructing and building irrigation schemes negatively affects stream flows, directly impacting the habitat of flora and fauna in the river basin (FAO, 2006: 11). Expanding the area under irrigation farming is associated with increasing salinity of soil and water resources, which reduces water and soil quality and also has a negative effect on the species living in the river basin. Both of these outcomes negatively impact the millions of people who depend on fishing for their livelihoods (Schoengold & Zilberman, 2000:14).

The use of pesticides, fertilisers, and other chemicals contaminates the water supply. In developing countries, most people do not have access to a basic water supply, and they rely on river basins for domestic water (FAO, 2020). Consumption of contaminated water causes diseases such as diarrhoea or typhoid fever. Without a sound and well-maintained drainage system, irrigation farming results in poor soil salinity control, which in turn leads to poor quality, alkaline soil (Minhas et al., 2006, 2020). Therefore, good maintenance of irrigation schemes is crucial to reduce the negative impacts and to improve water security.

2.6. Water policies and the governance of water resources in South Africa

South Africa's first national water legislation - the Irrigation Conservation Water Act of 1910 - was promulgated following the formation of the Union of South Africa in 1910 (Perret, 2002; Tempelhoff, 2017). Its main focus was irrigation water use, and the riparian principle (water access was based on land ownership). Given that white farmers owned more land (Gildenhuys, 1998; Goldin, 2010; van Koppen & Schreiner, 2014), 95% of irrigation water was used by large commercial white farmers, while black smallholder farmers used only 5% (Versfeld, 2003).

Following World War Two, the Irrigation Conservation Water Act was replaced by the 1956 Water Act. This was motivated by South Africa's industrial development and the consequent need for water rights to cover a broader scope, including domestic, urban and industrial use (Perret, 2002; van Koppen & Schreiner, 2014). The 1956 Act abolished the riparian principle, as riparian users were granted exclusive use but not ownership of water (Tempelhoff, 2017). Inequalities in water access made a profound mark on South Africa's history (Chikozho et al., 2017). The democratic government that came to power in 1994 is committed to transforming access to water through policy transformation (Tempelhoff, 2017; Goldin, 2010). The most recent policy changes include the Water Service Act, No. 106 of 1997 and the National Water Act, No 39 of 1998 (RSA, 1997, 1998; DWAF, 2006).

International experts in New Zealand, Mexico, the United States, France, Western Australia and Zimbabwe as well as various FOA organisations were consulted when the National Water Act of 1998 was formulated (van Koppen & Schreiner, 2014). These specialists advocated for the adoption of the integrated water resource management (IWRM) framework, which is recognised internationally. The framework is presented in Figure 2.1.

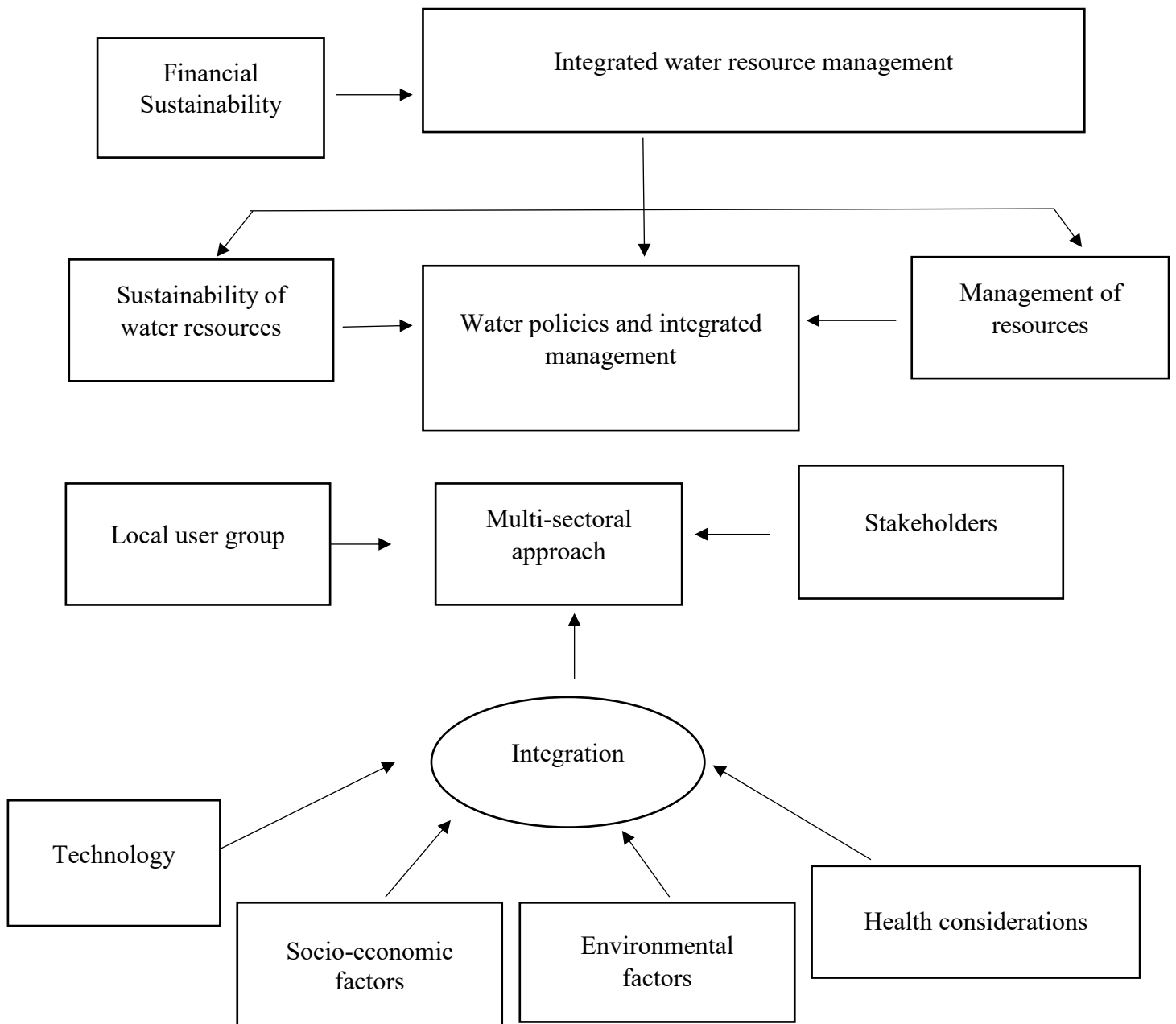


Figure 2.2: Integrated Water Resource Management Framework

Source: Radif (1999)

The IWRM framework emphasises the importance of integrated governance of water resources, integrating aspects such as technological, socio-economic, environmental, health and water policies as shown in Figure 2.1, rather than focusing on the narrow supply-driven management system (Radif, 1999; Biswas, 2008; Grigg, 2008). Its main focus is the involvement of multi-sectoral role players at the national, regional and local levels to ensure sustainable management and development of water resources (Bakker & Morinville, 2013;

Benson et al., 2015; Vorosmarty et al., 2010). Water challenges are multi-sectoral and multi-dimensional; hence, collaboration among various water users in different sectors such as agriculture, industry and municipalities are crucial (Baswas, 2004; Pahl-Wostl, 2008). Megdal et al. (2015) note that the IWRM framework favours bottom-up, participatory governance approaches. It has attracted considerable attention since the mid-1990s and remains a significant paradigm (Bakker & Morinville, 2013) in the water sector.

South Africa's National Water Act of 1998 is built on the IWRM framework's three pillars: economic efficiency, environmental sustainability, and equity (van Koppen & Schreiner, 2014). According to Backeberg (2005), it is in line with the global objective of promoting integrated water management by embracing equity, efficiency and sustainability through a decentralised water management system. Water resources such as groundwater, rivers, dams, and streams are governed by the National Water Act, while the Water Service Act of 1997 regulates domestic, business, and industrial usage. The core purpose of these Acts is to promote equity among all water users and to enable the government to manage and protect water resources on behalf of citizens (DWAF, 2006; van Koppen & Schreiner, 2014). The National Water Act of 1998 resulted in the abolition of the riparian principle, as water is considered a common asset (Perret, 2002).

In terms of institutions, unlike the former centralised bureaucratic system, the National Water Act enables marginalised people to participate in water management decisions (Backeberg, 1997). In addition, the National Water Resource Strategy was adopted to promote holistic, integrated catchment management by water management areas (WMAs). South Africa's 19 WMAs which cover all provinces (Tempelhoff, 2017; Goldin, 2010; Gildenhuys, 1998; DWAF, 2015) are managed by the DWAF, which is responsible for promoting the formation of Catchment Managing Agencies (CMAs) and multi-stakeholder forums such as WUAs (van Koppen & Schreiner, 2014). Local users and stakeholders establish several institutional arrangements in each catchment area to manage water resources. The aim is to create an opportunity for marginalised farmers to participate in decision-making and attain equity, and to promote efficient water management. Legal bodies in the form of CMAs are delegated by the central government (DWAF) to manage water resources at each WMA (Tempelhoff, 2017; DWAF, 2015). In order to avoid a decentralised decision-making system that can be influenced by power dynamics, the Water Act of 1998 provides for CMAs to constitute a governing body that oversees water use.

The primary responsibilities of CMAs include designing a catchment management strategy aligned with the National Water Resource Strategy; coordinating and managing water users' activities; setting and collecting water charges; and distributing available water within bounds specified by the national government (Tempelhoff, 2017; DWAF, 2015). In the context of the agricultural sector, the National Water Act of 1998 allows for subsidisation of water pricing rates, and maintenance and operations charges for irrigation schemes, as they benefit poor communities (Department of Water and Sanitation, 2015). However, after five years, farmers in poor communities are expected to start paying at an annual rate of 20%. This policy was implemented to increase black farmers' access to irrigation water (Versfeld, 2003).

2.7. Governance and institutions in managing water resources

Scholars and practitioners concur that improved water governance is crucial in solving water insecurity challenges in developing countries (Biswas & Tortajada, 2010; Rogers & Hall, 2003; Global Water Partnership, 2002). In the context of irrigation schemes, governance is defined as an interactive process where the actors (farmers) take decisions to solve collective problems, resulting in the formulation, implementation, and monitoring and reinforcement of rules and customs known as institutions (Hufty, 2011).

The term institution has been defined differently by different scholars (Veblen, 1909; Ruttan & Hayami, 1984; Williamson, 1985; North, 1990; Ostrom, 1990; Rodrik et al., 2004; Searle, 2005; Hodgson, 2006; Aoki, 2007; Rutherford, 2007). Veblen (1909) defined institutions as a habit of thought created relationally between individuals in a community, while Williamson (1985) described them as mechanisms of exchange that reduce transactional costs. For North (1990), institutions are the rules of the game or humanly devised constraints and opportunity sets that structure human transactions. Rodrik et al. (2004) and Searle (2005) concur and describe institutions as rules of the game created to achieve desirable outcomes and create institutional realities. Rutherford (2007) defines an institution as a shared system that shapes individuals' values in a community, while for Grief (2006), it is the broad context comprising factors such as beliefs, values, rules and organisations that motivate social behaviour. Hodgson (2006:19) conceptualised institutions as “durable systems of established social norms that structure social interactions”. Thus, all these scholars regard institutions as a rule governing human interactions.

North (1990) and Ostrom (1990) have been leading scholars in rethinking institutions for natural resource management and their definitions are the most cited in the literature (Kingston & Caballero, 2009). Following North (1990) and many studies on innovation (e.g., Edquist, 2005), the study differentiated between the rules of the game (i.e., institutions) and the players of the game (i.e., actors or organisations). North (1990) describes institutions as rules designed by people; norms that govern the behaviour of the participants or members of a community. They are designed to cope with uncertainty and reduce transactional costs and free-riding to increase individual utility. Ostrom (1990:25) notes that institutions are “fundamentally shared concepts that exist in the participants’ minds and sometimes shared as implicit knowledge rather than in an explicit and written form”. These shared concepts can be categorised as rules-in-use and rules-in-form (Quinn et al., 2007; North, 1990). Thus, rules-in-use are informal rules that individual farmers learn on the ground, while rules-in-form are formal rules documented in explicit form. Ostrom (2011) argues that researchers should focus on rules-in-use rather than rules-in-form because the former assist in identifying shared norms and relations and build trust among farmers or a society. Ultimately, they may strengthen collective action in a community.

Ostrom (2005) and Rasmussen and Meinzen-Dick (1995) classify institutions into three groups, namely, "operational rules, collective choice rules and constitutional rules". Operational rules refer to the access and boundary rules governing the use of a resource. In irrigation water, this includes water allocation rules, penalty rules and conflict resolution rules. Operational rules must be flexible to accommodate the dynamic challenges which various groups may face. Collective choice rules offer procedures to create, alter and implement rules. This includes clearly stating who is suitable to participate in the process and how it should operate. Constitutional rules look at the broader structure within which operational and collective rules operate (Ostrom, 2005). The government has the mandate to provide property rights, regulate a resource's use, and regulate the market through constitutional rules. Governance processes must be characterised by transparency, accountability and free participation among stakeholders, including marginalised farmers in the irrigation schemes (North, 1990; Magdal et al., 2015; Muchara et al., 2014).

The water policy frameworks implemented in South Africa influenced the governance and management of irrigation water. In managing water resources, the primary challenge is matching demand and supply. Water management in irrigated agriculture in South Africa is

categorised into water supply management and on-farm water irrigation management (DAFF, 2015). Water supply management, which is the responsibility of the Department of Water and Sanitation aims to ensure a consistent supply of adequate water at the right time to farmers with irrigation water licences. Numerous scholars have highlighted that the main limitation at scheme level is weak or poor institutional arrangements to govern water resources (Muchara et al., 2014; Gomo et al., 2014; Dirwai et al., 2019).

For example, according to the National Water Act of 1998, a WUA committee must be established at the irrigation scheme level to oversee on-farm water management (DAFF, 2015; Dirwai et al., 2019; Muchara et al., 2014). Water User Associations are made up of individuals registered for water use. The WUA is entrusted to design and implement institutions, collect water charges, and maintain infrastructure where there is capacity under the administration of the CMA (Dirwai et al., 2019; Muchara et al., 2014; Gomo et al., 2014; van Koppen & Schreiner, 2014). However, in most irrigation schemes, farmers are not paying for water use, with the government wholly subsidising it. Moreover, in South Africa, most smallholder irrigation schemes do not have volumetric measuring devices, making it impossible to introduce efficient water pricing strategies (Young & Loomis, 2014; Muchara et al., 2016). An argument against charging for water is that it will be a further burden on resource-poor farmers who are already struggling to make a living. However, subsidising water has resulted in perceptions that water is a gift to smallholders, as collecting water-related charges after the first five years remains a challenge (Muchara et al., 2014; Backeberg, 2006). Therefore, most schemes are deteriorating and there is unequal allocation of irrigation water among farmers, highlighting the importance of strengthening institutions and collective action to better manage water resources.

2.8. Importance of collective action in management of the schemes

2.8.1. Collective action theory

Most irrigation schemes, particularly in South Africa suffer from poor or weak institutional arrangements, making it difficult to enforce rules and ensure sustainable governance, and causing schemes to degenerate into open access or common-pool resources (Axelrod, 2010; Dirwai et al., 2019; Muchara et al., 2014). A “common-pool resource is defined as a natural or

manmade resource system that is sufficiently large and costly (but not impossible) to exclude potential beneficiaries from obtaining benefits from its use” (Ostrom, 1990:30). Hardin (1968) draws on the theory of the tragedy of the commons to argue that individuals tend to pursue their rational self-interest (Rational Choice Theory) to maximise utility. Due to rational choice behaviour, common-pool resources may not be monitored, resulting in deteriorating infrastructure and failure to exclude non-irrigators (trucks and livestock), leading to overexploitation of a resource (Muchara et al., 2014). However, an influential scholar in the field of management of common-pool resources, Ostrom (1990), argues that such resources are not problematic if the institutions in place effectively coordinate people’s behaviour.

Ostrom challenged the theory of the tragedy of the commons by arguing that individuals have the ability to co-operate to achieve better outcomes than those achieved individually (Ostrom, 2010, 2007). Ostrom presented many case studies where local communities were able to come together and manage common property resources by following customary rules and norms through collective action (Ito, 2012). Collective action theory, which was first conceptualised by Olson (1965), refers to actions collectively taken by a group to solve everyday problems (Keohane, 2010). The theory has been widely applied in managing common-pool resources (Axelrod, 2010; Graham et al., 2019; Keohane, 2010; Hezberg, 2020; Muchara et al., 2014; Ostrom, 2010; Shalsi et al., 2019). Therefore, collective action is crucial for the sustainable management of common-pool resources like irrigation schemes (Muchara et al., 2014; Shalsi et al., 2019). Through collective action, farmers are responsible for ensuring equitable allocation of water resources, maintenance of the schemes, and the adoption and implementation of effective sanctions mechanisms to eliminate free-riding issues and overexploitation of the common-pool resource.

2.8.2 Conditions required for successful collective action in management of the schemes

Figure 2.2 presents synthesis of seminal work by Ostrom (1990), Wade (1988), and Baland & Platteau (1996) on the conditions required for successful collective action. These conditions were selected based on these authors’ empirical case studies throughout the world (Spain, Philippines, California, Turkey, Sri Lanka, and India). However, the conditions identified depend on the context of the area or the type of common good shared by the community. Due to heterogeneity among groups, they should not be imposed and used as a blueprint to manage open access resources (Ostrom, 1990, 2010). The outcomes of collective action depend on the

physical and technical characteristics of a “resource system, group characteristics, institutional arrangements and external environment” (Agrawal, 2001).

The intrinsic nature of a good determines how the resource system can be managed. Irrigation water is a mobile resource; it is thus challenging to manage and difficult to predict its availability, especially in an era of growing water scarcity (Agrawal et al., 2014). Canal irrigation systems, which are on average more than 30 kilometres long, pass through different villages and are easily accessed by non-irrigators such as trucks and brick makers, making this resource an open resource. It is thus difficult to exclude non-users (Muchara et al., 2014). This has a negative impact on irrigators as competition for water increases. It results in difficulties in predicting whether water will reach farmers’ plots, with the risk even more severe for farmers located in the tail position. While storage dams are reserved, this tends to benefit farmers located at the head or middle position due to geographical location.

Group characteristics play a significant role in determining the outcomes of collective action. These scholars noted that, for effective management and enforcement of rules, groups should be smaller in size and boundaries on resource use should be well defined (Ostrom, 2010). Moreover, users should be located in close proximity to one another because it is difficult to monitor and conserve resources when users are scattered. Group size also significantly impacts cooperation because as the group size increases, the extent of collective action decreases (Esteben & Ray, 2001; Pena & Noldeke, 2016; Lee et al., 2019; Oliver, 1988). This is based on the hypothesis that "smaller groups tend to benefit each member equally because each member gets a significant share in the benefits from the resource, which may exceed their marginal costs of contribution and therefore, the possibility of free-riding is reduced" (Ostrom, 1990:25). However, Ostrom (1990) also documented successful stories of bigger groups, making the relationship between group size, collective action, and outcome a mixed one. Ostrom argues that the size of a group and its outcomes depend on many variables such as heterogeneity, technologies in use, dependence on the resource in use, gender, power and decision making.

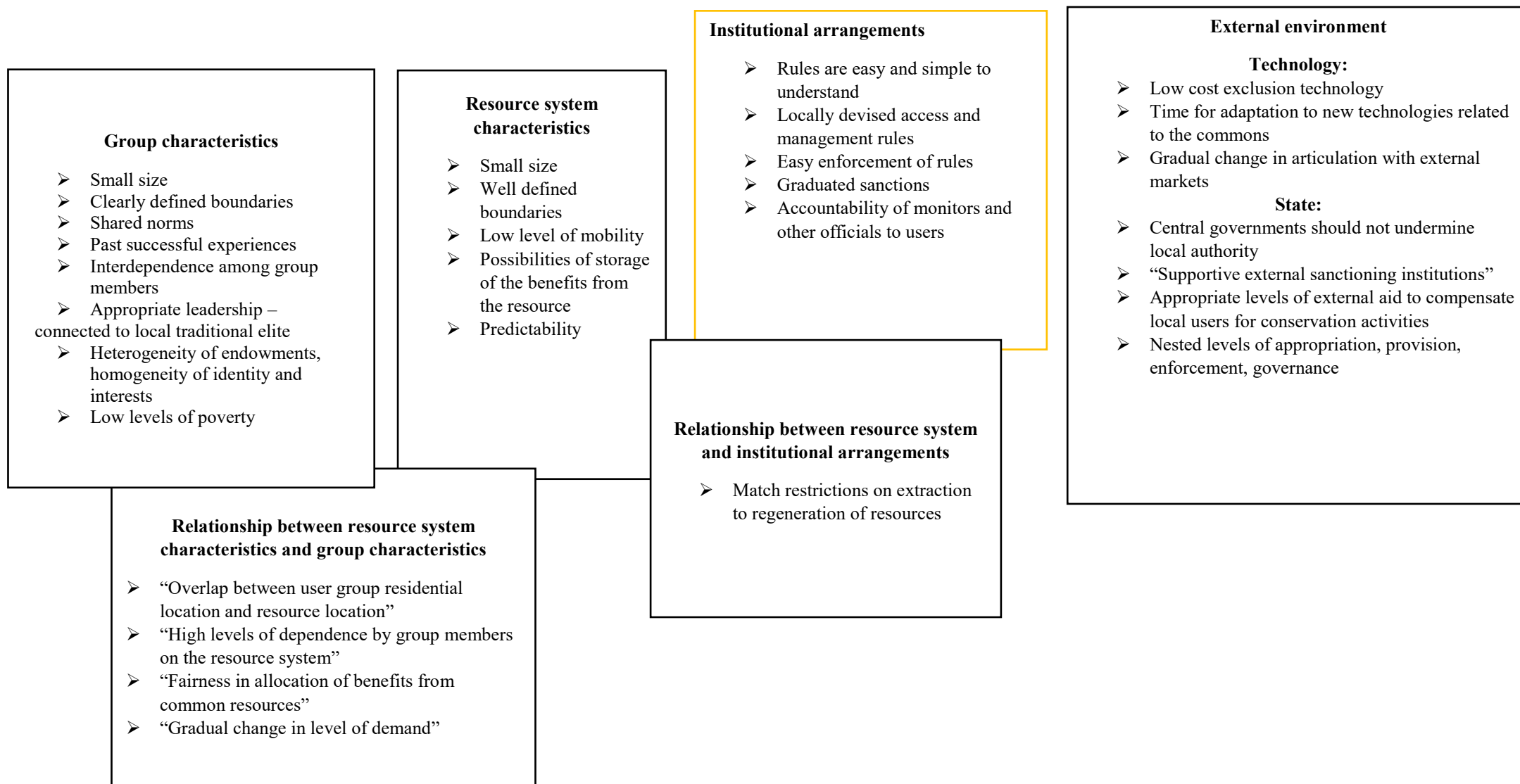


Figure 2.3: Conditions for successful management of common-pool resources

Source: Agrawal (2001)

When users are located in close proximity to one another, this may foster shared interest in the resource due to shared norms influenced by a similar culture within the same community (Ostrom, 1990). Moreover, the heterogeneities of asset endowments among groups correlate positively with the management of common pools (Ostrom, 2007, 2010). Farmers can borrow and have access to equipment that is difficult to acquire individually. However, heterogeneities in terms of identity pose challenges to collective action due to different ideologies influenced by culture, religion or experiences. Collective action is more successful if group members have the same interest in a resource; however, high poverty levels may result in more resource extraction, leading to over-exploitation. The high exclusion cost of common-pool resources makes it challenging to prevent free riders from benefiting from resources. Therefore, clearly defined boundaries are required in terms of who uses irrigation water, when and how. This will assist in overcoming the challenge of the prisoner's dilemma, where some individuals' choices lead to outcomes that are not ideal for other group members (Ostrom, 2010; Gross & Dreu, 2019; Heckathorn, 1996). For example, in the irrigation schemes, some individuals do not abide by their allocated irrigation slot, compromising other farmers' opportunity to irrigate their crops. Farmers therefore need to implement new institutions to address current challenges without major government intervention.

2.8.3. Ostrom's eight design principles

Ostrom (1990) summarised the conditions using eight design principles that are regarded as guidelines for managing common-pool resources (Agrawal et al., 2014; Ostrom & Benjamin, 1993; Ostrom, 1990). These principles can be adapted and applied to diverse environments that require cooperation among members to achieve shared objectives (Wilson et al., 2013). Ostrom's first principle is that clear boundaries should govern the use of irrigation water. Farmers must design and implement arrangements on when and how to access water to ensure that the water in the scheme is distributed equally. In most schemes, routines (when to access water and for how long) are apparent; however, the challenge is enforcement, monitoring and compliance (Dirwaia et al., 2019; Sharaunga & Mudhrau, 2016; Averbek et al., 2011).

The second design principle holds that benefits should be proportional to the cost of accessing water. In contrast, principle three highlights the importance of collective choice arrangements and emphasises that every farmer is expected to participate in designing, modifying, and implementing rules and regulations (institutions). This means that groups should create a

conducive environment, particularly for marginalised farmers, to participate effectively in decision making and reduce the influence of power dynamics based on gender or social status. This will ensure that the innovations implemented are legitimate. Sharaunga and Mudhrau (2016) and Muchara et al. (2014) indicated that most farmers in the Mooi River scheme did not abide by irrigation routines. They irrigated for longer than the days allocated, exposing other farmers to water insecurities. The fifth principle highlights the need for graduated sanctions, where farmers who violate resource-related rules are penalised in line with the seriousness and context of the offence.

The sixth principle is that conflict resolution mechanisms must be available at a low cost within local arenas (Ostrom, 2007). In most schemes, particularly in KZN, traditional authorities are custodians of the land. Farmers are the first to address issues; however, if the matter is a serious offence, it is taken up with the traditional authorities or the Department of Agriculture. These mechanisms are available free of charge to farmers. The seventh principle indicates that farmers must be recognised and have the right to devise their institutions and should not be inhibited by external parties such as government or traditional authorities. This principle is at the core of this study, as farmers should be given opportunities to devise and change their institutional arrangements with minimal government interference in the management of the scheme and groups. The government has failed farmers in various ways by imposing rules and using a "one-size-fits-all" approach (Fanadzo & Dube, 2018), even though smallholder farmers are heterogeneous. The last principle indicates the need for nested governance in which "appropriation, provision, monitoring, enforcement, conflict resolution, and governance are organised in multiple, nested layers" (Ostrom, 1990). Farmers may group themselves into smaller groups in order to effectively account for and monitor one another (Muchara & Mbatha, 2016).

2.8.4. The role of social capital in collective action

Social capital is a longstanding concept that can be traced back to the classical economist John Stuart Mill who contributed widely to social and political theory, and sociologist Max Weber who employed socio-cultural insights to explain economic phenomena. In the late 1980s, social capital received much attention in the academic and policy space as an essential element that can shed light on why some countries and organisations are more successful in their collective action and innovations despite similarities in technology and capital, and environmental

challenges (Barro & McCleary, 2002; Guiso et al., 2006; Bilig, 2000). Some scholars argue that it is imperative to view development from both economic and social perspectives because economic activities are deeply rooted in socio-cultural structures and social values that determine economic outcomes (Sabatini, 2006; Chuah et al., 2009; Carpenter et al., 2004; Inglehart, 1997; Sen, 1999; Landes, 2000).

Social capital is broadly defined as a "multidimensional phenomenon encompassing a stock of social norms, values, beliefs, trusts, obligations, relationships, networks, friends, memberships, civic engagement, information flows, and institutions that foster cooperation and collective actions for mutual benefits and contributes to economic and social development" (Bhandari & Yasunobu, 2009:8). The ability of people who work together to cultivate collective action, trust, reciprocity, solidarity, confidence and commitment to group goals is dependent on the level of internal social trust (Lin, 2001; Moody & Paxton, 2009; Paxton, 2002). Social capital can be used to address collective action challenges, boost social cohesiveness, improve innovations and access to information, and reduce free-riding problems.

Social capital is a source of wealth that can be used to eliminate inequality, social injustice and conflict (Fukuyama, 1995, 2001; Lin, 2001) and it is firmly embedded in the notions of trust, norms and informal networks. Coleman (1990:302) categorised it into reciprocity, including trust; information channels, and norms enforced by sanctions. The richness of social capital depends on the size of the network, degree of civic engagement, and voluntary participation, which fosters robust norms of reciprocity and trust (Quibria, 2003; Coleman, 1990). These values directly impact the productivity of groups or individual welfare (Putnam, 2000). However, Fukuyama (2005:10) notes that social capital is more about people's ability to work together to achieve set goals. Interpersonal trust is regarded as an element which is required for relationships to emerge and be sustainable.

While social capital has different functions, it is generally categorised into structural and cognitive social capital; bonding, bridging and linking social capital; strong and weak social capital; and horizontal and vertical social capital (Bhandari & Yasunobu, 2009:8). Structural social capital defines the network, relationships and associations in which organisations or groups operate. In contrast, cognitive social capital explains the shared norms, values, attitudes and beliefs of individuals who influence the level of trust, reciprocity and collective action among members (Uphoff & Wijayaatna, 2000). Shared norms and values are intangible

cognitive social capital that yields mutual collective benefits among individuals and increases trust and civic cooperation. On the other hand, bonding social capital relates to ties between individuals or groups with similar goals within a network. This form is more inward-looking, tightening solidarity and internal relationships (Hong & Sporleder, 2007).

Bridging social capital relates to groups establishing links with others outside their organisation. This form is outward-looking; it narrows the gap between different (less homogeneous) groups or communities. It is crucial to solve community problems, build relations and share external resources across social networks, which are not available to either of the groups. Linking social capital describes the group's ability to create vertical ties with higher formal institutional authority organisations (e.g., the state) in order to benefit from their resources or influence their policies (Woodcock, 2001). Strong and weak social capital describe how strong (close, persistent and binding) or weak (casual, temporary and contingent relationships) the ties are between individuals or groups. Lastly, horizontal social capital refers to ties between people with similar power and vertical social capital to ties between people with unequal power in a community (Sander, 2002). These forms of social capital are mutually exclusive as well as overlapping.

2.9. Challenges hindering smallholder irrigation schemes

The smallholder irrigation sector faces several challenges, such as poor access to the financial, human, physical, social and natural capital required to make farming a sustainable livelihood (Chipfupa & Wale, 2018). This results in low take-up of modern farming technologies like inorganic fertiliser and improved seed varieties, directly reducing productivity (Crawford et al., 2006; Morris et al., 2007; Cele & Wale, 2018; Selejio & Lasway, 2019). According to the sustainable livelihood approach, access to these five forms of capital assets is crucial to maintain a sustainable livelihood (Chambers, 1988; Chambers & Conway, 1992; DFID, 1999; Krantz, 2001; Li et al., 2020; Woyesa & Kumar, 2021). The sustainable livelihood framework in Figure 2.3 is a tool to understand the livelihoods of marginalised people and determine where interventions can best be made (DFID, 1999; Chambers & Conway, 1992).

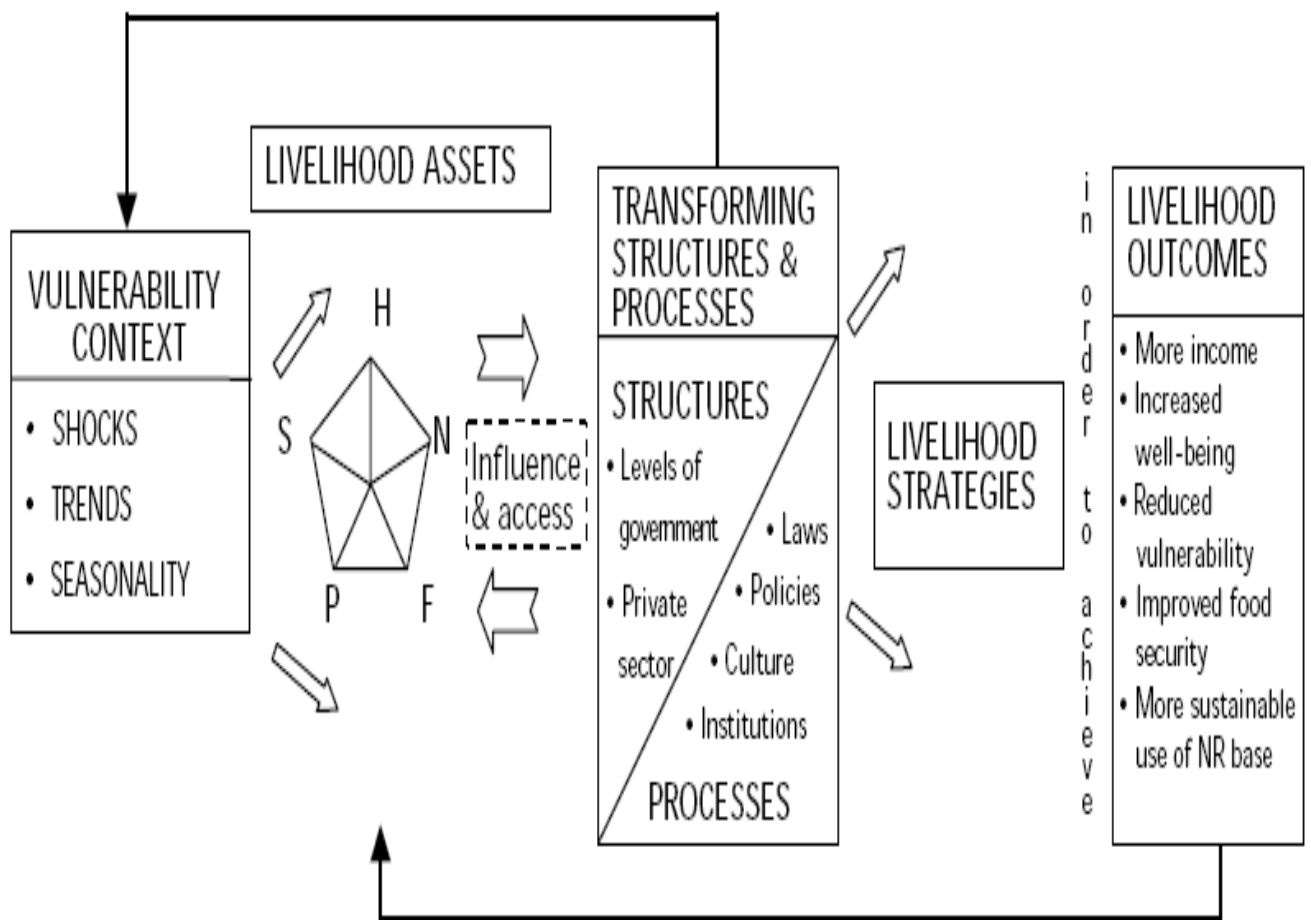


Figure 2.4: Sustainable Livelihood Framework

Source: DFID (1999)

This is a dynamic, responsive and participatory framework which is people-centred as it starts by understanding how vulnerable people live their lives (DFID, 1999; Morse & McNamara, 2013). It identifies factors that hinder or enhance the livelihoods of vulnerable households (Giller et al., 2009) and helps to identify and formulate policies and development activities that can uplift them. The sustainable livelihood framework facilitates practical actions which can be implemented based on available opportunities and the interests of marginalised people (Chambers, 1988; Li et al., 2020). The livelihood in this framework is made up of capital assets, capabilities and activities that are vital to life.

The five capital assets are human, social, natural, physical and financial. Human capital is generally measured by education, skills, knowledge and the ability to work (DFID, 1999; Li et al., 2020). In the context of this study, it refers to education, skills and experiences attained by

farmers to manage farming operations. Okpachu et al. (2014) argue that education is imperative in advancing technologies as farmers must understand complex scientific changes to adapt and remain productive. The majority of studies on smallholder agriculture note that farmers' education levels are relatively low, with the majority never having attended school (Cele & Wale, 2018; Dirwai et al., 2019; Gomo et al., 2014; Li et al., 2020; Sinyolo et al., 2014; Muchara & Mbatha, 2016). Natural capital takes the form of access to land and water for irrigation. The majority of farmers in smallholder irrigation schemes cultivate less than two hectares of land, making it difficult to expand their operations and limiting benefits from economies of scale. Given that smallholder farmers find it difficult to consistently supply large quantities of products, large retailers partner with commercial farmers to reduce transaction costs (Chipfupa & Wale, 2018; Chirwa et al., 2005; Chitsa, 2014). Increasing water scarcity further threatens the sustainable development of the agricultural sector, as water shortages reduce available water in river streams.

Physical capital refers to infrastructures such as roads, vehicles, storage facilities, a water supply and technologies (fertiliser, pesticides and seedlings) that is required to make farming a livelihood approach. Farming is unsustainable without access to such capital. According to the sustainable livelihood framework, every business requires access to physical capital to be successful. No matter how fertile the soil is and how accessible irrigation water may be, agricultural production levels will remain low without access to capital such as tractors, proper roads, and storage facilities (Phakathi & Wale, 2018). Access to physical assets makes farming a sustainable livelihood. For example, the location of smallholder irrigation schemes in rural areas makes it harder for farmers to access the market due to poor infrastructure development (Place et al., 2000; Hellin et al., 2009; Markelova et al., 2009; Godfray et al., 2010; Fischer & Qaim, 2012). Roads in South Africa's rural areas are gravel, unpaved, and are generally poorly maintained, making transport operators reluctant to service these areas (Chazovachii et al., 2012: 231). Market access has been identified as a major challenge limiting the economic growth of smallholder farmers (Barham & Chitemi, 2009; Fischer & Qaim, 2012).

Lastly, financial capital refers to access to credit facilities and sources of income such as pensions, wages and remittances. Financial institutions' exclusion of the rural poor persists. The vulnerable group theory of financial inclusion states that it is crucial for vulnerable or marginalised populations such as smallholder farmers to participate in the formal financial

sector in order to reduce poverty (Ozili, 2020). The majority of farmers do not have the collateral required by banks to access financial capital as the land they cultivate is under the traditional authorities in rural areas (Shangura & Mudhara, 2016). A lack of access to loans makes it difficult for farmers to purchase inputs such as fertiliser, pesticides and improved seed varieties (Crawford et al., 2006; Selejio & Lasway, 2019).

Moreover, due to a lack of financial capital, most farmers plant late in the season, resulting in low productivity (Phakathi & Wale, 2018). Thus, poor access to financial capital limits farmers' adoption of improved technology for crop production and their ability to purchase the equipment required to make farming a success (Giller et al., 2009). Access to credit is crucial because it improves farmers' liquidity and enables them to respond to adverse shocks. In order for a livelihood to be regarded as sustainable, it has to cope with vulnerable contexts such as shocks, seasonality and critical trends (Chambers, 1988; Chambers & Conway, 1992). In addition to these five capital assets, successful livelihood outcomes depend on the policies and institutions in place. The government and the private sector, which play a significant role in forming structures and policies, may hinder or open up opportunities for marginalised households.

The main challenge hindering the performance of irrigation schemes is related to institutional arrangements, directly linked to poor human capital to manage them. Poor institutional arrangements have resulted in inadequate infrastructure maintenance and unequal water distribution in most schemes. Authors such as Fanadzo (2012), Machethe (2004) and Muchara et al. (2014) attribute poor infrastructural maintenance to the rushed process of IMT, which challenged farmers' ability to manage and maintain the schemes. Irrigation management transfer, which is the current era of management of the schemes in South Africa, refers to the government transferring management, operation and maintenance to farmers (van Averbek, 2008:13).

As part of the IMT process, the government withdrew financial support and established WUAs to manage water use at the local level (Fanadzo et al., 2010:25). This was supposed to be a holistic development process, with farmers trained and capacitated to take on the responsibility

of managing complex irrigation systems. However, in contrast to Asia, this process was not gradual and smooth in Africa, resulting in system breakdown and weak infrastructure maintenance in many irrigation schemes. Political reforms in South Africa to redress apartheid inequalities also contributed to the failure of IMT because less attention was paid to capacitating farmers to effectively manage the schemes (Senanayake et al., 2015). Excessive transaction costs, coupled with insufficient government support and weak human capital to manage irrigation schemes, remains a significant bottleneck. Improving the performance of an irrigation scheme requires a holistic approach to address these challenges and the capacity to innovate to remain competitive.

2.10. Defining innovation

Innovation is regarded as a multifaceted phenomenon since it covers a wide variety of activities that are both tangible (technical product innovations) and non-tangible (non-technical process and service innovations) (Armbruster et al., 2008; OECD, 2005). The OECD (2005:46) describes "innovation as the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relation". Spielman et al. (2010: 196) define innovation as a "combination of new and existing knowledge introduced into and used in an economically or socially relevant process." It is a continual process that involves various actors, their actions, and the rules that inform how they interact formally and informally to change practices and behaviours influenced by evolving global changes (Spielman et al., 2010). Innovation involves interacting with various sources with the aim of seeking, and exchanging and integrating information that is then absorbed into social or economic practices that will alter the behaviour of the organisation at large (Martin, 2015).

According to the OECD (2005), innovations can be categorised into four types: product, process, marketing, and organisational (OECD, 2005). Product innovation "introduces a new or significantly improved good or service in the product's characteristics or its intended" uses to improve its functional efficiency and make it more user-friendly or tolerant of specific conditions (OECD, 2005). It is mainly associated with technological innovation and has been the subject of much research, especially in the agricultural sector (Prolinnova, 2012; Rogers, 2015). In this sector, product innovation could include introducing a new variety of seeds that

is highly resistant to drought and new or improved irrigation systems that are more efficient in delivering water to plots. It could also take the form of a new or improved mixture of fertiliser and pesticides application made by local farmers at an affordable cost (Tambo, 2018; Tambo & Wunscher, 2017; Twenya et al., 2011).

The OECD (2005) defines process innovation as introducing a new or significantly improved technique or method to deliver goods or services or new production techniques to reduce the unit cost of production. It includes new or significant ways of managing soil and water conservation for specific farmlands and planning irrigation scheduling and water management given increasing water scarcity that calls for innovative ideas to cope with climate change. Product and process innovations are directly related to technological innovations (Tambo & Wunscher, 2018).

Marketing innovation refers to the introduction of new or significantly improved marketing mechanisms for products and services. Marketing innovations include changes in the design, packaging, promotion and pricing of products to increase sales and profit (OECD, 2005). Access to lucrative markets is one of the significant challenges confronting most African farmers (Muchara et al., 2016; Baloyi, 2010). High transaction costs, limited market information and a lack of access to credit hinder marketing innovations. Organisational innovation is defined as the implementation of a new or significantly improved organisational method in farming business practices, scheme organisation or external relations (OECD, 2005). The concept of organisational innovation is somewhat related to institutional innovations.

Twenya et al. (2011:9) define institutional innovation as “changes made in redefining roles and responsibilities of different organisations or individuals to deliver more returns like improved water security, food security which directly reduces poverty and improves rural livelihoods”. Moreover, Raffaelli (2015) contributed toward the theorisation of institutional innovation and emphasised the importance of legitimacy, which have not been researched empirically, especially in the context of informal smallholder farmers, as stated in the introduction. Raffaelli (2015:7) defined institutional innovation as “novel, useful and legitimate change that disrupts, to varying degrees, the cognitive, normative, or regulative mainstays of an organisational field”. They argue that institutional innovation is comparable to other innovations such as product, marketing, and organisation but differ in that it should be legitimate, normative, progress over time, and be socially constructed and culturally embedded (Raffaelli, 2015). This

emphasises that the process of institutional innovation should be transparent and allow all actors to participate in the implementation of new change. Stinchcombe (1965) cited by Martin (2015) notes that institutions tend to follow the “imprinting theory” in which institutions often reflect the culture and times in which they were formed; their values, norms, ways of thinking and ways of acting and their routines tend to become ‘imprinted’ and to live on. However, Raffaelli, argue that institutional innovation should progress over time for stability to accommodate changes in values, norms and overcome challenges.

Institutional innovation is considered legitimate if all actors participate in the design and implementation of change. Actors are more likely to comply with the rules and regulations they perceive as legit. This emphasises the importance of all in the participation of decision making. Legitimacy in this study simple refers to how institutional innovations were designed and implemented. It is regarded as a normative approach, in which every farmer had a say in decision making regarding the design and the implementation of innovations to overcome institutional challenges. This means that for ensuring legitimacy in a group, fair and equal decision-making processes are crucial for innovations to be successful. The process in which institutional innovations were implemented determine whether farmers will comply with the rules and regulations. Therefore, this study incorporated the concept of legitimacy in examining institutional innovation implemented by farmers.

Local actors (farmers) should be continually allowed to come up with their own working institutional solutions to address their daily operations. This is because they are more knowledgeable about their challenges as local producers and should be allowed to implement their own solutions to improve institutional arrangements and livelihoods outcomes (Engel, 1997; Scoones and Thompson, 2009; Lorentzen, 2013; Cozzens and Sutz, 2014; Chataway et al., 2014; Lapple et al., 2015). According to Engel (1997) and Scoones and Thompson (2009), farmers have immense capacity to innovate, they are active and understand the impacts of their own practices. For instance, in the context of technological innovations, Scoones and Thompson (2009) further stress that most original ideas and successful local adaptations of modern varieties have been realised by farmers in the absence of formal research and extension support. The question then is: Should the government allow the irrigators to take the lead in devising the institutional and management rules to ensure efficient management of irrigation schemes, and only capacitate them in the processes of innovation rather than imposing rules on

them? To what extent will the institutional innovations that are farmer-driven result in better water security and welfare outcomes? The focus of the study will therefore be on solutions by the local people; that is, not only pro-poor solutions (solutions for the poor) but solutions by the poor farmers (Chataway et al., 2014; Cozzens and Sutz, 2014). As detailed explained in Chapter 1, innovation literature in the context of smallholder irrigation farmers has focused more on technological innovations specifically in South Africa (Prolinnova, 2012) and little is known about institutional innovation at the irrigation scheme level. Hence, Chapter 5 of the thesis will empirically answer this objective and provide more literature review since the thesis is structured by paper.

2.11. Institutional change

Various schools of thought have sought to explain institutional change. These include historical, sociological, and rational choice institutionalism (neoclassical) and New Institutionalism Economics. Historical institutionalists generally describe institutions as “the formal or informal procedures, routines, norms and conventions embedded in the organisational structure of the political economy” (Hall & Taylor, 1996: 6). However, they tend to focus more on formal institutions and power inequalities within an organisation. As a result, institutional change is primarily viewed as a path-dependent trajectory, where changes transpire due to critical junctures resulting from an economic crisis (Gorges, 2001; Hall & Taylor 1996). According to Bell (2011), the main criticism of historical institutionalism is that viewing institutions as sticky undermines the role of actors in organisations in being open to change.

Evolutionarily economists such as Hayek (1973), Veblen (1899), and Hodgson (2007) view institutional changes as natural processes that are selected based on efficiency and rational behaviour. According to evolutionary theory, institutional change emerges randomly through a decentralised selection process, where successful institutions spread to the population and replicate. Evolutional theories have no central mechanism, such as legislation that coordinates changes in rules. However, “new rules or behaviours (mutations), which may be either randomly or deliberately generated, undergo some decentralised selection process, as a consequence of which some (successful) institutions spread through the population, while other (unsuccessful) institutions die out” (Kingston & Caballero, 2009:160). Veblen’s (1899)

evolutionary theory of institutional change focuses on habits of thought valued for their bounded rationality.

Sociological institutionalism conceptualises institutions as more informal and mainly influenced by cultural practises (Torfing, 2001). Institutional formation is defined in light of “the symbol systems (formal system), cognitive scripts (how individuals are expected to behave in a certain context), and moral templates (solving disputes) that provide the ‘frames of meaning’ guiding human action” (Hall & Taylor, 1996:14). This conceptualisation gives members of society the power to interpret and respond to what they perceive as possible within a context, not only according to the power to set rules; however, institutions are viewed as very stable (Mahoney & Thelen, 2010).

Rational choice institutionalism considers institutions’ “coordinating mechanisms that sustain particular equilibria” (Mahoney & Thelen, 2010:6). This definition stems from the economic perspective that views actors as rational, strategic agents that aim to maximise utility. Rational choice focuses more on formal institutions (Cleaver, 2012). The primary critique of this school of thought is that viewing institutions as maintaining equilibrium means reliance on exogenous factors for change. It overlooks the role of power, culture, and ideology in institutional change (Mahoney & Thelen, 2010). New Institutional Economics (NIE), which was born out of rational choice institutionalism, extended rational choice theory by considering that institutional changes are not only affected by an actor’s bounded rationality; the fundamental institutional context plays a critical role (Jone, 2015; Hubbard, 1997). It explains institutional change using a design-based approach that involves gathering and analysing data based on the actual behaviour of the actors. This approach regards institutional change as a process of collective action, where groups of individuals strive through collective action to negotiate and design institutions based on the context (Ogawa, 2019; Kingston & Caballero, 2009; Ostrom, 2005; Libecap, 1989). Individuals deliberately design and implement institutional changes that are beneficial and block undesirable rules (Coccia, 2018; Kingston & Caballero, 2009; Libecap, 1989).

This study is situated within NIE, which is “defined as an interdisciplinary enterprise combining economics, law, organisation theory, political science, sociology and anthropology to understand the institutions of social, political and commercial life” (Klein, 1998:456). While

it draws on diverse social science disciplines, its primary language is economics. First proposed by Williamson (1975), NIE became well known during the 1980s (Richter, 2005; Klein, 1998). Significant contributors to the conceptualisation of NIE include Coase (1937), Olson (1964), North and Thomas (1973), Williamson (1975) and Ostrom (1990). These scholars pioneered the application of property right theory, public choice theory, collective action theory, and transaction cost theory, among many others. The aim was to differentiate between the old institutionalists and new ideas in economics. New Institutional Economics aimed to shed light on institutions, the purpose they serve, and how they emerge and change. Coase, North and Williamson won Nobel Prizes in 1991, 1993 and 2009, respectively, which led to significant development and increased influence of NIE.

New Institutional Economics builds on, adapts and extends neoclassical theory by relaxing some of its strong assumptions and integrating a theory of institutions into economics (North, 1993). The fundamental neoclassical assumption retained under microeconomics is that the scarcity of resources drives competition among organisations. The assumption abandoned by NIE is that of perfect rationality to maximise utility. In reality, individuals have incomplete information and bounded rational capacity to process information accurately (North, 1993). The method used to process information differs for each individual, as they are influenced by culture, values and norms, which vary between societies. Moreover, experiences gained in the local environment influence the mental models used to interpret information. Given diverse ideas and ideologies across the world, transaction costs result in an imperfect market.

On the other hand, formal learning influences individuals' perceptions of how they can view the world. Hence, the perfect rationality assumption does not hold in the real world. This suggests that we cannot assume a "one determinate equilibrium outcome; but multiple equilibria can occur" (North, 1993:3). Given incomplete information and constrained mental capacity to process it, transaction costs increase because actors exchange asymmetric information. Transaction costs are the "costs of negotiating contracts, monitoring performance and getting to know trading partners (Parada, 2002:50). The foundation of transaction costs is associated with searching for information, analysing options, drawing up the contract and realising it as well as the costs resulting from bounded knowledge and the tendency towards making mistakes" (Chotkowski, 2010:106). Therefore, institutions are devised to reduce the

transactional cost of enforcing agreements and uncertainty in human interactions. North (1993) argues that transaction costs, ideas, and ideologies play an essential role in forming institutions.

The role of collective action in changing the supply of institutional innovation encompasses struggles to eliminate power disparities, and this depends on the cost of achieving social consensus (Mahoney & Thelen, 2009; North, 1990, 1993; Ruttan & Hayami, 1984). However, if collective action fails, government can play a regulative role and enforce rules in order to eliminate power disparities in the management of common-pool resources. Libecap (1993) and Raffaelli and Glynn (2015) further note that institutional innovations are generally an incremental (modification of existing institutions), path-dependent process because organisations learn, and develop their ideologies in the context of already existing formal and informal rules. Incremental innovations arise purposefully to solve problems or add value, while radical innovations (creation of new institutions) usually occur due to significant shocks that can disrupt the status quo (Cleaver, 2012).

Mahoney and Thelen (2009) note that incremental innovations come about when a group adjusts its situational processes and regularisation over time. Situational adjustment allows actors to disentangle confusing situations by reinterpreting or redefining rules and relationships. Farmers may gradually or incrementally change their institutions to ensure that current institutions relate to current challenges. With gradual institutional change, a farmer group may apply displacement or layering to redesign institutions (Mahoney & Thelen, 2009). Displacement occurs when the existing rules and procedures in an organisation are entirely replaced by new ones through progressive change, while layering occurs when existing rules are a significant improvement on the previous ones. Changes take place as actors reassign or reinterpret rules, values, and norms to have a new purpose and meaning. This section is further elaborated in Chapter 5, which presents empirical chapter (paper) on institutional innovations.

2.12. Summary

This chapter presented an overview of literature review on the agricultural sector in South Africa, with a specific focus on the smallholder irrigation sector. Based on the international standard, it defined smallholder farmers as those farming less than two hectares of land. The

history of smallholder irrigation schemes was briefly described and it was noted that the current era involves IMT, where management of the schemes has been transferred from the government to farmers. The importance of irrigation farming was also described, drawing on empirical evidence from developing countries and South Africa. South Africa's water policies and governance issues were discussed, with a focus on how marginalised people such as smallholder farmers have been included in the management of water resources. The chapter presented collective action theory, which was the foundation for the study as it focuses on the management of common-pool resources, in this case, irrigation water. Ostrom's eight design principles, which are a blueprint for managing common-pool resources, were also explained. The sustainable livelihood framework was then presented to highlight some of the challenges hindering the performance of the smallholder irrigation schemes.

To conclude, the presented literature demonstrated the vital role the agricultural sector plays in economic development globally, especially in African countries where the majority make their livelihood through farming. In Africa, smallholder farmers and smallholder irrigation schemes, in particular, are regarded as an important vehicle to reduce food insecurity, unemployment and poverty. Their importance motivated this study to investigate further how smallholder irrigation schemes in South Africa can be strengthened because SA is regarded as the 40th driest country in the world. The literature highlighted that in South Africa, investing in the smallholder irrigation scheme remains crucial in achieving sustainable development goals despite their continual underperformance.

The gap identified in the literature is that the majority of studies in the context of smallholder farmers tend to focus more on technological, product, and marketing innovations and have overlooked the importance of farmer-led institutional innovations. Institutional innovations are crucial in every organisation because they enforce stable institutions, which are vital for the successful implementation of technological, product and marketing innovations. Moreover, the literature highlighted the importance of redefining institutional innovations and measuring water security in the context of heterogenous smallholder farmers facing various challenges that hinder their collective action, social networking, and institutional changes. Based on this background, the study sought to contribute to the body of knowledge by understanding,

investigating and evaluating the role institutional innovations can play in improving water security, scheme management and collective action, among many outcomes.

The empirical chapters presented on chapter 4, 5 and 6 will build from this overview literature review, and each chapter (paper) clearly outlines the gap and contribution of the study. The following chapter presents the research methodology employed to achieve the research objectives set out in Chapter 1.

CHAPTER 3: RESEARCH METHODOLOGY

3.0 Introduction

This chapter presents the research methodology employed to conduct this study. It describes the study areas and the location of the selected irrigation schemes in KZN and EC Provinces. The justification for the selection of these schemes is explained as well as their management system in order to better understand how they are managed in the era of IMT, when full responsibility has been transferred to farmers. The chapter discusses the post-positivist worldview which was selected as the research paradigm for this study. The purposive and multistage sampling approaches used in the study are explained as well as the justification for selecting these techniques. Lastly, the chapter elaborates on the use of focus group discussions (FGDs) and thematic analysis. The research methods outlined in this chapter apply to all three empirical chapters that follow.

3.1. Study area description

3.1.1. The Tugela Ferry and Mooi River Irrigation schemes in KwaZulu-Natal Province

The study was conducted in the EC and KZN provinces of South Africa. KwaZulu-Natal covers 94361 km² and is the third-smallest province in terms of land size but the second largest by population size. South Africa has an estimated population of 60.14 million, and KZN is home to around 19.1 million people (Stats SA, 2021). It is positioned in the southeastern seaboard of South Africa. About 6.5 million hectares of land in KZN is under agricultural production, of which 82% is suitable for livestock production (DARD, 2020). The province's agricultural sector contributed 4% to gross value added (GVA) in 2020/2021 (DARD, 2020).

The Mooi River and Tugela Ferry irrigation schemes are located in uMzinyathi District in uMsinga Local Municipality. uMzinyathi District is situated in the north central part of KZN, while uMsinga Local Municipality is located in the northern part in the town of Tugela Ferry. uMsinga covers a total area of 2 500 km², subdivided into six traditional authorities (Qamu, Mchunu, Bomvu, Zondi, Mabaso and Mthembu) (Dearlove, 2007; uMsinga Local Municipality, 2020). uMsinga is a mainly rural area, with 69% (1 725km²) of the land under traditional authorities in the form of the Ingonyama Trust, and 31% under commercial farming

(uMsinga Local Municipality, 2020). In 2016, it was reported that the total population was approximately 184 494, making up 33.2% of the population of uMzinyathi District. Women made up 55.3% of this population. About 30% of Msinga residents have never attended school, with only 2.5% holding tertiary qualifications (uMsinga Local Municipality, 2020).

UMsinga is a poor area with a reported unemployment rate of 49.5% while approximately 63% of the population earns R1-R400 per month. Infrastructure development is challenge because most of the land is owned by traditional authorities, making it difficult for investors to acquire it for developmental purposes. Agricultural production in uMsinga largely takes the form of subsistence farming, and adverse climatic conditions hinder productivity as the area is mainly dry with poor vegetation. UMsinga area is “characterised by a moderate climate, with warm to hot summers and mild to cool winters, receiving medium to low rainfall of less than 600 mm per annum” (uMsinga Local Municipality, 2020:95). The main crops are tomatoes, cabbage, maize, spinach, and onions.

The Tugela Ferry irrigation scheme shown in Figure 3.1 is located in Wards 3, 4 and 5 of uMsinga Local Municipality. Established in 1896, it has been operating for more than 120 years. The total irrigable size is 837 hectares of land. Water is diverted from the Tugela River using a 34 km long canal under gravity feed for blocks 1 to 5, and the canal flow rates range between 0.1 and 0.4 m³. s⁻¹ (Dirwai et al., 2019; Sinyolo et al., 2014; Cousins, 2012). Due to their geographical location, other blocks draw water using either electric (4A and 7) or diesel pumps (4B) as broken canals result in water shortages, particularly on the tail-end position. The scheme consists of 1 500 plots of 0.1 hectares each and is accessible through the traditional authorities (Dirwai et al., 2019; uMsinga Local Municipality, 2020). The main crops are maize, tomatoes, cabbages, and spinach.

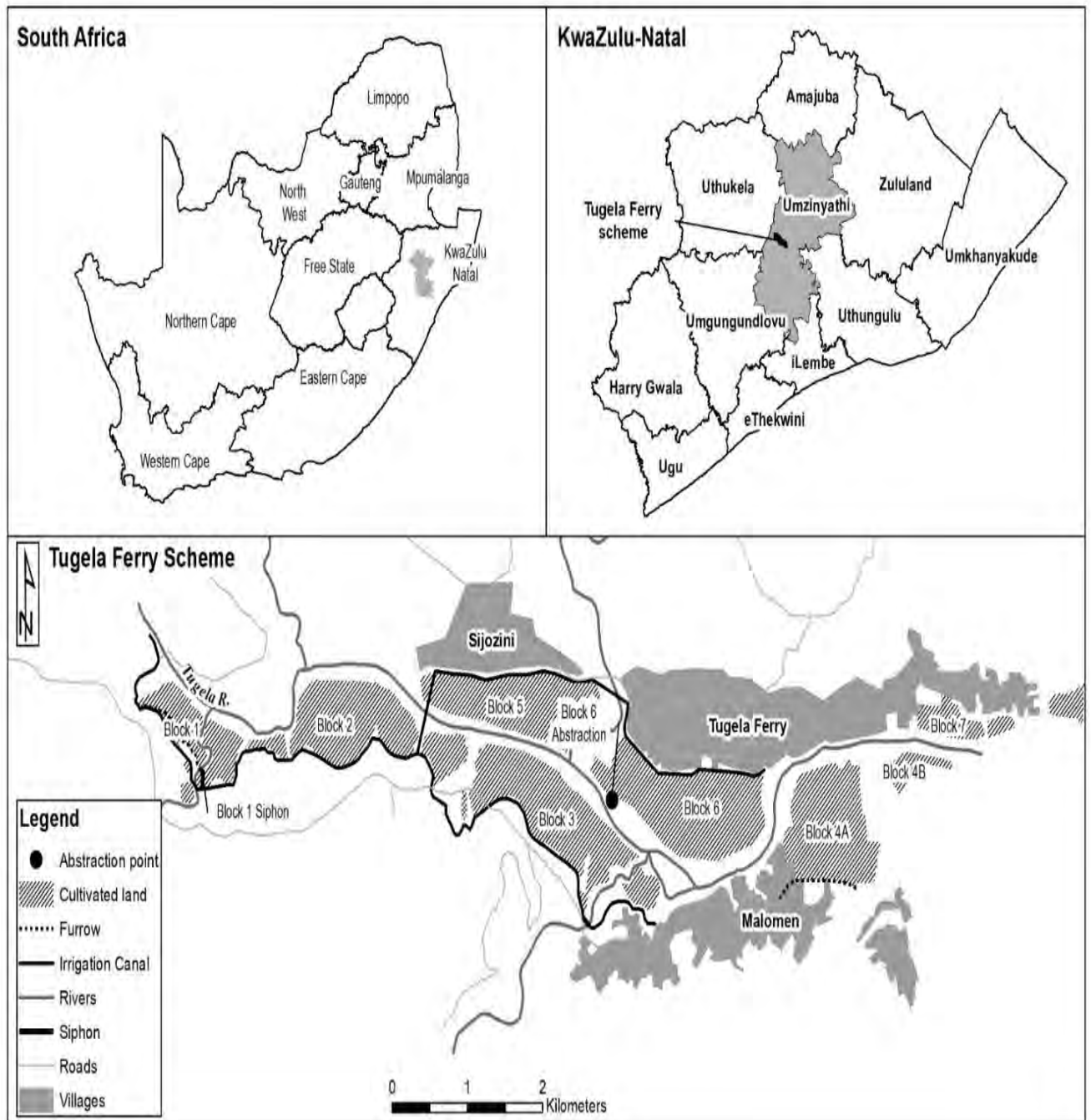


Figure 3.1: Location of the Tugela Ferry Irrigation Scheme

The Mooi River irrigation scheme shown in Figure 3.2 covers 600 hectares divided into 0.1-hectare plots, and benefits 842 farmers (Muchara et al., 2014). However, some farmers own more than 0.1 hectares of land. The scheme was constructed around 1902 (Dirwai et al., 2019; Gomo et al., 2014). It is subdivided into 15 blocks that are supplied by a 25 km main canal with a flow rate of $0.36 \text{ m}^3 \cdot \text{s}^{-1}$. The main crops are maize, tomatoes, potatoes and spinach.

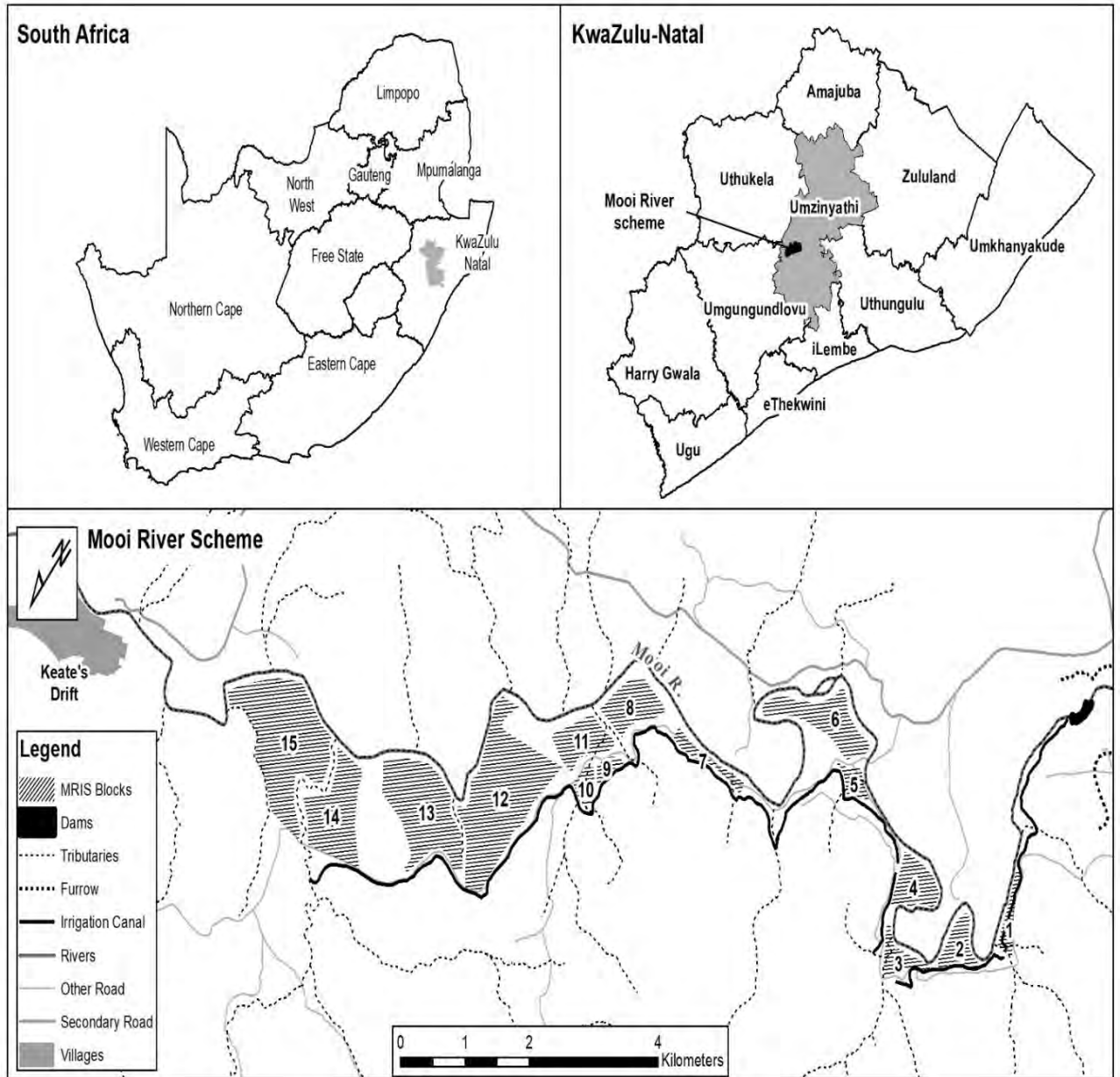


Figure 3.: Location of the Mooi River Irrigation Scheme

The Mooi River IMT took place from 1997 to 1998, when its management was handed over to farmers. In the Tugela Ferry and Mooi River schemes, the land is mainly registered to men, as the patriarchal system dominates.

3.1.2. The Zanyokwe and Qamata irrigation schemes in the Eastern Cape Province

In terms of land size, the EC is the second-largest province, covering 169 580 km², representing 13.9% of the total South African land area (Eastern Cape Provincial Government, 2021). It is the third most populous province, with an estimated population of 6.6 million, comprising 11.1% of the total South African population (StatsSA, 2021). The EC Province is situated in the south-eastern part of the country. The rainfall pattern is bimodal, with the summer rainfall zone in the east, while the western zone experiences winter rainfall (Mnkeni et al., 2010). The EC receives between 100 mm and 520 mm of rainfall per year (Botai et al., 2020). It is the poorest province, with 67,3% of adults living below the poverty line (StatsSA, 2020).

Figure 3.3 shows the Qamata irrigation scheme, which is situated in Chris Hani District under Intsika Yethu Municipality. Chris Hani District covers 36 756km², and the majority (63.8%) of its population lives in rural areas. Intsika Yethu Municipality covers an area of about 2 873km², housing a total population of 153 000 (18% of the Chris Hani District). In 2016, it was reported that 69.1% of people in this municipality were living below the poverty (Chris Hani District Municipality, 2020). The agricultural sector is the main livelihood activity and it is reported that communal and informal land ownership is a significant constraint to the development required to improve rural livelihoods. The Qamata irrigation scheme was established in the late 1960s by the former Transkei government. Traditional authorities administer the land under the communal land tenure system. Qamata experiences unreliable rainfall totalling between 6mm and 86 mm per annum and droughts are common. The Lubisi Dam was completed in 1968 to supply irrigation water that is diverted from the Indwe River through a 28 km canal. Initially, the scheme was subdivided into individual food plots of 0.25 hectares, with two hectares targeted for commercial purposes (Chitsa, 2014). Qamata uses a short-furrow irrigation system, and the main crops are maize, cabbages and lucerne.

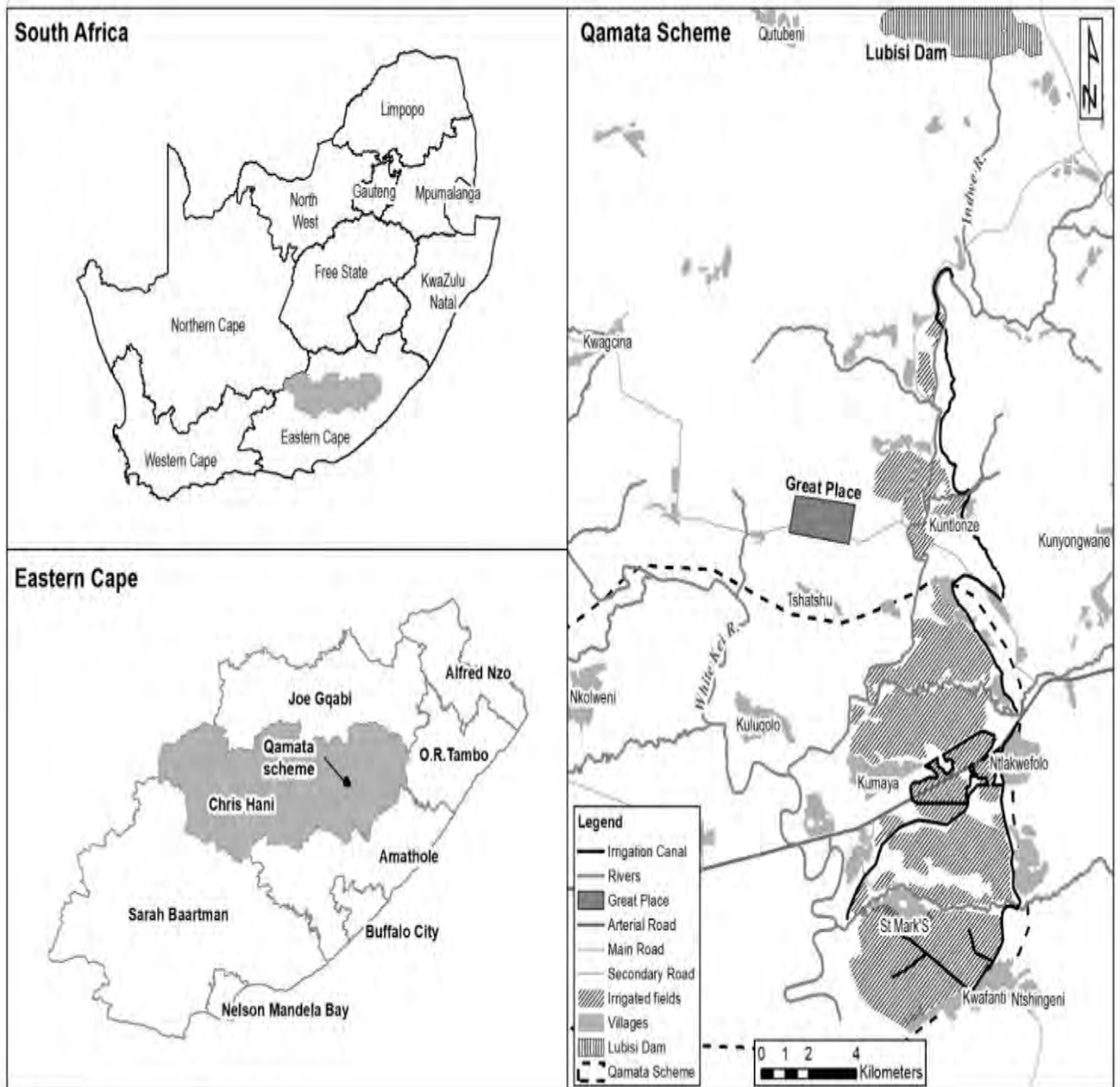


Figure 3.2: Location of the Qamata Irrigation Scheme

The Zanyokwe irrigation scheme shown in Figure 3.4 is situated in Amathole District, under Amahlathi Local Municipality. Amahlathi Municipality is located in the northern part of Amathole District. The district covers 21 229km² of land, while Amahlathi covers 42 66.21 km². In 2016, the population of Amahlathi Municipality stood at 101 826, with a majority of females (51.75%) (StatsSA, 2017). The agricultural sector contributes 6% to the municipality's GDP. The Amahlathi Municipality is located within the summer rainfall region, receiving 70%

of rainfall from October to March. On average, the area receives about 400 mm annually. Zanyokwe receives 590mm of precipitation each year.

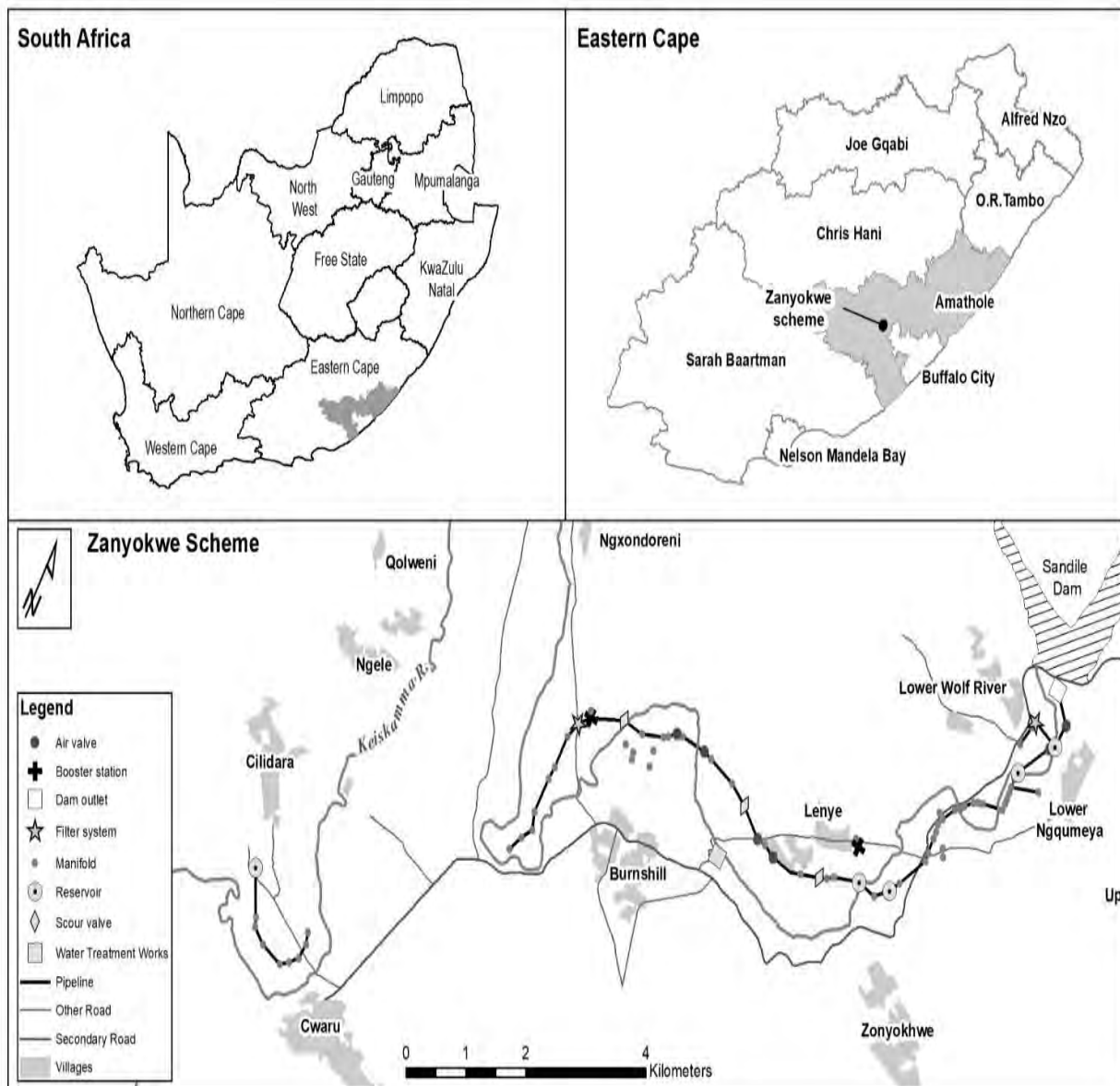


Figure 3.3: Location of the Zanyokwe Irrigation Scheme

The Zanyokwe irrigation scheme was established in 1983 by the Israeli government. It is divided into patches of six villages, namely Kamma-Furrow, Burnshill, Lenye, Lower Ngqumeya, Lower Zingcuka and Mkhubiso. Kamma-Farrow in the far tail end has not been cultivated for about five years because of water issues (Njaimwe et al., 2018). It consists of 450 hectares with 164 beneficiaries (Fanadzo et al., 2010). Following the first democratic election in 1994, the Ulimocor co-operative, a government parastatal, managed the scheme. In

1997, management of the scheme was transferred to farmers. Due to management challenges, the Zanyokwe scheme was vandalised, but in 2004, co-operatives were formed, and the government revitalised the irrigation system. A sprinkler irrigation system is used, and the major crops are cabbages, maize, and butternuts.

3.1.3. Management of the four irrigation schemes

The four irrigation schemes are located in rural areas, where the land is under the ownership of traditional authorities. These authorities have the full title deed to the irrigation plots and are responsible for allocating them to communities. The traditional authorities also play a significant role in addressing conflicts regarding land issues among farmers. Married couples in the village are given first preference when land is allocated as this is a means to ensure food security within the area. Male farmers are generally the sole custodian of the land, and it is registered in their name. Once a household is allocated a plot of land, it is responsible for cultivating it and covering the total cost of operations. The Department of Agriculture and Rural Development works closely with farmers, offers extension support, and provides funding for inputs and equipment, and financial capital. To reduce the transaction cost of offering training, the government implemented a policy where every farmer was encouraged to be part of a farmer group to share the costs of production, product information, and marketing. These groups elect a committee made up of the group chairperson, deputy chairperson and secretary. The committee is responsible for applying for inputs and financial support from the government and private organisations and for liaising with the traditional authorities.

The group committee and the other members collectively manage the scheme and draw up a schedule for irrigation water. However, because most farmers are poor, the government still covers the total cost of maintaining the irrigation infrastructure and water for the schemes is provided free by the government. The Department of Agriculture and Rural Development is the main stakeholder that works with farmers. A non-governmental organisation (NGO), the Lima Rural Development Foundation, also support farmers by offering extension services. These two agencies mainly provide farmers with extension support, including training, drafting business proposals and assisting farmers with market access. The extension officers are government employees who hold degrees in agriculture related fields, including Agricultural

Economics, and Agronomy. The schemes are sub-divided into blocks or groups, and each is allocated an extension officer who works directly with farmers.

3.2. Research Paradigm

The four prominent research paradigms are positivism, post-positivism, interpretivism or constructivism, and pragmatism (Creswell, 2009; Creswell & Clark, 2011; Phillips & Burbules, 2000). The researcher's discipline and the purpose of the study determine the research paradigm. Constructivism is more applicable in qualitative research as researchers use subjective meaning based on their experience to understand human behaviour (Creswell, 2009). The pragmatic paradigm employs abductive reasoning as the researcher actively moves back and forth from inductive and deductive reasoning and draws from three paradigms (Tashakkori & Teddlie, 2003; Goldkuhl, 2012; Morgan, 2007; Creswell & Clark, 2011). According to Creswell (2009:34), "pragmatism allows a researcher to use multiple methods, different worldviews, and different assumptions, as well as different forms of data collection and analyses". It focuses on action-based research grounded on what works to provide solutions to problems. It uses several approaches to conceptualise and understand a problem. A pragmatic worldview gives a researcher the freedom to choose methods and techniques that will best achieve the study's objectives.

The positivist paradigm world view is the traditional way of doing research grounded on the scientific method of investigation (Creswell & Poth, 2016). It focuses on quantitative methods to understand human behaviour and relies on formulating and testing a hypothesis (Kivunja & Kuyini, 2017). Positivism's main shortcoming is that it assumes that only absolute or scientific truth can be used to understand human behaviour. Post-positivism was developed to challenge the traditional notion of the absolute truth of knowledge (Phillips & Burbules, 2000). It acknowledges that "reality is imperfect, and that truth is not absolute but probable" (Kivunja & Kuyini, 2017:32). Post-positivism employs deductive reasoning (Feilzer, 2010), as it holds that theories govern the world, and that these can be tested, verified and refined in studying human behaviour. A post-positivist research inquiry starts from the theoretical framework, data collection, and analysis of the results to refute or accept proposed claims. The post-positivist research approach comprises an investigation, assessment and identification of the causes that

influence outcomes. The knowledge generated by a post-positivist lens is thus dependent on observations and measurements.

This study adopted a post-positivist worldview and a mixed-method approach (Creswell, 2009). It was situated within the post-positivist paradigm as it was grounded in deductive reasoning using the prominent theories developed in studying human behaviour in economics, especially in managing common-pool resources. The aim was to verify and test the claims made. The rationale for using a mixed method approach was that neither quantitative nor qualitative methods are sufficient on their own to capture the details of a situation; thus, data from both methods provides a richer base for analysis.

3.3. Sampling Framework

In general, two main sampling techniques can be used to select a sample, namely, probability or random sampling, and non-probability or non-random sampling. In probability sampling, every case in the population has an equal chance of being selected for the sample (Ghauri & Gronhauf, 2005). It thus reduces sampling bias. However, probability sampling costs both time and money (Taherdoost, 2016). Random sampling approaches include simple, stratified, cluster, systematic and multistage sampling. Simple random sampling is preferable as the results can be projected to the larger population; however, it can be costly and time-consuming. Stratified sampling ensures that all crucial sub-populations are included in the sampling frame, which improves representation.

Non-probability sampling is often used in case study research and generally focuses on small samples. It is commonly used in qualitative studies where the researcher seeks to gain in-depth understanding of a particular case through examining a real-life phenomenon (Yin, 2003). Non-probability sampling includes quota (looking at certain characteristics), snowball (investigating rare characteristics where cases are difficult to access), purposive (selected deliberately to provide crucial information) and convenience (selecting cases based on availability) sampling (Breweton & Millward, 2001; Yin, 2003; Maxwell, 1996).

This study employed multistage purposive sampling. In purposive sampling, cases are deliberately selected because they provide crucial information relevant to the study that cannot be obtained from other sources (Maxwell, 1996). Multistage probability sampling, which involves moving from a broad to a narrow sampling approach using a step-by-step process, was employed. The cases are divided into a number of geographical regions, with cases in the region chosen using simple random sampling. This approach is less costly and time-consuming when dealing with a large population (Taherdoost, 2016).

Firstly, the EC and KZN provinces were purposively selected because they have the second- and third-largest number of irrigation schemes after Limpopo Province in South Africa. The latter was not selected because of the language barrier. Furthermore, in KZN and the EC, irrigated agriculture is the primary source of livelihood among rural farmers due to high temperatures and low precipitation (Muchara et al., 2014; van Averbeke et al., 2011). In stage two, four irrigation schemes were purposively selected from a list of irrigation schemes in the two provinces. The lists were obtained from the provincial Departments of Agriculture. After field visits to most of the schemes and informal discussions with farmers on scheme dynamics, the Qamata and Zanyokwe irrigation schemes in the EC and Tugela Ferry and Mooi River schemes in KZN were selected. The selection criteria included the number of years the scheme had been in operation, number of beneficiaries, land size, and water management challenges such as free-riding issues, weak penalty systems, and weak monitoring mechanisms.

Following the purposive sampling, a multistage sampling approach was implemented, where farmers were first subdivided into blocks of those who shared irrigation water infrastructure. The next stage involved the selection of farmer groups in the four irrigation schemes. All farmers share the same irrigation water in these schemes and they are subdivided into blocks or villages. The contact details of a group or block chairperson were obtained from the local extension officers in the provincial Departments of Agriculture, and appointments were made with them with the assistance of the extension officers. The total number of groups selected based on blocks or villages was 28 (Tugela Ferry seven, Mooi River nine, Qamata six and Zanyokwe six).

These irrigation groups share water from the same secondary canal; hence, they have to work together to devise water management and distribution institutions. The aim was to select groups/blocks located at the upper, middle, and lower ends of the participating irrigation schemes. All the blocks in the schemes were selected, except in Mooi River, where nine of 15 were selected. This was because the other blocks did not cultivate any crops as the scheme was undergoing upgrades during data collection. The group chairpersons were interviewed to provide information on the groups' socio-demographic characteristics, social capital, and management. The study targeted blocks rather than individual farmers for institutional innovations for water management because Tambo (2018) reported that institutional innovations in the smallholder sector are mainly implemented at group level.

The next step involved the random selection of individual irrigators within these blocks or villages. A list obtained from extension officers and group chairpersons was used to randomly select irrigators. Scheme members were further categorised into those who are part of farmer co-operatives and those who are not members of a co-operative. Farmers form co-operatives or farmer groups to engage in collective activities like purchasing fertiliser. However, being a group member is not compulsory. Simple random sampling requires an adequate sample size to reduce sampling bias and to better represent the entire population. To avoid sampling bias, the total sample size should at least be 10% of the population (Bartlett et al., 2001). A total of 401 irrigators was randomly selected, ensuring that at least 10% of the population was sampled from each scheme to represent the entire population. The total sample size was motivated by data adequacy for the proposed empirical model, such as PCA, Propensity Score Matching and Ordinary Least Squares (OLS). According to Costello and Osborne (2005), PCA observations to variable should be at least in the ratio of 10:1. Moreover, the study adhered to ten observations per parameter for the Logit and OLS model (Long & Freese, 2014). Therefore, the sample size of 401 was adequate for data analysis.

3.4. Data collection instruments

3.4.1 Face-to-face surveys

Face-to-face individual interviews were conducted with the irrigators using structured, closed-ended questionnaires. Paper and pen interviews were used, with the questions read to farmers

in their home language. A face-to-face survey enables the researcher to ask and explain complex questions which the participants might find challenging to comprehend in self-administered interviews. Moreover, face-to-face surveys enable a researcher to conduct more complex, longer interviews, which can last for about an hour (Fowler, 2014; Schnell, 2019). According to Schröder (2016), face-to-face surveys usually have a higher response rate than self-administered interviews because of the physical presence of the interviewer. However, there is the risk of the researcher trying to influence the participant's responses, resulting in biased results. Moreover, participants may not feel comfortable due to certain characteristics of the interviewer. For example, in an environment dominated by a patriarchal system, female farmers may not feel comfortable with a male interviewer (Groves et al., 2009; Loosveldt, 2008). Therefore, measures to minimise these shortcomings are crucial when collecting data using face-to-face surveys.

In this study, data were collected from 2018 to 2019 by four enumerators in each scheme (16 in total) who spoke IsiZulu and IsiXhosa, the home language in each scheme using structured questionnaires (see Appendix B). The questionnaires were translated into the farmers' home languages. The enumerators were trained, and the questionnaires were pretested before the survey. A sample of five irrigators in different groups was interviewed in each scheme during the pretesting. A few questions that were not clear were edited to make them more explicit. Pretesting also helped in the translation of the questionnaire into local languages. This improved the readability and validity of the questionnaire. After modifying the questionnaire, the five irrigators from the blocks selected for pretesting were interviewed again, mainly for those modified questions.

However, only 15 were willing to be interviewed again, which resulted in five irrigators being excluded from the sample. The questionnaire covered questions relating to socio-demographic characteristics, production, and perceptions of internal group dynamics. Interviews to gather information on the group/block were conducted with each group's chairperson, secretary, and treasurer. It is important to note that the target was irrigators responsible for managing farming on an irrigation plot and for making farming decisions, whether or not they were household heads. To avoid the bias associated with face-to-face surveys, the enumerators or research assistants were strategically deployed and using local enumerators made farmers feel more comfortable during the interviews. Furthermore, the enumerators were thoroughly trained for a week before the final survey commenced.

3.4.2. Key informant interviews

Key informant interviews were employed to collect in-depth information on the schemes' management and the study participants. The concept of "key informants" originated in ethnographic research and it was commonly used in cultural anthropology. It was identified as an anthropological technique around 1936 (Tremblay, 2003; Skinner, 2012). Marshall (1996:92) describes key informants as "knowledgeable, willing to participate, communicative, impartial and have a role in the community or understanding of the phenomenon that gives them information that the researcher is seeking". Key informants are not participants per se in the research, but they provide information about the research participants because of their position in the community (Innes et al., 2017).

This method has been employed in different disciplines to gain more insight into the research community or phenomenon under study. The advantages of using key informants include enabling a researcher to collect quality data within a short period of time and reducing the costs associated with data collection (Adekannbi & Dada, 2017; Innes et al., 2017; Katiambo, 2015). The main disadvantage of key informant interviews is when key informants report only politically acceptable, and thus biased information (Cossham & Johanson, 2019). This shortcoming was addressed in this study by holding individual face-to-face interviews and FGDs with farmers.

The key informants in this study were extension officers in the Department of Agriculture and Rural Development, NGOs working with farmers such as the Lima Rural Development foundation, water management agencies such as Amathole, traditional authorities such as induna (the King's liaison officer) and farmer group leaders. Extension officers have in-depth knowledge of the management, productivity, and operation of the schemes, while water management agencies provided information on water distribution and maintenance issues. The farmer group leaders provided in-depth information on internal group dynamics and the King's liaison officer (induna) related how traditional leaders address disputes among farmers. Key informant interviews were held with each extension officer responsible for offering extension support in each block.

3.4.3. Focus group discussions

Focus group discussions (FGDs) were conducted with farmers and extension officers to supplement the quantitative data. An FGD is a qualitative technique used to gain in-depth understanding of a particular phenomenon from a group of individuals. The researcher aims to solicit the participants' diverse personal experiences, beliefs, perceptions and attitudes (Nyumba et al., 2017). Participants from a group are purposively selected in order to gain a broader perspective (Nyumba et al., 2017). In general, this method is used in conjunction with other techniques and its popularity was due to the rise of the participatory paradigm approach around the 1980s (Morgan, 2002). The use of FGDs also increased as researchers aimed to bridge the gap between scientific enquiry and local knowledge (Cornwall & Jewkes, 1995). The advantage of FGDs is that they are a cost-effective technique that has been implemented in different disciplines including psychology, sociology, education, communication and marketing research (Nyumba et al., 2017). The researcher takes on the role of facilitator or moderator and ensures that every individual has a chance to express his/her opinions (Thomas & Robson, 2001). Focus group discussions result in both qualitative and observational data.

In this study, a single FGD (one group and facilitators) was conducted with farmers and stakeholders in the agricultural sector comprising of extension officers, NGO representatives (Lima Rural Development Foundation), and agencies responsible for managing water resources (Amathole Water) to gather in-depth qualitative information to supplement the quantitative data gathered during one-on-one interviews (Cornwall & Jewkes, 1995). The FGD started before data collection, when discussions were held with the extension officers and scheme group leaders to obtain an understanding of scheme management. Focus group discussions were held according to the blocks as the schemes are demarcated per block or village. In each block, five FGDs comprised of a maximum of 10 people were held. Each lasted for no more than two hours to avoid participant fatigue (Nyumba et al., 2017). The questions related to scheme management, institutional innovations, water security issues, collective action and social capital.

3.5. Summary

This chapter described the four irrigation schemes selected, and the justification for their selection, and outlined the post-positivist paradigm employed. A mixed-method approach was employed to collect data. The chapter also highlighted the sampling framework and the data collection processes. The following chapter presents the first empirical analysis, which focuses on the internal dynamics of farmer groups and their impact on household welfare.

CHAPTER 4: HETEROGENEOUS WELFARE EFFECTS OF FARMER GROUPS IN SMALLHOLDER IRRIGATION SCHEMES IN SOUTH AFRICA¹

4.0. Abstract

This paper analyses the heterogeneous effects of membership of a farmer group on access to water, use of inorganic fertiliser, household incomes, and farm asset holdings. A sample of 401 irrigators in South Africa was analysed using propensity score matching (PSM). The study found that group membership had a positive effect on all four outcomes. Group members had an additional four days' access to water in a month, and applied at least 130 kg/ha more inorganic fertiliser than non-groupmembers. Group members also had a higher household income per capita and more assets than non-group members. However, the results revealed a heterogeneous effect among group members, with the benefits varying according to members' socio-economic characteristics as well as internal groupdynamics. The government and private donors should continue to promote the formation and organisation of farmers into groups. The role of group membership in farming outcomes can be enhanced if smaller groups are promoted. It is also crucial that strategies to promote trust, reciprocity and group commitment be implemented for improved group outcomes.

Key words: farmer groups; smallholder; heterogeneous impact; propensity score matching

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4.1. Introduction

In many developing countries, particularly in SSA, smallholder agriculture is a key vehicle to reduce poverty (Cele & Wale, 2018; Phakathi & Wale, 2018; Van Auerbeke et al., 2011). In South Africa, the DAFF (2012) and DED (2010) aimed to increase food security, job opportunities and agriculture's contribution to GDP by expanding the commercially-oriented smallholder farming sector by 300 000 farmers by 2020. However, the performance of the smallholder sector is still reported to be below potential because of limited access to irrigation, low rates of adoption of modern farming technologies (such as inorganic fertiliser), and poor access to farming equipment, among other challenges (Crawford et al., 2006; Morris et al., 2007; Cele & Wale, 2018; Selejio & Lasway, 2019).

Improved soil fertility is required to boost agricultural growth in Africa in a bid to achieve Sustainable Development Goals such as eradicating poverty and hunger by 2030 (Crawford et al., 2006; Sinyolo & Mudhara, 2018b). Sub-Saharan African countries, in particular, have experienced low crop productivity due to limited use of inorganic fertiliser. The average use of inorganic fertiliser in the region of 8 kg per hectare, is far below the 78, 96 and 101 kg per hectare used in Latin America, and East and South Asia, respectively (Crawford et al., 2006; Morris et al., 2007). Limited use of modern technologies such as inorganic fertilisers is due, among other things, to the higher transactional costs of accessing input and output markets (Duflo et al., 2011; Sinyolo & Mudhara, 2018b). Water insecurity is prevalent among smallholder irrigators in South Africa due to economic and physical water scarcity, which disincentivises farmers from adopting inorganic fertilisers (Cousins, 2013, Sinyolo et al., 2014; Sharaunga & Mudhara, 2016). Modern inputs such as inorganic fertilisers are costly, but produce higher yields under conditions of adequate moisture. As such, farmers are more likely to invest in these technologies when they have access to secure and reliable irrigation water, which reduces the risk of crop failure and results in increased production and returns (Hussain & Hanjra, 2004; Sinyolo et al., 2014).

Farmers' groups or producer organisations are regarded by policy makers as a key strategy for rural development, especially in Africa and South Asia (Bijman & Wijers, 2019). Farmer groups are defined as formal or informal collective institutions aimed at improving the welfare of members (Bizikova et al., 2020; Ifejika et al., 2016; Thorp et al., 2005; Markelova

& Mwangi, 2010). Also known as farmer clubs, co-operatives, and producer organisations, they are established for various purposes such as marketing, producing or buying inputs collectively to benefit from better terms of trade (Bizikova et al., 2020; Markelova & Mwangi, 2010).

Participating in farmer groups reduces transaction costs, as it enables information, inputs and transportation costs to be shared. Furthermore, farmers in groups often buy in bulk, resulting in economies of scale and improved bargaining power. These advantages lead to a greater likelihood of the use of inorganic fertiliser, among other inputs, improved access to water, higher productivity and better output prices, which in turn boost household incomes and asset accumulation (Nilsson, 2001; Fischer & Qaim, 2012; Abebaw & Haile, 2013; Sinyolo & Mudhara, 2018a; Bachke, 2019; Tilahun et al., 2016). Several empirical studies have reported the positive effect of farmer groups on various outcomes in the smallholder sector, such as fertiliser use, crop yields, market access, income and poverty reduction (Ali & Abdulai, 2010; Bernard et al., 2008; Cadzow & Binns, 2016; Hellin et al., 2009; Markelova et al., 2009; Kaganzi et al., 2009; Nilsson, 2001; Fischer & Qaim, 2012; Abebaw & Haile, 2013; Sinyolo & Mudhara, 2018a, 2018b; Bachke, 2019; Tilahun et al., 2016; Ma & Abdulai 2016). Abebaw and Haile (2013) reported that group members' fertiliser adoption rate was nine to 10 percentage points higher than non-members in Ethiopia. In South Africa, Sinyolo and Mudhara (2018b) found that group members applied an additional 170 kg/ha inorganic fertiliser, and that the average income per adult equivalent of group members was R3 000 more than that of non-group members. In China, Ma and Abdulai (2016) observed that being a member of a group improved apple output, net returns and incomes by 5.36%, 6.06% and 4.66%, respectively.

Studies have also found that the benefits of group membership vary among members, based on the groups' internal dynamics as well as individual members' socio-economic characteristics. A few studies (e.g., Barham & Chitemi, 2009; Sebhatu et al., 2021) have shown how group characteristics and internal dynamics affect the influence of groups. However, the focus is often on whether a farmer belongs to a group, without investigating the characteristics of the different groups that farmers belong to. No two farmer groups are the same, as they are likely to differ in terms of group size, members' socio-characteristics, available capital assets, internal dynamics, etc., which affect their strength and success (Barham & Chitemi, 2009). Barham and Chitemi (2009) found that groups that were characterised by maturity, strong internal institutions, sound asset bases of natural capital and

male dominance had better market outcomes. Sebhatu et al. (2021) highlighted the importance of total group assets, membership size and occurrence of conflict among members as vital factors that influence group performance. It is difficult to monitor and enforce rules in bigger groups because of the increased transactional cost of enforcement due to free-riding among members (Gezahegn et al., 2019).

Groups dominated by males tend to be more successful because male farmers have better access to resources in rural areas due to patriarchy (Barham & Chitemi, 2009; Sharaunga & Mudhara, 2016; Sinyolo et al., 2018). However, few studies in South Africa have evaluated the heterogeneous effect of group membership on various outcomes, with most focusing on one or two outcomes (e.g., Sinyolo & Mudhara, 2018a, 2018b). While an increased number of empirical studies has examined their effectiveness, the question remains as to whether these farmer groups benefit all members equally, especially the poorest and most vulnerable farmers in terms of participating in decision making (Shiferaw et al., 2011; Chirwa & Kydd, 2005). In order to answer this question, it is necessary to analyse the heterogeneous effect of group membership on various outcomes, such as access to water and fertiliser, asset holdings and household income.

The contribution of this paper is to analyse the heterogeneous effect of group membership on inorganic fertiliser use, access to water, household incomes and asset holdings in four irrigation schemes (Qamata, Zanyokwe, Tugela Ferry and Mooi River) in the EC and KZN provinces of South Africa. Secondly, the paper presents the characteristics and internal dynamics (e.g., group cohesion, trust, cooperation, etc.) of the farmer groups. These provinces were chosen because they have the second- and third-largest number of irrigation schemes in South Africa, and irrigated agriculture in these areas is an important source of livelihood, given the high temperatures and low rainfall (Van Averbeke et al., 2011). Improving agriculture presents an opportunity to alleviate the high poverty rates in these provinces.

The chapter is organised as follows: Section 4.2 provides a theoretical framework on collective action and random utility theory. Section 4.3 presents the research methodology, study area, sampling framework and data collection tools. Section 4.4 discusses the empirical methods, while Section 4.5 presents the results and discussion. Section 4.6 summarises the chapter.

4.2. Theoretical framework

This paper evaluates voluntary farmer choice to participate in a group based on random utility theory. It is postulated that farmers are rational agents, and their decision to be part of a group is based on individual expected utility, which should be greater than not being a member of a group (Fischer & Qaim, 2012; Sinyolo et al., 2018a). This means that a farmer will participate in a group if the anticipated net utility is more than zero. Farmers who are group members benefit from economies of scale because they share information, transaction costs and farming equipment (Nilsson, 2001; Sinyolo & Mudhara, 2018a; Gezahegn et al., 2019). The study postulated that being a member of a group improves bargaining or negotiation power, resulting in a more effective collective voice that enables farmers to fight for better access to water and farming equipment. Moreover, economies of scale are realised, as a group buys inputs in bulk and shares input costs, improving fertiliser adoption among farmers. Sharing information and equipment leads to better crop management practices, which might improve household incomes. Improved income enables a farmer to further invest in asset accumulation (Shiferaw et al., 2009). The cost of being a member involves joining fees and opportunity costs for meeting attendance. These costs and benefits are viewed differently by individual farmers, influencing their choice to join a group. The latent utility function can be expressed as follows:

$$Vi(\beta X_i), \text{ where } U_i = Vi(\beta X_i) + u_i \quad (4.1)$$

X_i represents farmers' exogenous socio-demographic variables (education, experience, age, gender and asset ownership), while unobservable characteristics are signified by the error term (u_i). U_i is a binary indicator that is equal to 1 if the farmer is a group member and 0 if the farmer is not a group member. Choosing to be a member is represented by the probability: $P(U_i < \beta X_i)$. Therefore, the model can be estimated using a logit model or the probit model.

4.3. Research methodology

4.3.1. Sampling approach and data collection

As explained in Chapter 3, the study adopted post positivism as its paradigm, with mixed methods employed to understand the internal dynamics of farmer groups, level of inclusiveness and the groups' impact on household welfare. Multistage sampling was

employed. In the first stage, the EC and KZN provinces were purposively selected as they have the second- and third-largest irrigation schemes in South Africa. The second stage involved purposive selection of four irrigation schemes from a list of irrigation schemes in the two provinces. After field visits to most of the schemes and informal discussions with farmers on scheme dynamics, the Qamata and Zanyokwe irrigation schemes in the EC and Tugela Ferry and Mooi River irrigation schemes in KZN were selected. Table 4.1 summarises the characteristics of the selected irrigation schemes as explained in detailed in Chapter 3 (Van Averbeké et al., 2011; Cousins, 2013; Cele & Wale, 2018; Phakathi et al., 2021).

Table 4.1. Characteristics of the selected irrigation schemes

	Tugela Ferry	Mooi River	Qamata	Zanyokwe	Average
Province	KZN	KZN	EC	EC	-
Year formed	1 898	1 902	1 960	1 983	-
Irrigable size (ha)	837	600	400	450	572
Main canal length (m)	34	25	28	-	29
Average plot size (ha)	0.2	0.4	2	3	1.4
No. of irrigators	1 500	824	350	164	710
No. of blocks	7	15	7	6	9
No. of blocks selected	7	9	6	6	7

The next sampling stage was the selection of farmer groups in the four chosen irrigation schemes, where a total of 28 groups was selected (Tugela Ferry – 7, Mooi River – 9, Qamata – 6, Zanyokwe – 6). Lastly, 228 group members were sampled, ensuring that at least 10% of the population was sampled from each group. Furthermore, 173 non-group members located in the same communities and irrigation schemes as the group members were randomly selected using a list obtained from the extension officers. The total sample size was 401, because it represented at least 10% of the population and considered the method to be used to analyse the data.

4.4. Empirical methods

4.4.1. The logit model

The logit or probit model can be used to determine the factors that influence the decision to join a farmer group as the dependent variable takes a value of 1 if a member and 0 if a non-member. According to Cakmakyapan and Goktas (2013), and Maddala (1983), the logit model is more suitable for a sample size larger than 300 observations. Since the sample size for the study was 401 observations, the logit model was used to determine the factors influencing the decision to join a group. The estimated conditional probabilities of the logit model lie between 0 and 1. The model uses the logistic cumulative distribution function as shown below.

$$P_i = \frac{1}{1+e^{-z_i}} \quad (4.2)$$

P_i presents the probability of joining a group and $Z_i = \beta_0 + \beta_1 X_i$. The logit model is then derived from the logistic cumulative distribution function by linearising the logistic function. This is achieved by linearising the odds ratio between the probability of joining a group and the probability of not joining a group. Therefore, the probability of not joining a group is given by $1-P_i$, as shown below.

$$1 - P_i = \frac{1}{1+e^{z_i}} \quad (4.3)$$

To derive the odds ratio, the formula is given as

$$\frac{P_i}{1-P_i} = \frac{1+e^{z_i}}{1+e^{-z_i}} = e^{z_i} \quad (4.4)$$

Then taking the natural log of the odds ratio, the logit model is given as

$$L_i = \ln\left(\frac{P_i}{1-P_i}\right) = \beta_1 + \beta_2 X_i + \mu_i \quad (4.5)$$

The logit model becomes increasingly large and positive as the odds ratio increases from 1 to infinity. The intercept β_0 is the value of the log-odds in favour of Y when X is zero ($Y=1$ and $X=0$). The slope coefficient β_1 measures the change in L for a unit change in X. The Akaike

Information Criterion was used to select the variables in the model, and multicollinearity was checked using the variance inflation factor (VIF).

4.4.2. Dependent and independent variables

Table 4.2. presents the variables that were used in the analysis. The independent variables presented are pre-treatment variables, while the outcome variables are post-treatment variables. To capture access to water, farmers were asked about the number of days they had uninterrupted access to water in the past 30 days. This procedure was considered reliable, because asking about the previous four weeks was regarded as short enough to minimise recall problems and long enough to allow for some variation in the number of days that they had access to water (Sinyolo et al., 2018). Fertiliser was measured in kilograms per hectare, while asset holdings were measured by the total value of farming assets owned by the farmer, such as a tractor, hand hoes, shovels, spades, a wheelbarrow and fertiliser sprayer. Lastly, household income was calculated as the total annual household income from irrigated crops after subtracting all the costs.

The independent variables specified in Table 4.2 were identified from the existing literature (Abebaw & Haile, 2013; Sinyolo & Mudhara, 2018b; Bachke, 2019). There have been mixed results on the determinants of being a group member in smallholder farming. Socio-economic variables such as experience in farming, size of household, farmer's age, marital status, gender, education, land size, access to extension services and wealth-related measures (size of livestock herd) have been found to be positively correlated with group membership (Ouma & Abdulai, 2009; Abebaw & Haile, 2013; Sinyolo & Mudhara, 2018a). In terms of gender, empirical results have indicated that men tend to participate and benefit more than women (Ouma & Abdulai, 2009; Fischer & Qaim, 2012; Sinyolo & Mudhara, 2018b). This is due to unequal access to farming assets, as patriarchal systems create a multitude of socio-cultural obstacles that inhibit female participation, particularly in relation to land ownership (Cousins, 2013; Sharaunga & Mudhara, 2016).

Table 4.2: Description of variables per group membership status

Variable code	Variable description	Expected sign
Outcome variables		
WATER ACCESS	Number of days with access to water in past 30 days	
FERTILISER USE	Kg of fertiliser per ha	
INCOME PER CAPITA	Household income per capita (ZAR)	
ASSET VALUES	Asset holdings value (ZAR)	
Treatment variable		
FARMER GROUP MEMBER	Group membership (1 = yes; 0 = no)	
Independent variables		
AGE	Age (years)	+/-
EDUC	Education level (grade)	+
GENDER	Gender (1 = male; 0 = female)	+
FARM_EXPERIENCE	Years of farming experience	+/-
MARRIED	Marital status (1 = married; 0 = otherwise)	+
FULL-TIME FARMER	Occupation (1 = fulltime farmer; 0 = otherwise)	+
HHS	Household size (number)	+
TOT_HA	Land size (hectares)	+
CROP_TYPE	Type of crop grown (1 = cash crop; 0 = food crop)	+
ACCESS_EXTENSION	Farmers access to extension service (1 = yes; 0 = no)	+
ACCESS_CREDIT	Farmers access to credit (1 = yes; 0 = no)	+
GRAVITY_MODE	Mode of irrigating (1 = gravity; 0 = otherwise)	+/-
QAMATA	Scheme (1 = Qamata; 0 = otherwise)	+
ZANYOKWE	Scheme (1 = Zanyokwe; 0 = otherwise)	+
MOOI RIVER	Scheme (1= Mooi River; 0 = otherwise)	+

Grillos (2018) found that the traditional culture significantly affects men’s willingness to accept women’s opinions or decisions. Bryceson (2019) notes that, in sub-Saharan African countries, women do not participate in groups because they cannot freely make their own decisions, but require approval from their husbands even though women work the land. Therefore, women opt out of groups because they are viewed as burdensome.

Age has often been positively associated with group membership, because older farmers benefit more from other group members' labour (Fischer & Qaim, 2012; Ouma & Abdulai, 2009; Sinyolo & Mudhara, 2018b). However, studies have reported that farming experience is negatively associated with group participation, suggesting that experienced farmers acquire sufficient capacity to farm individually over time, as they have established various networks (Sinyolo & Mudhara, 2018b). Fischer and Qaim (2012) and Sinyolo and Mudhara (2018b) found a positive relationship between education level and group membership. Education level represents human capital, and it enables a farmer to acquire, interpret and understand circulated knowledge better, which directly reduces transactional information costs and increases the net benefits of being a member.

Various studies have found that land size under production is positively correlated with group membership (Francesconi & Heerink, 2011; Fischer & Qaim, 2012, 2014; Abebaw & Haile, 2013; Tilahun et al., 2016; Sinyolo & Mudhara, 2018). Farmers that cultivate larger plots tend to benefit more from groups because the joining fee is fixed. Moreover, access to extension services has been found to have a positive relationship with group membership because farmers with access to extension officers gain information on groups that are available to join and because of the new government mechanism of only supporting (providing inputs such as fertiliser and pesticides) farmers who are part of farmer groups. Therefore, extension officers are likely to influence farmers' decision to join a group. The current study added the variable of whether a farmer is full time or part time. It was hypothesised that being a full-time farmer would be positively associated with group membership. Full-time farmers are able to focus on farming and can participate more in group activities such as meetings and training. The schemes were included in the model to capture the geographical location of each farmer as the study was conducted in KZN and the EC.

4.4.3. Propensity score matching

While there is an increasing number of randomised impact studies, most of these studies in the field of economics depend on ex-post observation data (Fischer & Qaim, 2012; Sinyolo & Mudhara, 2018a, 2018b; Bachke, 2019). Controlling the treatment group, particularly in market-driven development programmes, is difficult in observational case studies. Econometric methods have been employed to account for the differences in observed

covariates between the control and treatment groups. Caliendo and Kopecký (2008:24) note that "every microeconomic valuation study has to overcome the fundamental evaluation problem and address the possible occurrence of selection bias." Selection bias results in hidden differences between the treatment and control group due to unrandomised procedures (Mendola, 2007). As a result, quasi-experimental methods, such as PSM, have been used to account for selection bias in observable impact analysis studies. Observing the socio-economic characteristics of the treatment group at the same time remains difficult, calling for the use of a statistical technique that can separate the programme's impact from confounding factors.

The PSM method has been frequently used in developmental economics to estimate various programme interventions using socio-economic factors' impact on welfare outcomes. In Mexico, Becerril et al. (2010) applied PSM to examine the impact of improved maize variety on rural poverty. In Bangladesh, Mendola (2007) employed PSM to examine the impact of technological adoption on poverty reduction. Fischer and Qaim (2012), Sinyolo and Mudhara (2018a, 2018b); and Bachke (2019) used PSM to investigate the effects of group membership on market access, household income, and fertiliser use. Moreover, in Ethiopia, Kassie et al. (2008) used this technique to estimate the impact of the adoption of soil conservation technologies on returns.

This study used PSM, which is a widely-used tool for impact valuation, to investigate the influence of group membership on access to water, inorganic fertiliser use, asset holdings and incomes (WFAI). Propensity score matching is used to generate a statistical contrast group based on model probability to evaluate the treatment effect of a set of exogenous factors (Nguyen, 2006). It has commonly been used in the agricultural sector to investigate the effects of group membership on various outcomes (Fischer & Qaim, 2012; Sinyolo & Mudhara, 2018a, 2018b; Bachke, 2019). The PSM method requires a treatment variable to be binary; therefore, group membership status was treated as a binary treatment, and non-group members as a control group. Propensity score matching is grounded in the conditional independence or confoundedness assumption, which assumes that the selected outcomes (WFAI) are independent of membership status of the farmer group, conditional on the set of observable characteristics. It relies on non-parametric regression methods to construct the counterfactual based on the observable pre-treatment characteristics (Baker, 2000; Blundell & Costa Dias, 2000).

This paper assumes that M_i represents the farmer's membership status i , where $M_i = 1$ if the farmer is a group member and $M_i = 0$ if the farmer is not a group member. If a farmer is a group member, access to water, fertiliser, asset holdings and income (WFAI) is Y_{1i} . Therefore, if the i th farmer is not a member, these outcomes (WFAI) are represented by Y_{0i} . The average treatment effect (ATE) denotes the weighted average, which tells us about the expected effect of group membership status on the selected outcomes (WFAI) for the whole population (Cobb-Clark & Crossley, 2003).

$$ATE = E[\Delta i] = E [Y_{1i} - Y_{0i}] \quad (1)$$

$$= E [Y_{1i} - Y_{0i} | M_i = 1] Pr (M_i = 1) + E [Y_{1i} - Y_{0i} | M_i = 0] Pr (M_i = 0), \quad (6)$$

where $E[\Delta i]$ is the anticipated effect on household i ; Pr is the probability of participating in a farmer group; and the other variables are as explained above. However, this paper intended to evaluate the effect of being a group member on those farmers who are group members, which is the average treatment effect on the treated (ATT). The ATT represents the possible change in these outcomes (WFAI) gained by being a group member.

$$ATT = E [\Delta i | M_i = 1] = E [Y_{1i,t} | M_i = 1] - E [Y_{0i,t} | M_i = 1], \quad (7)$$

where $E [\Delta i | M_i = 1]$ represents the expected treatment effect; $E [Y_{1i,t} | M_i = 1]$ denotes the selected outcome variables (WFAI); and $E [Y_{0i,t} | M_i = 1]$ is the ATT for the WFAI outcomes of the members if they were not part of a farmer group (Nguyen, 2006).

In comparing group members and non-group members, survey data was used to generate scores from the population over a set of pre-treatment socio-economic variables, as shown in Table 4.2. The p-scores were generated based on pre-treatment covariates using recall data. Generating a propensity score (probability of being a group member) is imperative when employing matching as the valuation approach; therefore, the logit model was employed to estimate the p-scores. However, the likelihood of detecting binary units with the identical value of the p-scores is zero. Therefore, neighbour, kernel and radius matching algorithms are generally used to validate the results (Becker & Ichino, 2002; Caliendo & Kopeinig, 2008). This is because these matching algorithms methods are not dependent on a particular functional form of the outcome; hence, they eliminate linearity imposition, multicollinearity and

heteroskedasticity challenges (Nguyen, 2006). The function of these matching algorithms estimators includes comparing the outcomes of the treated group with one or more of the control sample (Rosenbaum et al., 1985). The estimators maximise the statistical comparisons between the two groups, resulting in reduced bias, while others increase the number of matches, leading to low variation between the two groups.

The nearest neighbour matching algorithm matches the propensity scores of the treatment group with the propensity score of the nearest control group. The researcher may use the replacement procedure, which allows the control group sample to be put back into the sample and re-matched with the other treatment group sample. However, if no replacement is made, the control group is only used once to match and then dropped from the sample. Using the replacement procedure ensures that treatment bias decreases and the quality of matching improves. Another matching algorithm is the radius method, where a researcher pre-defines the radius of propensity scores to be matched. This method allows the control group members within a specified radius to be matched more than once, reducing the chances of bad matching, which enforces common support (Dehejia & Wahba, 2002).

The kernel matching algorithm is the most commonly used matching method as it employs all the control group members in generating a counterfactual. The kernel uses weights to assign scores according to the similarities or differences between the treatment and control group. According to Mendola (2007:8), “the matched observation is identified as the weighted average of all households in the opposite treatment status within a certain propensity-score distance, with weights inversely proportional to the distance”. This results in minor variance between the two groups, thus eliminating bias. For the sake of robustness, most scholars use more than one matching algorithm to present their results (Becerril et al., 2010; Mendola, 2007; Kassie et al., 2008; Fischer & Qaim, 2012; Sinyolo & Mudhara, 2018a, 2018b; Bachke, 2019). Kernel matching and replacement methods are the preferred techniques when the pre-treatment socio-economic characteristics have significant differences. When the results from more than one matching algorithm are similar or comparable, the estimates are regarded as robust.

However, the PSM application may result in potential bias if the conditional independence assumption is violated (Becker & Caliendo, 2007; Heckman & Navarro-Lozano, 2004; Smith & Todd, 2003). Propensity score matching is increasingly employed based on the conditional independence or confoundedness assumption. This assumption “states that the researcher should observe all variables simultaneously influencing the participation decision and outcome variables” (Becker & Caliendo, 2007:72). This is the reason for debate in the applied evaluation literature on checking for the sensitivity of the estimated results based on the independence assumption (Becker & Caliendo, 2007).

To test the robustness of the estimated results to hidden bias, Rosenbaum (2002) proposed the bounding approach in which the researcher can test “whether unobserved factors can alter inference about treatment effects” (Becker & Caliendo, 2007:73). The Rosenbaum bounds approach assesses the degree of sensitivity of results due to hidden bias since PSM relies only on observed characteristics. The study employed the R-bound sensitivity test because the outcome variables were continuous in scale (Rosenbaum, 2002; Nguyen, 2006). This test indicates how strongly an unobservable variable must influence the selection process to undermine or reverse the findings based on the matching of observables. Studies by Sinyolo and Mudhara (2018); Abebaw and Haile (2013); and Cunguara and Damhofer (2011) on the impact of farmer groups also applied the Rosenbaum approach to test for hidden bias.

The estimation of the ATT assumes a homogenous effect among group members, even though they do not have similar socioeconomic backgrounds. Unlike other studies (Fischer & Qaim, 2012; Sinyolo & Mudhara, 2018a, 2018b; Bachke, 2019) that used standard outcome indicators to assess who benefits more from groups, this study followed Verhofstadt and Maertens (2015) and Wossen et al. (2017), who used the ATT of each outcome indicator as a dependent variable to test who is likely to benefit more from group membership. The advantage of using the ATT scores is that the scores are already tested for confounding assumptions and hidden bias, hence improving the validity of the results. The OLS regression, a commonly used method for estimating the coefficients of linear regression equations which describe the relationship between one or more independent variables and a dependent variable was employed to investigate the extent to which the treatment effect varied among group members according to background characteristics.

4.5. Empirical results and discussion

4.5.1. Descriptive statistics on the internal dynamics of groups

The group chairpersons, deputy chairpersons, and secretaries were interviewed to examine the internal group dynamics within the 28 farmer groups. This study provides an in-depth internal dynamic analysis of the farmer's group, which other scholars have overlooked (Fischer & Qaim, 2012; Abebaw & Haile, 2013; Cunguara & Darnhofer, 2011; Tilahun et al., 2016; Sinyolo & Mudhara, 2018). Farmer groups must be inclusive of marginalised households in terms of gender, age and education (Mwambi et al., 2012). The total sample size of farmer groups from the four schemes was 28 groups (Zanyokwe - 6, Mooi River - 9, Tugela Ferry - 7 and Qamata - 6). The low number of farmer groups were not expected; hence, the results of the internal group dynamic analysis are presented using means, graphs and tables. It is important to highlight that these farmer groups are supposed to be operating as farmer-co-operatives but in these irrigation schemes they do not operate as formal co-operatives because individual farmers still manage their plots and have the flexibility of making independent decisions on how to produce, what to plant, and where to sell.

During the FGDs, extension officers elaborated that the government only supports farmers in groups. Therefore, to obtain input support such as seedlings, fertiliser and farming equipment, the farmer must be part of a farmer group. This model was implemented because farming in groups reduces the high transaction cost of accessing inputs and outputs. It further helps smallholder farmers to collectively market their products to meet large quantities. Moreover, government officials and NGOs are able to communicate with farmers in a group setting, thus reducing the time and financial costs of dealing with individual farmers. This means that some farmers join groups to benefit from government support, while they mainly farm individually and remain inactive in the group. This causes further challenges as some farmers do not put much effort into ensuring that the group is successful.

The group leaders were asked to rank the primary purpose of the establishment of these farmer groups. Figure 4.1 shows that 39% of the groups were formed for multipurpose activities such as buying inputs and collective marketing, while 29% mainly specialise in marketing products and 32% focus on buying inputs to reduce high transaction costs. According to Markelova et al. (2009), farming collectively is the main mechanism to overcome marketing challenges and negotiate better terms of trade (Reardon et al., 2019).

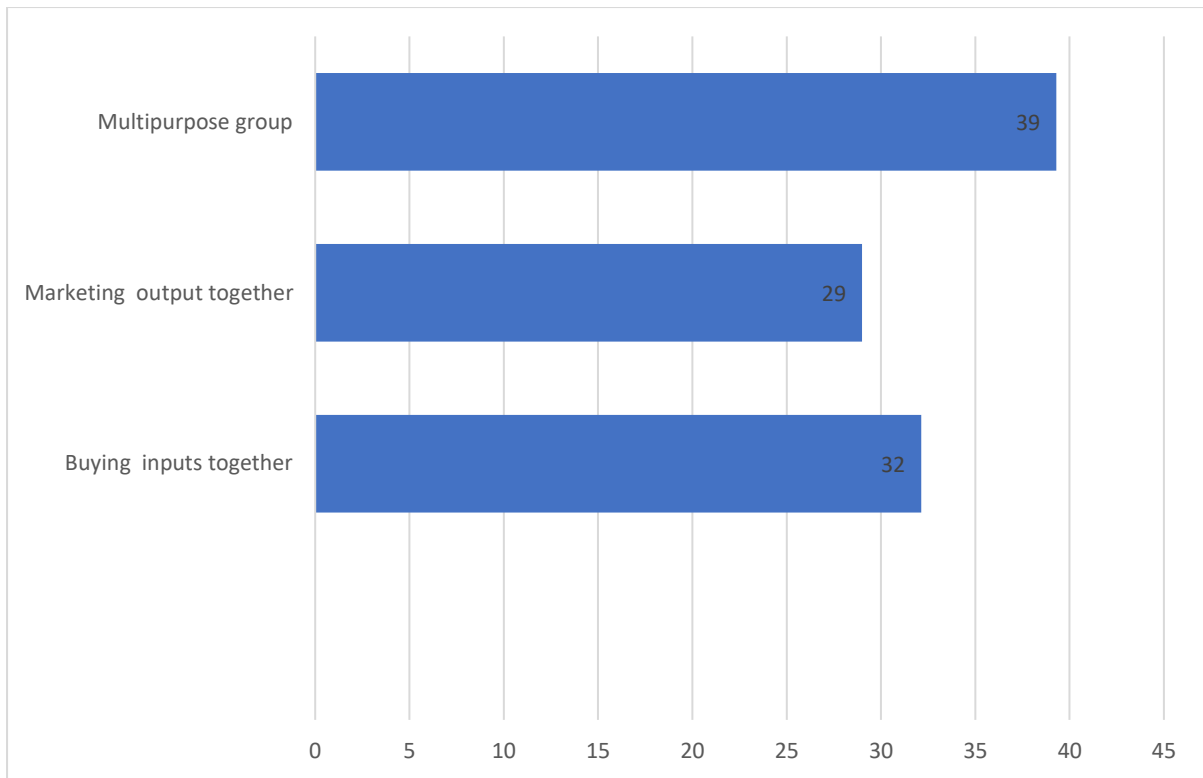


Figure 4.1: Primary objective of farmer groups in percentage

Figure 4.2 below shows farmers in the Tugela Ferry irrigation scheme marketing cabbages collectively. In this scheme, the minimum plot size per farmer is 0.1 hectares, making it relatively difficult to supply in large quantities. Therefore, groups secure markets collectively and decide to grow the same crops to meet the required quantities and reduce high transportation costs.



Figure 4.2: Collective marketing in Tugela Ferry

Table 4.3 shows the results pertaining to the groups' socioeconomic demographics. It shows that, on average, Zanyokwe and Qamata had smaller groups than the Tugela Ferry and Mooi River irrigation schemes. During the FGDs, some group leaders in Tugela Ferry highlighted the difficulties of managing bigger groups due to different ideologies, resulting in weak cooperation and free-riding issues. According to Markelova et al. (2009), an organisation's success depends on group size. Smaller groups have the advantage of reducing free-riding issues and improving collective action among members (Ostrom, 2010). Group size directly impacts the level of co-operation because as it increases, the level of collective action decreases (Esteben & Ray, 2001; Pena & Noldeke, 2016; Lee et al., 2019; Oliver, 1988). However, Gezahegn et al. (2019) found that larger groups tend to gain more from economies of scale, as they share the costs of input procurement and hiring transport for market produce, among other things.

Members are required to pay an annual fee to cover the cost of running the group. The fees vary among groups; for example, in Zanyokwe, the average group fee was R308.33 per annum, while in the other schemes, it was just over R100. The fee is based on the number of activities

conducted by the group, such as searching for markets and buying inputs together to cover transportation costs.

Table 4.3: Group characteristics per scheme (n=28)

		Zanyokwe (n = 6)	Mooi River (n = 9)	Tugela Ferry (n = 7)	Qamata (n = 6)	Total (n = 28)
Group size (number)		12	95	81	30	53
Joining fee (ZAR)		308.33	112.00	125.00	170.00	176.43
Gender composition of group members	Male	0.71	0.33	0.29	0.52	0.46
	Female	0.29	0.67	0.71	0.48	0.54
Age categories of group members	15–39	0.26	0.17	0.17	0.16	0.19
	40–49	0.35	0.20	0.21	0.21	0.24
	50–59	0.26	0.37	0.34	0.37	0.34
	Above 60	0.13	0.26	0.29	0.26	0.24
Education attainment of group members	No education	0.25	0.60	0.44	0.37	0.41
	Primary	0.29	0.17	0.33	0.35	0.30
	Secondary	0.35	0.24	0.22	0.22	0.25
	Post-secondary	0.03	0.00	0.02	0.04	0.02
Received government input	1 = yes; 0 = no	100	0.60	100	0.78	0.86
Production training	1 = yes; 0 = no	0.33	0.60	0.75	0.78	0.64
Established networks for market	1 = yes; 0 = no	0.33	0.40	0.50	0.44	0.43
Own tractor	1 = yes; 0 = no	0.83	0.40	0.63	0.56	0.61
Own harvester	1 = yes; 0 = no	0.00	0.00	0.50	0.44	0.29
Trailer	1 = yes; 0 = no	0.50	0.20	0.25	0.33	0.32

The results show that in the Tugela Ferry and Mooi River irrigation schemes, female farmers dominated the groups. In the EC province, male farmers dominate the groups; in the Zanyokwe and Qamata schemes, 71% and 52% of members were male, respectively. In terms of age,

farmers in these groups are relatively old; the results indicate that 34% were under the age of 50-59 while only 19% were 15-39 years old. Furthermore, 24% of the members were over the age of 60, indicating that relatively older people still dominate farming in the smallholder sector. The results show that a significant proportion of group members (41%) had no education, with a tiny fraction having attained education beyond matric (2%). The majority of these members (30%) attained primary level education. This indicates a relatively low level of the human capital required to run a farm as a business.

The results further indicate that most of these groups had received input support from the government, such as inorganic fertilisers, pesticides and herbicides. Such support improves farmers' adoption of modern farming technologies which are vital to improve crop productivity and incomes. Moreover, while groups in Zanyokwe had better access to farming equipment, most groups in the other schemes did not have access to equipment such as tractors, harvesters, and trailers. All the groups in these schemes do not have proper storage facilities such as cold rooms, barns, granaries and storerooms to store their produce after harvesting. This is a significant bottleneck as produce perishes, and farmers cannot sell during the off-season to benefit from higher prices. As shown in Figure 4.3 below, farmers use their houses to store produce.



Figure 4.3: Storage facility in Zanyokwe

According to the sustainable livelihood framework, farmers cannot reap all the potential benefits without the equipment required to make farming a success (Ellis et al., 2003; Scoones, 2009; Phakathi & Wale, 2018). These results indicate that the government and private donors can significantly support farmer groups, especially with storage facilities, which are important for storing perishable agricultural products to make farming a sustainable livelihood.

4.5.2. Social capital and level of inclusiveness within the groups

Individual group members were randomly selected to further examine group cohesion and inclusiveness. The list obtained from the group leaders and the extension officers was used to select a sample of 228 group members within the 28 farmer groups. The success of a group depends on its level of social capital. The ability to cultivate a feeling of collective action, trust, reciprocity and commitment to group goals depends on the level of internal social trust because set goals are fruitless if there is no trust (Ostrom & Ahn, 2003; Moody & Paxton, 2009).

Group members were asked to rank their perception of the variables set out in Table 4.4 using a five-point Likert scale. The ranking took a value of one when the farmer strongly disagreed and five when the farmer strongly agreed. Table 4.4 shows the summary statistics presented as the average of group perceptions. The results show that most farmers were neutral in their perceptions. The scores are between 2.62 and 3.64, from slightly above disagree to just above neutral. While commitment to group goals was rated the highest, the easiest way to talk and share opinions was scored the lowest. There were also low scores for fair treatment in a group, feelings of togetherness and cooperation, and freeness of information sharing.

Trust among group members and leaders was slightly above neutral. Trust determines the level of cooperation, and group success is dependent on the level of mutual trust and commitment. According to Fukuyama (2001), Putnam (1993), and Lin (2001), social capital is a source of wealth that can be used to address inequality, social injustice and conflict and is firmly embedded in the notion of trust, norms and informal networks. Therefore, for these groups to function more efficiently, there is a need to create a conducive environment where group members feel free to share their opinions or ideas.

Table 4.4: Farmers’ perceptions of the level of cohesion (n=228)

Variable	Mean
I am treated fairly in a group	2.63
There are feelings of togetherness and cooperation among group members	2.64
There is little conflict in the group	2.70
It is easy to talk openly with all members of the group	2.62
I feel free to share information with other group members	2.66
Everyone in the group does his or her responsibility	3.47
Commitment to group goals	3.64
I trust my group members	3.33
I trust my group leaders	3.23
I have confidence and trust the competitiveness of my group leaders	3.39
The purpose of the group is clear	3.46
There are common norms within group members	2.98

Promoting optimal levels of social cohesion among members is central to achieving success as a collective. The 12 variables in Table 4.4 were added together to generate a proxy for group cohesion (to be used later to determine the impact). The scores were used to categorise the groups into two classes of relatively high and low group cohesion, using the 50th percentile as the cut-off.

4.5.3. Perceptions of group principles

Group members were also asked to rank their perceptions of whether their groups abided by the presented group principles using a five-point Likert scale. The results are presented in Table 4.5. The variables or attributes captured were democratic control, equitable economic member participation, autonomous self-help and the importance of training. These principles were adopted from Ortman & King’s (2007) study on the principles of farming co-operatively. Liang & Hendrikse (2013) note that, in theory, every farmer group is guided by the principle of democratic control; however, in practice, decision-making is in the hands of a few individuals based on their wealth, status and power. The results show that 46.05 and 21.49% of members disagreed and strongly disagreed, respectively, that there is democratic

control within their groups, where every member feels that they can fully participate in decision-making. This means that more than 67.5% of farmers feel that this principle is violated.

Table 4.5: Perceptions on whether the groups abide by group principles

Variable	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
In a group there is democratic control by ensuring that every group member participates in decision making	11.84	8.33	12.28	46.05	21.49
In a group there is equitable member economic participation	3.95	19.74	12.72	26.75	36.84
In a group there is autonomous self-help, as the group is not entirely dependent on the government	19.91	36.84	12.28	23.51	7.46
The group emphasises the importance of member co-operation	3.95	28.07	12.28	43.24	12.28
The group provides training to improve members' skills	8.33	28.51	14.04	35.96	12.72

During the FGD, female farmers indicated that it is still taboo to disagree with or challenge males' decisions or ideas. This is embedded in the patriarchal system, which remains dominant in rural areas. Moreover, during data collection, it was observed that most females did not participate in the discussions and decision-making during farmers' meetings. Relatively few farmers, mainly male, drove and participated in discussions.

Members were asked to rank their perception of equitable member economic participation within their groups, where a member benefits in proportion to his/her transaction within the group. The results show that 63.59% (26.75% disagreed and 36.84% strongly disagreed) of the members perceived no equitable economic participation within their group. These members indicated that, most of the time, a few farmers benefited more from the groups; when there is a contract for market access, all their products are purchased, and they also tend to receive more inputs than other group members. The members were further asked to rate if the group is entirely dependent on government support or is autonomous. The results show

that about 56.75% indicated that they are not entirely dependent on government support such as inputs, financial capital and market access. These farmers indicated they were required to apply as a group. It was noted that, most of the time, the government provides inputs such as fertiliser or seedlings very late after the production season. Moreover, farmers complained that the inputs supplied by the government are incorrect, which is a waste of government resources. For example, they will be supplied with seedlings which are not suitable for their particular location or what is required by the market. Therefore, more than 50% of the members perceived that their groups are autonomous because government support is not reliable.

A total of 32.02% of the members perceived that the importance of co-operation is emphasised in their groups, while 55.52% disagreed. It was noted that most farmers are reluctant to do all farming activities collectively as some mainly joined groups to benefit from government support. However, they mainly farm individually; even when the group has signed contracts for marketing various crops, some members refuse to plant new or different crops required by the market as they all tend to cultivate the same products. These results point to the need to re-think how group members are selected rather than automatically grouping farmers based on their location. Farmers have different goals and passions and grouping those with different goals may hinder the success of the ones who strive to become commercial farmers. While farming in groups is crucial to reduce transactional costs, groups must be strategically formed based on farmers' objectives and passion in order to reduce free-riding issues and conflict.

Members' participation in management of the group is vital for accountability and to enhance group performance (Bijman et al., 2014; Meier zu Selhausen, 2015; Jussila et al., 2012). Thorp et al. (2005) note that participation of the marginalised in decision making may alleviate poverty, as they can articulate their needs. Farmers were asked to rank their participation level within the group and whether they were satisfied with the level. Figure 4.2 shows that 57.98% had low participation in their groups, while only 18.49% ranked their level of participation as very high.

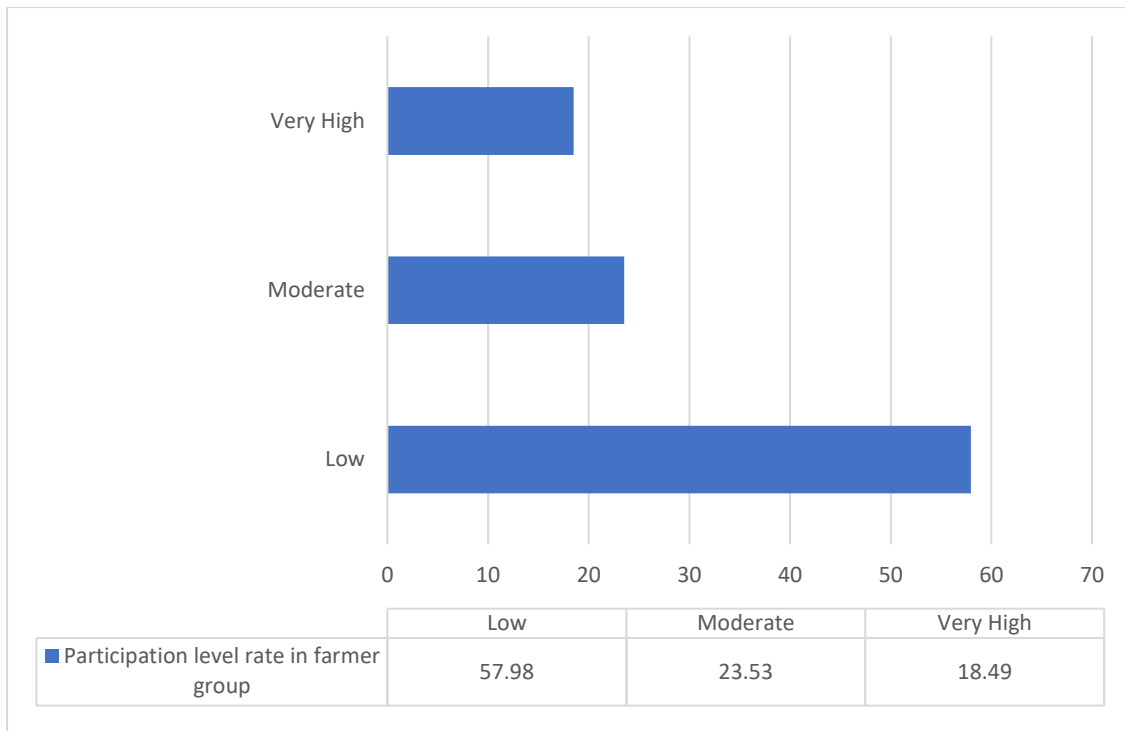


Figure 4.4: Participation rate in decision making

These results are interesting as Figure 4.5 shows that some members that claimed a low or moderate level of participation indicated that they were satisfied with the participation rate.

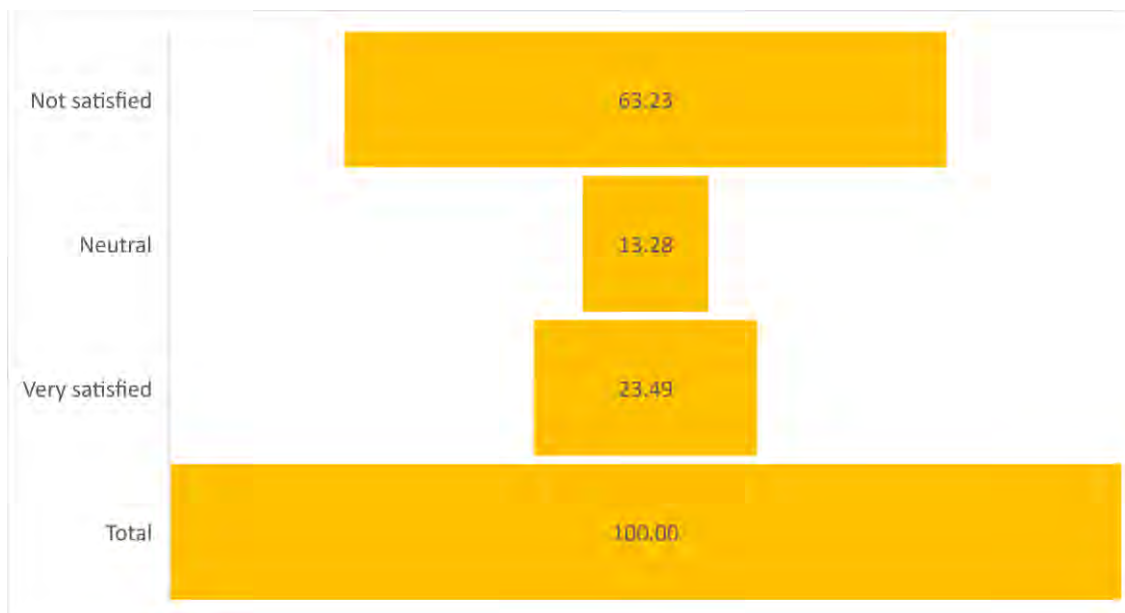


Figure 4.5: Level of satisfaction with participation rate

The majority (63.23%) of farmers were not satisfied with the level of participation. However, the discussions with the group leaders revealed that poor meeting attendance led to a low participation rate. The leaders also acknowledged the challenge of the patriarchal system as the participation rate among female farmers is poor. Given the importance of farming collectively, current group members were asked whether they were still interested in remaining part of the group. The results show that 28.51% of the farmers were no longer interested in being group members.

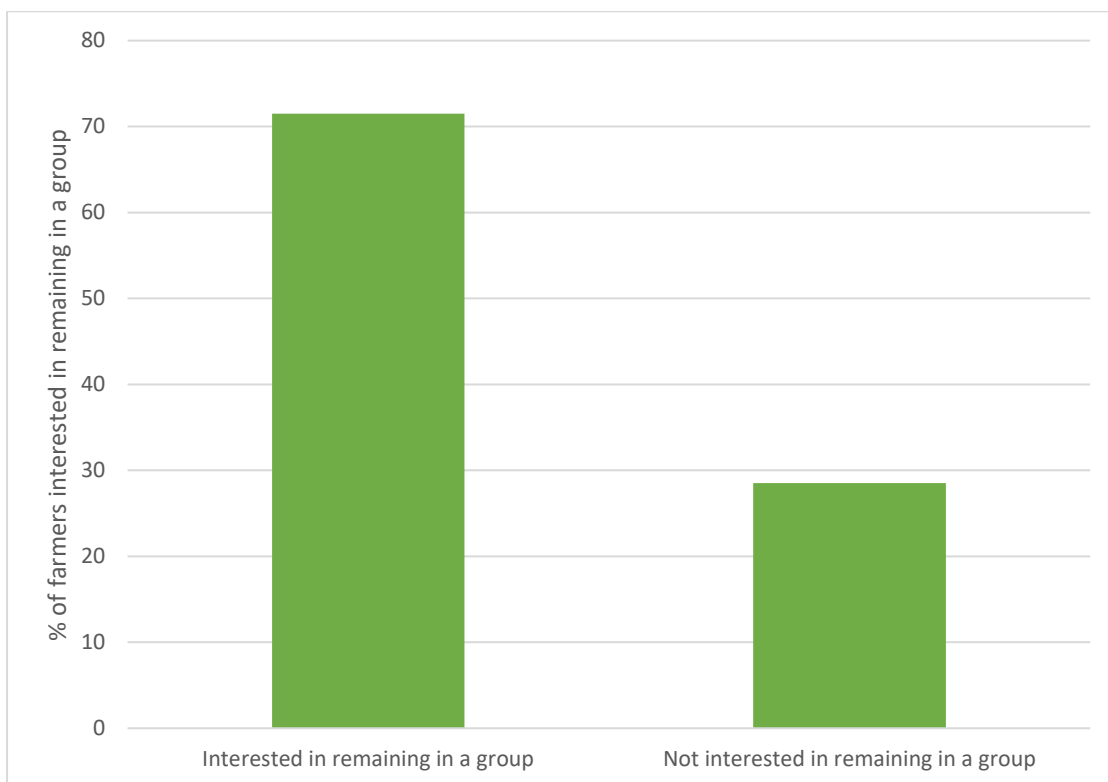


Figure 4.6: Interest in remaining in a group

The reasons ranged from a lack of group direction and supervision to lack of trust in group leaders and members. Some farmers pointed to weak economic participation, as they felt that only a minority benefits from the group, while others highlighted corruption linked to inputs supplied by the government.

4.5.4. The impact of farmer groups on household welfare

The study also investigated the impact of being a member of a farmer group on household welfare. Group members as well as the control group of non-members were randomly sampled using a list obtained from the extension officers. Table 4.6 presents the farmers' socio-economic characteristics according to their membership status. The total sample size was 401, of which 57% were group members, and 43% were non-group members. Policymakers promote the formation of farmer groups as a mechanism to enhance smallholders' inclusion in economic development (FAO, 2017; Reardon et al., 2019; Sinyolo & Mudhara, 2018). The results show that more than 50% of the participants were part of farmer groups, which points to successful implementation of this strategy. The respondents were asked to provide information on their situation before joining the group. While recall data may be sensitive to recall bias, the pre-treatment socio-economic variables are comparable to those in studies by Chitsa (2014), Muchara et al. (2014) and Sinyolo et al. (2014), who collected similar data in the same irrigation schemes in the previous five to six years.

Table 4.6 shows that group members had participated in farmer groups for an average of 5.44 years. The differences between the two groups are statistically significant at a 1% level in all the outcome indicators (water access, fertiliser use, income and asset holdings (WFAI)). The outcomes for group members were better than those for non-group members. The results indicate that, on average, group members applied 183 kg/ha of inorganic fertiliser, compared to 53 kg/ha applied by non-group members. Being a group member thus increases the quantity of fertiliser applied, which is reported to be lower in SSA, at 8 kg per hectare. The quantity applied by group members (183kg/ha) is comparable to South Asia at 101 kg per hectare (Crawford et al., 2006; Morris et al., 2007). Moreover, group members had two more days' access to irrigation water, which is vital, given high temperatures and persistent drought. The results further show that group members' average per capita income was R3 526.35 compared to R1 260.41 among non-group members, a difference of R2 265.94. Higher income enables a farmer who is a member of a group to invest in more assets than non-group members.

Table 4.6: Descriptive statistics of farmers based on group membership

Factors	Means			T-test
	Pooled sample (n = 401)	Group members (n = 228)	Non-group members (n = 173)	
DEPENDENT VARIABLE				
YEARS_FARMER-GROUP	3.12	5.44	-	
OUTCOME VARIABLES				
WATER ACCESS	4.27 (0.27)	6.14 (0.41)	3.81 (0.19)	8.76***
FERTILISER USE KG/HA	126.93 (7.97)	183.16 (12.13)	52.82 (5.51)	8.84***
INCOME PER CAPITA	2 548.78 (277.76)	3 526.359 (324.63)	1 260.411 (464.32)	4.1204***
ASSETS VALUE (logged)	8.67 (0.05)	9.251 (0.06)	7.900 (0.05)	15.207***
DEPENDENT VARIABLES				
AGE	53.69 (0.557)	53.74 (0.72)	54.82 (0.87)	0.90
EDU	4.48 (4.49)	4.62 (0.29)	4.31 (0.34)	0.66
GENDER	0.33 (0.02)	0.33 (0.03)	0.32 (0.04)	0.32
FARM_EXPERIENCE	19.16 (0.54)	18.46 (0.71)	20.09 (0.84)	1.49
MARRIED	0.58 (0.02)	0.61 (0.03)	0.54 (0.04)	1.24
FULL-TIME FARMER	0.89 (0.02)	0.96 (0.01)	0.81 (0.03)	4.83***
HHS	6.22 (0.15)	6.50 (0.20)	5.97 (0.23)	1.64*
TOT_HA	1.36 (0.09)	1.37 (0.13)	1.33 (0.11)	0.24
CROP-TYPE	0.74 (0.29)	0.73 (0.03)	0.75 (0.03)	0.39
ACCESS_EXTENSION	0.82 (0.01)	0.89 (0.02)	0.72 (0.03)	4.26***
ACCESS_CREDIT	0.26 (0.02)	0.32 (0.03)	0.19 (0.02)	2.93**
GRAVITY_MODE	0.85 (0.02)	0.74 (0.03)	0.99 (0.01)	7.58***
QAMATA	0.24 (0.02)	0.07 (0.02)	0.46 (0.04)	10.2**
ZANYOKWE	0.16 (0.02)	0.22 (0.03)	0.08 (0.02)	4.09***
MOOI RIVER	0.25 (0.02)	0.29 (0.03)	0.20 (0.03)	2.23**
TUGELA FERRY	(0.34) (0.02)	(0.40) (0.03)	(0.27) (0.03)	2.89***

Standard errors in parentheses. Significance levels are represented by * = 10%, ** = 5% and *** = 1%

Similar to other studies (Muchara et al., 2014; Sinyolo & Mudhara, 2018; Sharaunga & Mudhara, 2016), the results show that older farmers dominate smallholder irrigation schemes with an average age of 54 years. It remains a challenge to attract youth to the agricultural sector as farming is regarded as unattractive because it takes months to generate an income. Moreover, the results show relatively low levels of education among these farmers, with an average level of Grade 5. This indicates a relatively low level of the human capital required to manage the schemes and run farming as a business. Figure 4.7 below presents a breakdown of education level by category. It shows that 39% of the farmers never attended school, indicating relatively limited ability to read and write. Furthermore, during data collection, when farmers were required to sign a consent form, the majority could not sign the document.

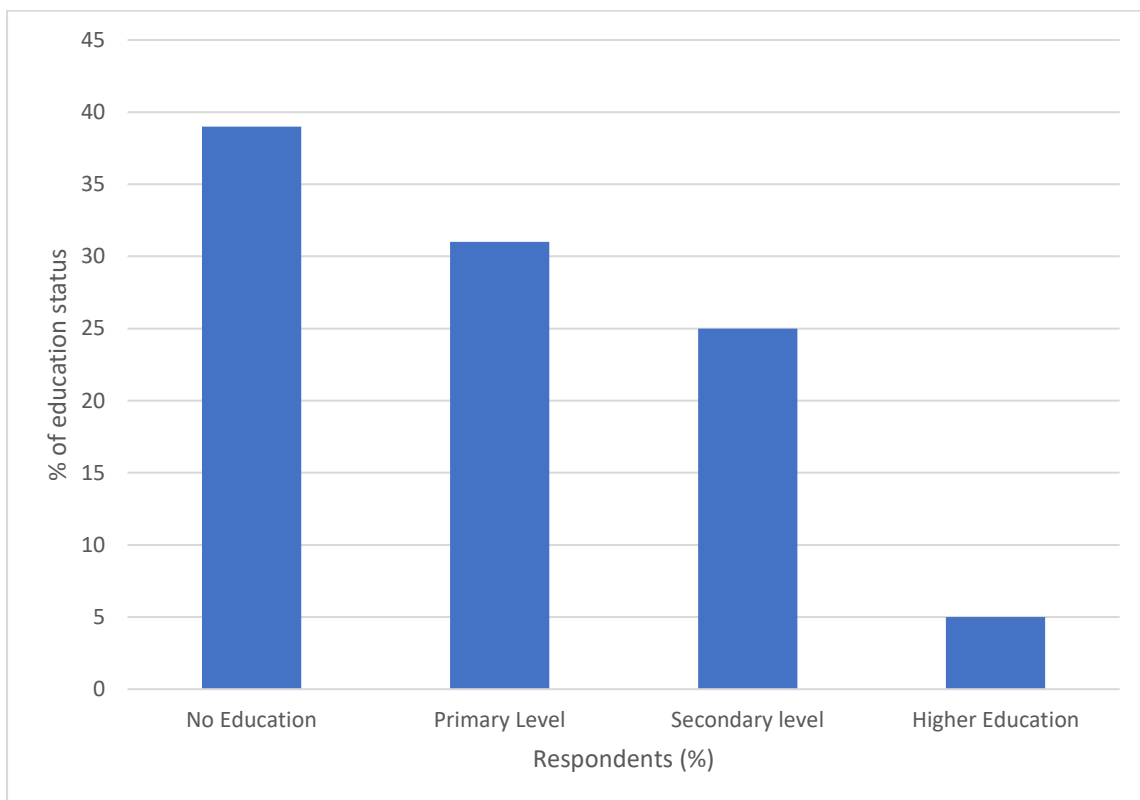


Figure 4.7: Farmers' education level

The results further show that relatively few farmers hold higher education qualifications. These farmers were mainly retired individuals (over the age of 60) who returned home after working in industry. A relatively low level of human capital, measured by education level, is of concern in terms of the economic development of the smallholder sector in general.

The results in Table 4.6 above show that, on average, smallholder irrigation is dominated by female (67%) farmers, with male irrigators compromise only 33%. Females, both adults and children) contribute the most labour in the smallholder sector as males tend to migrate to urban areas while women remain in rural areas to care for their children (Cousins, 2013). The study further analysed the outcomes of male and female farmers to assess the extent of inequality. Table 4.7 below indicates significant differences in all four outcome variables between male and female farmers at a 1% level of significance. Male farmers had greater access to water, held more than twice the value of female farmers’ assets, and had higher income per capita at R3 809.06 than female farmers (R1 937.31). This points to a high level of gender inequality in rural areas where patriarchy accords men more say in decision making and management of economic resources (Cousins, 2013; Sharaunga & Mudhara, 2016).

Table 4.7: Access to assets by gender

	Means		T-test
	Male	Female	
Water access	5.39	3.73	2.95***
Asset value	22 313.4	9 474.28	2.53***
Fertiliser use (kg/ha)	160.27	110.76	2.94***
Income per capita	3 809.06	1 937.31	3.19***

*Significance levels are represented by * = 10%, ** = 5% and *** = 1%*

In terms of farming experience, another proxy for human capital, the results in Table 4.6 show that the average years of farming experience is relatively high at 19 years, while non-group members had 20 years’ experience. This is a positive result considering the relatively low level of education among farmers. More than 57% of the farmers are married due to the fact that married couples are given first preference when the traditional authorities allocate plots to the community. This system aims to improve household food security within rural areas. Moreover, 89% are full-time farmers, relying solely on irrigation farming to earn a living. In these irrigation farming areas, the unemployment rate is relatively high, and farming is the primary source of income, especially for those with a lower level of human capital. The average household size for the pooled sample was six, a relatively large household size.

The results in Table 4.6 also show that the average plot size is relatively small, at less than 1.5 hectares of land, with a minimum of 0.1 hectares. This is directly linked to the fact that the majority of farmers cannot farm bigger plots because of poor access to capital assets. While it reduces the chances of supplying significant markets, farming in groups provides an opportunity for these farmers to produce large quantities. More than 70% of the farmers cultivate cash crops such as vegetables, including cabbages, tomatoes, and spinach, to sell and use the income to pay for non-food items, such as children's school fees. A relatively large number of farmers had access to extension officers in the past 12 months. Extension officers play an important role in advising farmers on general agricultural and production matters.

There is a statistically significant difference in access to credit between the group and non-group members at a 1% significance level. The results show that most irrigators are unable to access financial capital such as loans from formal institutions to boost their productivity. The 26% of the farmers who had access to credit indicated that they used it to purchase inputs such as fertiliser and seedlings. Farmers with no access to credit (73.57%) were asked to cite the main reasons; Figure 4.8 below presents the results.

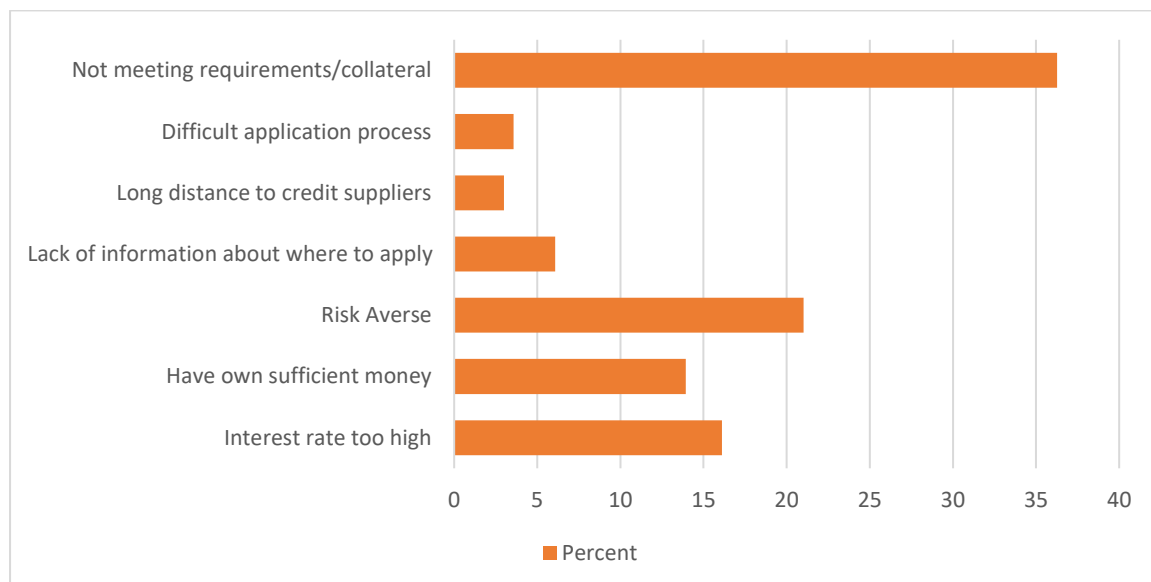


Figure 4.8: Reasons for no access to credit

The results show that not meeting the requirements was the main hindrance, followed by farmers being risk adverse, while a minority cited the difficult application process and the long distance they would have to travel to access credit suppliers.

4.5.5. Factors associated with group membership

The model was first tested for the presence of multicollinearity using the VIF approach. The VIF is a technique used to detect multicollinearity in the dependent variables. It quantifies how much the variance of the estimated co-efficiencies are inflated due to the presence of multicollinearity. The general rule of thumb indicates that when the VIF of each predictor exceeds four, there is a need for further investigation and estimates to correct for multicollinearity (Gujarati, 2009). Moreover, VIFs exceeding ten indicate the presence of serious multicollinearity, which requires correction. The results in Table 4.8 show that no variable's VIF exceeded four, and the mean VIF is 1.70, indicating no to low levels of multicollinearity. The probit model was then estimated to determine the factors associated with group membership.

Table 4.8: Variance inflation factor

Variables	Variance inflation factor
AGE	1.53
EDUC	1.56
GENDER	1.51
FARM_EXPERIENCE	1.51
MARRIED	1.12
FULL-TIME FARMER	1.18
HHS	1.23
TOT_HA	2.75
CROP_TYPE	1.06
ACCESS_EXTENSION	1.25
ACCESS_CREDIT	1.09
GRAVITY_MODE	1.24
QAMATA	3.91
ZANYOKWE	3.91
MOOI RIVER	1.44
MEAN	1.70

Table 4.9 presents the logit model results of the factors associated with group membership. The chi-square is highly significant at 1%, signifying that the model fits the data well, and R² is 0.35, which is considered suitable for cross-sectional data.

Table 4.9: Logit model results: factors associated with group membership

Variables	Coefficient		Marginal effect	
	Coefficient	Standard error	Coefficient	Standard error
AGE	0.015	0.015	0.002	0.002
EDUC	0.067*	0.037	0.010*	0.005
GENDER	0.832***	0.370	0.123***	0.053
FARM_EXPERIENCE	-0.031**	0.016	-0.005**	0.002
MARRIED	0.144	0.278	0.021	0.041
FULL-TIME FARMER	1.649***	0.540	0.243***	0.076
HHS	0.054	0.046	0.008	0.007
TOT_HA	0.415***	0.139	0.061***	0.020
CROP_TYPE	0.120	0.302	0.018	0.045
ACCESS_EXTENSION	1.222***	0.410	0.180***	0.058
ACCESS_CREDIT	0.370	0.299	0.055	0.044
GRAVITY_MODE	-4.012***	1.033	-0.592***	0.146
QAMATA	-2.790***	0.614	-0.412***	0.081
ZANYOKWE	-0.077	0.727	-0.011	0.107
MOOI RIVER	0.422	0.332	0.062	0.049
_constant	0.109	1.480		
Number of observations	401			
Pseudo R-squared	0.35			
Wald Chi-square	192.23***			
VIF	1.65			

*Significance levels are represented by * = 10%, ** = 5% and *** = 1%*

In line with Fischer and Qaim (2012) and Sinyolo and Mudhara (2018b), education level, which represents human capital, was positively associated with group membership. Education enables a farmer to acquire, interpret and understand circulated knowledge better,

which directly reduces transactional information costs and increases the net benefits of being a member. The variable of gender is positive, indicating that men are more likely to participate in groups than women. During the FGDs, women indicated that it was difficult for them to participate in group activities because they have many responsibilities, such as household chores and caring for children. Mayoux (1999) and Abebaw and Haile (2013) also found that women have limited opportunity to participate in co-operatives.

Consistent with Sinyolo and Mudhara (2018b), Table 4.9 shows that farming experience is negatively associated with being a member. One additional year in farming is related to a 0.5% decline in the likelihood of group membership. This could be because more experienced farmers have acquired sufficient farming skills and established sufficient working conditions, such as better market information and input procurement to work alone. As expected, Table 4.9 shows that being a full-time farmer is positively associated with group membership. Full-time farmers are able to focus on farming and participate more in group activities such as meetings and training. In line with Fischer and Qaim (2012) and Sinyolo and Mudhara (2018b), our data show that land size is positively associated with group membership. Owning a larger plot improves the net benefits of access to inputs and output markets that collective action provides. Moreover, farmers who have received agricultural training are more likely to be group members because extension officers offer training and might influence their decision to join a group.

Access to extension officers increases the likelihood of group membership. Farmers with access to extension officers obtain information on existing groups in their area and receive extension support services. There was a negative association between farmers who use the gravity model to extract water for their plots and being a group member. This is because those using this system do not have to pay collectively for water, as do those using an electric or diesel pump. In summary, the results indicate that education, gender, full-time farmer status, total hectares of land, and access to extension and training had a significantly positive effect on farmers' voluntary decision to be part of a group. Experience in farming and using the gravity-fed system to access water had a negative effect on group membership.

4.5.6. The impact of group membership on farmers' welfare

Table 4.10 presents the results from matching quality between members and non-members. “Psmatch2” (nearest neighbour one) was used to test the difference before and after matching. The results show that there is no statistically significant difference between the two groups after matching. This indicates that the groups have similar characteristics, unlike the unmatched sample in Table 4.6 above, which indicates a statistically significant difference between the two groups in several variables. Moreover, the standardised differences (% bias) in all the mean values of the covariates between members and non-members are below 20%, implying that the balancing requirement is adequately satisfied.

Table 4.10: Matching test quality for covariates

Variables	Means		% Bias	% Reduction in bias	P-value of equality of mean
	Members	Non-members			
AGE	51.96	51.39	5.0	43.4	0.72
EDUC	4.59	4.65	-1.3	79.8	0.91
GENDER	0.30	0.32	-4.8	-47.4	0.69
FARM_EXPERIENCE	19.58	18.18	12.9	14.4	0.28
MARRIED	0.58	0.51	13.8	-10.1	0.27
FULL-TIME FARMER	0.93	0.94	-2.4	94.8	0.80
HHS	6.27	6.56	-9.7	49.4	0.44
TOT_HA	1.21	1.27	-3.1	-25.1	0.79
CROP_TYPE	0.71	0.69	5.1	-29.2	0.69
ACCESS_EXTENSION	0.86	0.86	0.0	100	1.00
ACCESS_CREDIT	0.33	0.31	-3.5	88.3	0.79
GRAVITY_MODE	0.97	0.94	9.6	88.2	0.24
QAMATA	0.12	0.18	-15.3	84.5	0.17
ZANYOKWE	0.17	0.14	8.7	79.6	0.49
MOOI RIVER	0.35	0.28	15.9	29.9	0.23

4.5.7. Propensity score quality matching test

Table 4.11 shows a summary of quality-matching tests for the nearest neighbour, kernel and radius-matching algorithms. The results illustrate that, after matching, there is no statistically significant difference between the two groups. The table also shows that, before matching, the pseudo R-square was relatively higher, but it was very low across all the algorithms after matching, indicating that there was no systematic difference in the distribution of covariates.

Table 4.11: Summary of quality-matching test for selected algorithms

Algorithms	Sample	Pseudo R-squared	Wald chi-square (p-value)	Mean standardised bias	Median standardised bias
Nearest neighbour	Unmatched	0.352	192.90 (0.000)	29.1	19.2
	Matched	0.021	8.89 (0.88)	7.4	5.1
Kernel	Unmatched	0.352	192.90 (0.000)	29.1	19.2
	Matched	0.02	9.55 (0.845)	8.0	6.3
Radius	Unmatched	0.352	192.90 (0.000)	29.1	19.2
	Matched	0.01	4.95 (0.99)	4.7	3.8

Moreover, the Wald chi-square on the joint significance before matching was not rejected ($p = 0.000$). However, it was rejected for all selected algorithms after matching, indicating that the matching was successful between the two groups (Caliendo & Kopeinig, 2008). The mean standardised bias for all algorithms is below 20%, implying that the balancing requirement is satisfied. The relatively low pseudo R-square, low mean standardised bias and insignificant joint covariates when testing after matching indicate successful balancing of the PSM quality test. Figure 4.9 provides a visual picture of the estimated PSM scores, indicating that the common support condition is satisfied.

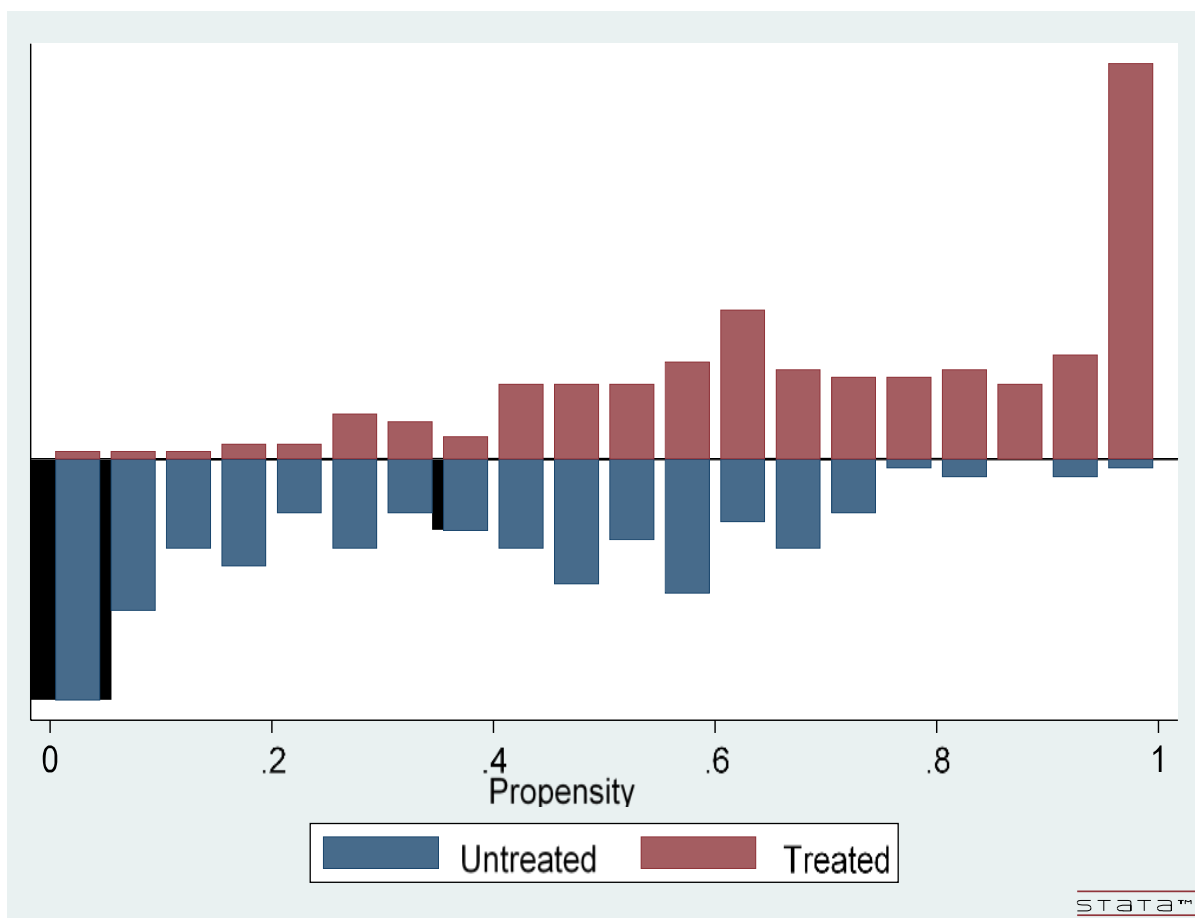


Figure 4.9: Propensity score distribution and common support

4.10.2 PSM Results on the homogenous effect of group membership on outcomes

The PSM was then used to evaluate the effect of being a group member on access to water, fertiliser use, household income per capita and asset holdings. The study used nearest neighbour, kernel, radius and stratification matching to estimate the average treatment effect on group members (Baker, 2000; Nguyen, 2006). The results in Table 4.12 show that the estimated effect values across all the outcomes are very similar with minimal differences, implying that the estimates are robust.

Table 4.12: Homogenous effect of group membership on outcomes

Outcome variables	Nearest neighbour	Kernel matching	Radius matching
Water access (number of days)	4.866*** (0.604)	4.379** (0.670)	4.673*** (0.548)
Fertiliser use (kg/ha)	143.577*** (20.526)	131.276** (17.315)	140.130*** (15.539)
Asset value (logged)	1.606*** (0.229)	1.466*** (0.176)	1.412*** (0.091)
Income per capita (ZAR)	2 894.422** (472.791)	2 662.189*** (421.600)	2 791.467*** (383.491)

*Significance levels are represented by * = 10%, ** = 5% and *** = 1%. Standard error values are given in brackets.*

The results indicate that being a member of a group was associated with positive and statistically significant levels of access to water, fertiliser use, household income and asset holdings. Furthermore, the results are consistent across the different matching algorithms. They also show that access to water would be about five days less if these farmers had not been group members. Moreover, inorganic fertiliser use would be about 131 kg/ha to 143 kg/ha less if not a group member; this is consistent with Sinyolo and Mudhara (2018b) who reported 170 kg/ha of fertiliser usage among group members in KZN. The results show that group members earned an additional R2 662 to R2 894 per capita annually compared to non-group members. This result is in line with Sinyolo and Mudhara (2018a), who reported that members earned about R3 000 more in KZN.

4.5.8. Rosenbaum bounds test results for sensitivity analysis

The Rosenbaum sensitivity test was performed after kernel matching to assess the sensitivity to hidden bias. This test enables the researcher to determine how strongly an unmeasured confounding variable must affect the selection into treatment in order to change the results, which show a positive effect – as presented in Table 4.12. The results in Table 4.13 are highly insensitive to hidden bias, as it would take extremely large increases in the odds of treatment to change the conclusions.

Table 4. 13: Rosenbaum bounds test for sensitivity analysis

Gamma	Access to water (number of days)	Fertiliser used (kg/ha)	Asset holding value (ZAR)	Income per capita
r	Upper bound	Upper bound	Upper bound	Upper bound
1	0.00	0.00	0.00	0.00
31	0.00	0.00	0.00	0.00
61	0.01	0.01	0.01	0.01
91	0.04	0.03	0.03	0.03
121	0.06	0.06	0.06	0.06
151	0.09	0.07	0.08	0.08
181	0.99	0.09	0.098	0.9
211	0.11	0.11	0.12	0.11

4.5.9 Heterogeneous effect results according to socio-economic characteristics

Figure 4.10 shows how the ATT of the four outcomes vary over the estimated propensity scores. The results show that the slopes of three variables (fertiliser, income per capita and assets) were negative, indicating that the effect of group membership on outcomes decreases with the propensity of membership. The slope for water access was positive, implying that the effect of group membership on water access increases with the propensity score. The slopes of fertiliser use and water access varied more significantly than those of household income per capita and assets. These results imply that the effect of group membership is stronger for households with a lower propensity to join a group.

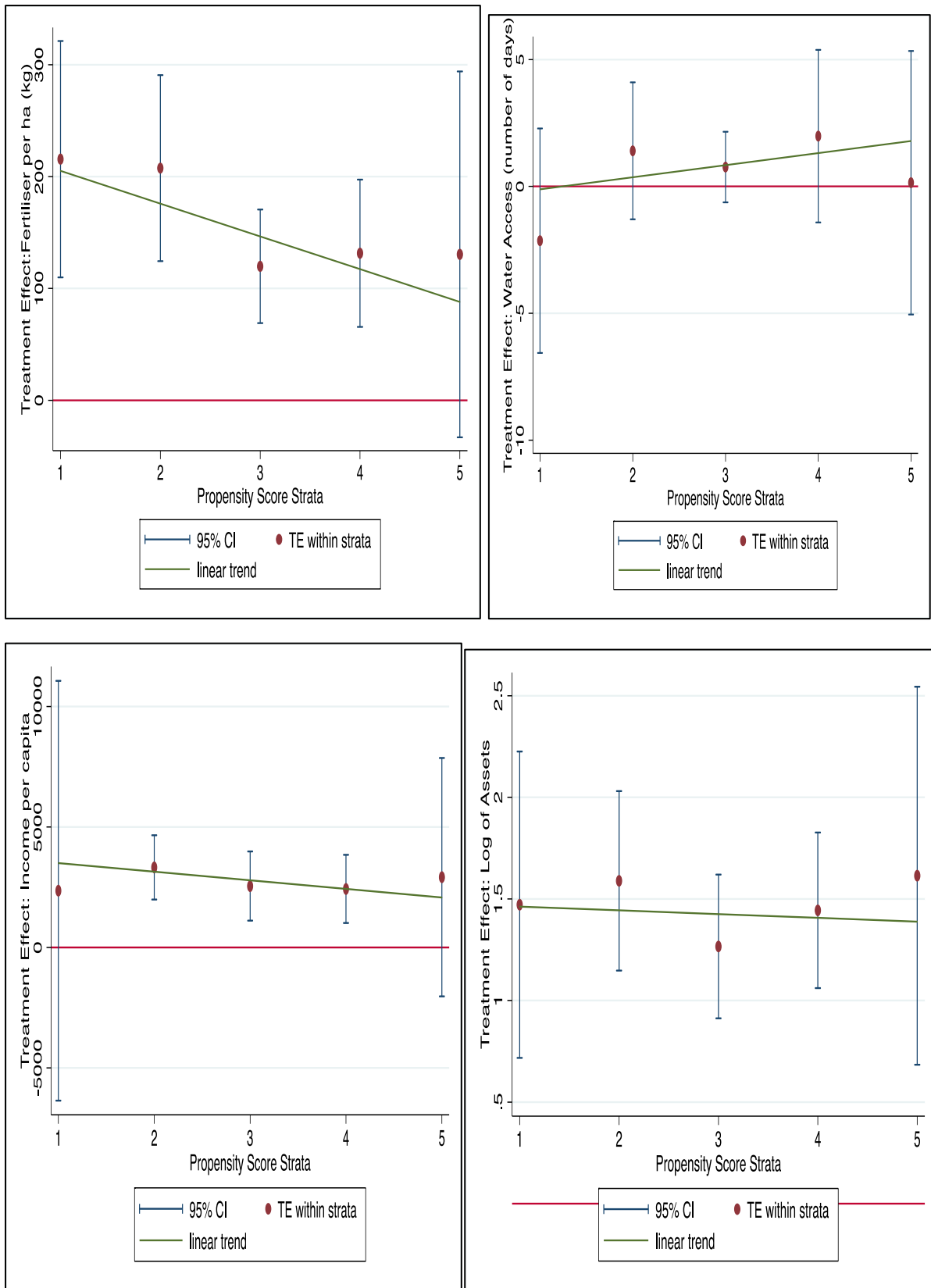


Figure 4.10: Heterogeneity of treatment effect over the propensity score

The study also investigated the heterogeneous effect of group membership according to socio-economic characteristics using OLS regression and propensity scores of each irrigator generated in the first stage of PSM as the outcomes (Table 4.14). The results show that members with a higher level of education benefitted more from group membership than those with lower levels of education. Education enables a member to better understand and interpret information shared in groups.

Table 4.14: Heterogeneous effect according to socio-economic characteristics

Variables	Fertiliser use (Kg/ha)	Water access (number of days)	Income per capita (ZAR)	Logged assets value
	Coef.	Coef.	Coef.	Coef.
AGE	-0.18 (0.46)	-0.01 (0.02)	-2.89 (7.36)	0.00 (0.01)
EDUC	0.43** (1.14)	0.01 (0.04)	6.86** (18.17)	0.02** (0.01)
GENDER	6.64 (11.08)	0.27 (0.39)	106.59** (177.37)	0.23* (0.14)
FARM_EXPERIENCE	0.21 (0.48)	0.01 (0.02)	3.30 (7.72)	0.00 (0.01)
MARRIED	-1.22 (8.45)	-0.07 (0.30)	-18.63 (135.23)	0.06 (0.11)
FULL-TIME FARMER	-6.83 (19.06)	-0.31 (0.67)	-107.59 (304.99)	-0.37 (0.24)
HHS	3.49*** (1.46)	0.12*** (0.05)	55.78*** (23.40)	0.03* (0.02)
TOT_HA	-3.55 (3.63)	-0.19 (0.13)	-56.63 (58.09)	-0.07 (0.05)
CROP_TYPE	-5.61 (8.75)	-0.22 (0.31)	-89.39 (139.97)	0.03 (0.11)
ACCESS_EXTENSION	17.00 (13.20)	0.41 (0.46)	271.04 (211.24)	0.08 (0.17)
ACCESS_CREDIT	-17.08** (8.63)	-0.63** (0.30)	-273.54** (138.05)	-0.20* (0.11)
GRAVITY_MODE	26.23*** (11.31)	1.38*** (0.40)	423.02*** (181.04)	0.74*** (0.14)
QAMATA	46.42** (21.43)	1.64*** (0.75)	740.38*** (342.92)	0.40 (0.27)
ZANYOKWE	52.20*** (20.92)	2.02*** (0.74)	833.59*** (334.75)	0.53** (0.26)

MOOI RIVER	-3.59 (10.36)	-0.09 (0.36)	-56.73 (165.84)	-0.20 (0.13)
Constant	8.51 (34.44)	0.23 (0.21)	129.47 (551.09)	7.54*** (0.43)
R squared	0.14	0.18	0.14	0.19
Prob > F	0.009	0.000	0.0094	0.0002
Number of observations	228			

*Dependent variables are the ATT of each outcome. Significance levels are represented by * = 10%, ** = 5% and *** = 1%. Standard errors are in brackets.*

Male members benefitted more from membership in relation to household income per capita and asset holdings. These results are consistent with Table 4.13, which indicated gender inequalities in terms of asset ownership. The results also show that group members with bigger households benefitted more from membership because of the availability of family labour. Farmers without access to credit benefitted more from group membership than those with access to credit. This is because group membership assists members to share costs, which most benefits those with limited access to credit. In groups, farmers gain access to financial assistance from the government and donors. Farmers using gravity modes of irrigation benefitted more from group membership than those who rely on diesel and electric pumps. Lastly, the results show that the Qamata and Zanyokwe farmer groups benefitted more from farmer cooperatives.

The study also analysed heterogeneous effects according to group characteristics. Table 4.15 shows the ATT outcomes according to group size. The results illustrate that smaller groups had better outcomes than the larger groups. This supports Markelova et al.'s (2009) hypothesis that an organisation's success depends on group size and smaller groups have the advantage of reducing free-riding issues and improving collective action (Ostrom, 2010). However, Gezahegn et al. (2019) found that larger groups benefit more from economies of scale, as they share the costs of input procurement and hiring transport to market produce. Thus, the study's results show that small groups have better outcomes, even though the differences were minimal.

Table 4.15: Heterogeneous effect according to group size

	Membership of smaller groups (n = 94)	Membership of bigger groups (n = 134)
Water access (number of days)	1.49	1.14
Fertiliser use (kg/ha)	45.43	35.57
Household income per capita	725.31	567.69
Logged assets value	7.62	7.66

Table 4.16 shows that farmers belonging to female-dominated groups had lower outcomes than those in male-dominated groups. This is not surprising as male farmers have better access to resources and opportunities than their female counterparts, especially in rural areas dominated by patriarchal governance systems (Sharaunga & Mudhara, 2016; Sinyolo et al., 2018).

Table 4.16: Heterogeneous effect according to gender composition of groups

	Membership of female-dominated groups (n = 137)	Membership of male-dominated groups (n = 91)	T-test
Access to water (number of days)	1.08	1.56	1.74*
Fertiliser use (kg/ha)	34.84	46	1.84*
Household income per capita	555.93	734.68	1.49
Logged assets value	7.59	7.73	1.39

Table 4.17 indicates that 131 members belonged to groups in which they perceived the level of cohesion to be low. Members of groups characterised by high cohesion had better outcomes than those with less group cohesion. Group cohesion is imperative for improved

collective action.

Table 4.17: Heterogeneous effect according to level of group cohesion

	Low cohesion (n = 131)	High cohesion (n = 97)	T-test
Water access (number of days)	1.57	1.08	1.69*
Fertiliser use (kg/ha)	47.61	34.08	1.19
Household income per capita	543.39	761.38	1.70*
Logged assets value	7.73	7.56	1.72*

The results support the literature that argues that the ability of people working together to cultivate a feeling of collective action, trust, reciprocity, solidarity, confidence and commitment to group goals depends on the level of internal social trust or group cohesion (Lin, 2017; Moody & Paxton, 2009). Social capital is a vital asset in solving collective challenges as it boosts social cohesiveness,

4.6. Summary

This chapter evaluated the internal group dynamics (size of a group, level of social capital, inclusiveness, and group cohesion) to examine what makes farmer groups successful. The study further analysed the heterogeneous effect of group membership on access to water, fertiliser use, household income and asset holdings to assess who benefits more from membership. The positivist research paradigm was employed to determine the factors that influence farmers' decision to join a group. The sample of 28 groups and 401 irrigators (228 group and 173 non-group members) was sampled from the four irrigation schemes in KZN and EC provinces in South Africa. The collective action and random utility theories were employed as the theoretical framework, and descriptive statistics, the logit model, and PSM were employed to analyse the data.

The results indicated a relatively low number of farmer groups within these smallholder irrigation schemes. The size of these groups was generally bigger, with an average of 53 group members. Group sizes were much bigger in KZN than in the EC. The main reason was that the size of the plot allocated to farmers in KZN was a minimum of 0.1 hectares. The majority of

the farmers' groups were established for multipurpose activities (39%), while 32% mainly focused on input procurement and 29% specialised in marketing products. The results revealed a low level of education among group members, with 41% of farmers having never attended school while 30% attained primary level.

Older farmers dominated the groups, with 58% of the members over the age of 50 while only 19% were aged 15-39. In general, the results indicated a lack of access to capital assets such as facilities to store produce after harvesting. Moreover, the results revealed a low level of group cohesion, particularly in the bigger groups; as a result, conflict was prevalent, and the level of trust and democracy within groups was also weak. The majority of group members felt that their groups did not abide by the principles of democratic control, equitable economic participation, and group cooperation. A total of 63.23% was not satisfied with the level of participation in decision making in their groups, and 28.51% indicated that they were no longer interested in remaining a group member.

The results indicated that farmer groups have a positive impact on household welfare. Group members had five more days' access to irrigation water in one production cycle, applied 143kg more fertiliser, and earned more than R2 000 additional income. However, the heterogeneous impact results indicated that group membership benefitted male farmers, better educated farmers and those with poor access to credit. Furthermore, smaller groups with better social cohesion earned a higher income than bigger groups. In summary, organising farmers in groups is a sound strategy to improve their welfare, but smaller groups should be considered for improved welfare outcomes and sustainable development in these schemes. The conclusion and policy implications are presented in chapter 7.

Chapter 5 which follows is the empirical chapter on institutional innovation for improved water security that builds on the problem statement and justification presented in Chapter 1.

CHAPTER 5: FARMER-LED INSTITUTIONAL INNOVATIONS IN MANAGING SMALLHOLDER IRRIGATION SCHEMES IN KWAZULU-NATAL AND EASTERN CAPE PROVINCES, SOUTH AFRICA²

5.0. Abstract

Farmer-led institutional innovations have been touted as the key to improving the management of water resources in irrigation schemes. However, little is known about them in South Africa. This study documented institutional innovations by 28 farmer groups in four irrigation schemes in KwaZulu-Natal and Eastern Cape provinces, South Africa. Induced institutional innovation theory, Ostrom's eight design principles, and thematic analysis were used to analyse the data. The results show that 21 groups engaged in institutional innovations, indicating high levels of farmer-led innovative activity among these irrigators. Examples of innovations include, among others, the introduction of a secret voting system to improve marginalised people's participation in decision-making processes, designing daily rotation rosters to reduce conflict, using an attendance register for participation in group activities, and rewarding members according to their participation levels. The majority of these innovations were designed to improve the graduated sanction mechanism (22.2%), enhance the penalty system for non-compliance; improve collective action arrangements (27.8%); monitor attendance of group meetings (18.5%); democratise decision making; and ensure equitable water distribution. However, these innovations mainly focused on addressing challenges rather than exploiting opportunities, and were mostly incremental (94%), involving an adjustment or reinterpretation of rules and regulations. Radical institutional innovations accounted for only 6%. The innovative groups were smaller in size and experienced less conflict than the non-innovative groups. Both types of group had low levels of education and most were dominated by female farmers. Based on these results, it is recommended that the government should build on the irrigators' agency to improve the effectiveness and legitimacy of institutional arrangements in irrigation schemes. The findings also suggest that small groups should be actively promoted, while tailored training should be offered based on the groups' specific needs to improve institutional innovations in the smallholder irrigation sector in South Africa.

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5.1. Introduction³

As discussed in Chapter 1, overcoming poor and outdated institutional arrangements in smallholder irrigation schemes requires efficient institutions to manage them. Institutions are defined as a set of common habits, norms, routines, practices, or laws that govern the behaviour of participants or members of a community (Edquist, 2005; North, 1990). They are designed to cope with uncertainty, and to reduce transactional costs and free-riding issues. Following North (1990) and many studies in the innovation literature (e.g., Edquist, 2005), we differentiate between the rules of the game (i.e., institutions) and the players of the game (i.e., actors or organisations). Institutions are shared concepts that exist in the minds of the actors as mainly implicit norms rather than explicit rules (Ostrom, 1990). These shared concepts can be categorised as rules-in-use and rules-in-form (North, 1993; Ostrom, 2008; Quinn et al., 2007; Wilson et al., 2013). Rules-in-use are informal rules that an individual farmer learns on the ground, while rules-in-form are formal rules that are documented in an explicit form (Ostrom, 1990). According to Ostrom and Benjamin (1993), researchers should focus more on rules-in-use because they assist in identifying shared norms, relations, and the building of trust among a group of farmers or a society. These will eventually lead to stronger collective action (Spielman et al., 2011).

Institutional innovations and changes are implemented to stimulate and strengthen new attitudes and practices that promote inclusive development in society (Coccia, 2018; Ritchie, 2016). This involves adapting to a composite set of rules, customs, and practices that form institutional arrangements (Coccia, 2018; North, 1990). Institutions in society aim to reduce uncertainties by establishing stable rules for human interaction. However, even if institutions are stable, they need to continually innovate because customs and behaviour gradually change over time (North, 1990). Institutions must continually adapt to the external and internal environment by innovating.

Raffaelli and Glynn (2015: 2) define institutional innovation as "novel, useful and legitimate change that disrupts, to varying degrees, the cognitive, normative, or regulative mainstays of an organisational field". While most definitions of innovation emphasise newness and usefulness (Muchara & Mbatha, 2016; OECD, 2018; Spielman et al., 2011), Raffaelli and

³ This chapter builds on the problem statement and justification of the study presented in Chapter 1.

Glynn (2015) argue for the inclusion of legitimacy as a key dimension when dealing with institutional innovation. That is, an institutional change should be novel (unique), useful (solve a problem or add value) and legitimate (be accepted by users) for it to be considered an innovation (Raffaelli & Glynn, 2015). This study expands the concept of legitimate to include environmental and ecological sustainability. This means that since the sources of irrigation water, which are rivers, are shared by multiple actors, institutional innovation implemented by farmers should not have an adverse negative impact on end-users and the environment.

Usefulness and novelty should be judged or defined within the context of the adopting group because innovation does not cease being an innovation because it already exists elsewhere (OECD, 2018). However, Raffaelli and Glynn (2015) argue that the novelty of institutional innovation should be less localised and be perceived in terms of the broader community in which innovations arise. This means that novelty must be perceived by relevant audiences or users such as farmers or the community as legitimate, credible, and appropriate. Legitimacy is crucial when dealing with institutional innovations because, for institutions to be stable over time, credible and appropriate transformation processes are required that are socially constructed and culturally embedded to ensure the inclusion of all actors and sustainability (Libecap, 1993; Ostrom & Benjamin, 1993; Raffaelli & Glynn, 2015). However, usefulness is more important than novelty when dealing with innovations in developing countries in general, and in the smallholder sector in particular, because the important aspect of an innovation is that it should be value-laden or solve challenges that induce groups to innovate.

Therefore, farmer-led institutional innovation refers to a process in which farmers themselves initiate, establish, and improve institutions based on their context-specific challenges or opportunities (de Bont & Veld-Wisch, 2020). Farmers are rational agents who understand their local context and are capable of negotiating, designing, adapting, and implementing innovations that relate to their local realities and can facilitate adaptation to rapidly changing environments (Ostrom, 2008; Reij & Waters-Bayer, 2001; Tambo, 2018; Tran et al., 2019). The current literature on inclusive innovation (Cozzens & Sutz, 2014; Fressoli et al., 2014; Gupta, 2012) highlights the importance of not only ensuring that marginalised or poor people benefit from the outcomes of innovation, but also that they participate in innovation processes. That is, it is not just about innovations *for* the poor, but innovations *with* the poor (Gupta, 2012).

Innovations can be incremental (less disruptive change), comprising the modification of existing institutions, or radical (more disruptive change), involving the creation of new institutions that lead to significantly different ways of doing things (Raffaelli & Glynn, 2015; Rogers, 2010). Mahoney and Thelen (2009) note that incremental innovations occur when a group adjusts its situational processes and regularisation over time. Situational adjustment allows actors to disentangle confusing situations by reinterpreting or redefining rules and relationships. Farmers may gradually or incrementally change their institutions to ensure that current institutions relate to current challenges. With gradual institutional change, a farmer group may apply displacement or layering to redesign institutions (Mahoney & Thelen, 2009).

Displacement occurs when the existing rules and procedures in an organisation are entirely replaced by new ones through progressive change, while layering occurs when existing rules are significantly improved. Changes take place as the actors reassign or reinterpret rules, values, and norms to have a new purpose and meaning. Libecap (1993) and Raffaelli and Glynn (2015) add that institutional innovations are generally an incremental (modification of existing institutions), path-dependent process because organisations learn and develop their ideologies in the context of already existing formal and informal rules. Incremental innovations arise purposefully to solve problems or add value, while radical innovations (creation of new institutions) usually occur due to significant shocks that can disrupt the status quo (Clever, 2012).

In line with Hargrave and Van de Ven (2006) and Raffaelli and Glynn (2015), in this study, institutional innovation includes both the creation of new institutions and change in existing ones. Legitimate institutional innovations are often path-dependent, involving incremental changes to previous institutions, which actors can easily comprehend and accept (Raffaelli & Glynn, 2015). Such innovations can occur at the micro and macro levels when users invest in, adopt, or adapt innovations (Armbruster et al., 2008). Roger (1962, 2003) draws on the theory of diffusion of innovation to argue that innovations or ideas emerge over time. According to Van de Ven et al. (2008:9), “whereas invention is the creation of a new idea, innovation is more encompassing and includes the process of developing and implementing a new idea. The idea may be a recombination of old ideas, a scheme that challenges the present order, a formula or a unique approach perceived as new by the individuals involved”.

It is vital to highlight that even though farmer-led institutional innovations are touted as the key to improving water resources management due to farmers' capabilities to implement context-specific solutions (de Bont & Veldwisch, 2020; Mdee & Harrison, 2019), farmer-led irrigation schemes must occur within a regulated context to avoid externalities and improve their long-term sustainability (Lefore et al., 2019). Woodhouse et al. (2017) noted that in SSA, the extent of irrigated hectares in most farmer-led irrigation schemes was greater than official government assessments, resulting in over-exploitation of water resources. Therefore, the government's role is to regulate and support farmers to govern water resources within the wider landscape (supportive legislation and regulations). It should control and mitigate negative externalities such as over-exploitation of water resources, and contamination of soil and water with agrochemicals to avoid environmental degradation (Lefore et al., 2019) and allow farmers to play a prominent role in the management of irrigation schemes.

This chapter is organised as follows: Section 5.2 provides a brief definition of innovations, while Section 5.3 sets out a theoretical framework on how institutional change emerges and induces institutional innovation theory. Section 5.4 discusses the research methodology, and Section 5.5 presents and discusses the empirical results, followed by a chapter summary in Section 5.6.

5.2. Theoretical Framework

5.2.1. Induced institutional innovation theory

Various approaches are used to study innovations, including the linear model of innovation, non-linear model of innovation, Schumpeterian theory, and the national system of innovation (Acemoglu, 2015, 2011; Edquist & Hommen, 1999; Lundvall, 2010; Schumpeter, 1934; Strang & Soule, 1998; Rogers, 1962). However, these approaches often focus on studying formal innovations in industrial development. The main incentive for innovation in formal organisations or firms is the difference between what the firm can earn if it invested in research and development compared to what it would earn if it did not do so (Gilbert, 2006; Roger, 2015; Acemoglu, 2015). Innovation incentives depend upon “many intellectual property protections, the extent of competition before and after innovation, barriers to entry in production, research and development and the dynamics of research and development” (Gilbert, 2006:8). In the context of this study, which was at the farm level in the management of the common-pool resource, where informal institutions dominate, these formal innovation

theories do not fit well. Therefore, Ruttan's (2006) induced institutional innovation theory, which was conceptualised following the work of North (1990) and Ostrom's (1990) seminal work on managing common resources, was employed. Institutional innovation is described as a process induced by exogenous and endogenous factors due to demand and supply dimensions.

In developing the institutional innovation theory, Ruttan's (2006) point of departure was the neoclassical theory of demand and supply. He (2006) argues that institutional innovation results from long-term changes in resource endowments such as water, population growth, and the price of resources. Ruttan (2006) rejected the idea of choosing between organic or constructive approaches to explain the theory of institutional innovations. Instead, he borrowed from both perspectives because innovations may be designed through collective action or occur spontaneously through evolution or organic processes. According to Ruttan, these approaches to institutional change should be viewed as complementary rather than as alternatives. Ruttan (2006) postulates that institutional innovations are induced by changes in resource and cultural endowments, and technical and price changes. North (1993) emphasised these factors and their influence on institutional innovation.

Firstly, North (1993) argues that competition is the primary driver of institutional change. Competition results from the constant interaction of organisations (government, farms, community) and institutions (rules and regulations) in an economic setting of scarcity. North emphasises that scarcity of resources is the main exogenous factor, which induces organisations to implement change to remain competitive. Ruttan (2006) conceptualises this as changes in resource endowment driving competition among users. As resources become scarce, prices change. For example, it is expected that competition among water users will intensify due to climate change that has resulted in physical water scarcity. The agricultural sector is under particular pressure to improve water use productivity because it uses more water than other sectors yet contributes less to GDP.

Secondly, due to competition because of scarce resources, organisations are induced to advance skills and knowledge to survive. North (1993) argues that, under conditions of scarce resources, continuous interaction between actors in an organisation increases competition. Competition leads groups to observe, learn, and innovate to survive and remain stable. The

type of knowledge and skills acquired will inform the choice of incremental change to be implemented by the organisation. Skills and knowledge can be attained from observation and learned from experience in a local arena. Thirdly, the institutional arrangements direct the type of "skills and knowledge perceived to have the maximum pay-off". Ostrom (2005) emphasises that actors are rational agents as they calculate the cost and benefits of changing institutions. Fourthly, individual perception is derived from the mental capability to interpret information, influenced by the knowledge gained from experience and formal learning. Lastly, North argues that the "economies of scope, complementarities, and network externalities of an institutional matrix make institutional change overwhelmingly incremental and path-dependent" (1993:6). This implies that institutional change is a continuous, incremental process resulting in everyday interactions.

The process of institutional innovations involves altering and restructuring existing rules. Gradual change or modification of institutions occurs due to individual perceptions of the need to perform better due to exogenous factors. Factors such as culture, ideology, and power (North, 1990; North & Thomas, 1970; Ruttan & Hayami, 1984) determine institutional innovation's speed and supply (cost of initiating). However, existing internal institutions determine which innovations will be accepted by members based on the maximum payoff because of factors such as culture, ideology, and power. Particular ideologies and traditional cultures can enable certain institutional innovations to be more easily established and accepted by actors if they share the same values and norms.

Due to the fact that power dynamics play a crucial role in determining the demand and supply of institutional innovation in society, institutional innovation may not occur at a socially optimal level. Actors who wield power may design and implement institutions that redistribute returns in their favour or they may resist change that redistributes economic advantages away from them. Therefore, the role of collective action in changing the supply of institutional innovations encompasses struggles to eliminate power disparities, and this depends on the cost of achieving social consensus (Nardis, 2012; Mahoney & Thelen, 2010; Spielman et al., 2011; North, 1990, 1993; Ruttan & Hayami, 1984). However, if collective action fails, government can play a regulative role and enforce rules in order to eliminate power disparities in the management of common-pool resources.

Induced institutional innovation was more applicable in the study context because intensifying climate change, which has resulted in water scarcity, has increased competition for water in South Africa. The agricultural sector is under particular pressure because it consumes more water than other sectors. Secondly, farmers are under pressure to innovate institutionally in order to overcome weak or poor institutional arrangements, which many studies have highlighted as the key obstacle to smallholder farmers' successful performance. Thirdly, the dynamic and changing nature of water policies and changes in irrigation systems due to rehabilitation programmes require farmers to implement institutions that are aligned with the recently upgraded systems, especially in Tugela Ferry and Mooi River.

In the context of smallholder irrigation schemes, Ostrom's eight design principles (Ostrom, 2008; Ostrom & Benjamin, 1993; Wilson et al., 2013) offer guidelines for designing efficient institutional conditions for their effective management. A design principle refers to that condition which enables the successful design of irrigation institutions that are self-governing and self-managing over a period of time (Sarker & Itoh, 2001). The eight design principles are: (1) clearly defined boundaries, in which unentitled external parties are effectively excluded from using the resource. (2) Congruence between the resource environment and its governing structures; the rules in place should fit local conditions. (3) Collective choice arrangements (participatory decision-making among resource users). (4) Rules should be enforced through effective monitoring. (5) Graduated sanctions for those who abuse resources and for free-riders. (6) Easily-accessible conflict resolution mechanisms. (7) Minimal recognition of rights to organise, and (8) rules should be organised and enforced through nested enterprises (Ostrom, 2008; Ostrom & Benjamin, 1993).

These principles can be adapted and applied to diverse environments that require cooperation among members in order to achieve shared objectives (Sarker & Itoh, 2001; Wilson et al., 2013). Given the importance of these design principles in the management of irrigation schemes, this study used them as the key themes across which the irrigators should innovate. For example, in most schemes, routines (when to access water and for how long) are apparent; however, the challenge is enforcement, monitoring, and penalising free-riders (Phakathi & Wale, 2018). Dirwai et al. (2019) and Muchara et al. (2014) indicated that most farmers in the Mooi River and Tugela Ferry schemes did not abide by irrigation routines as they irrigated more days than allocated, exposing other farmers to water insecurities.

Moreover, Muchara et al. (2014) reported that there is weak or no collective action in the management of the schemes, as few farmers participate in decision-making, canal cleaning and scheme maintenance. It is therefore expected that irrigators would be induced to continually design, reassign, or reinterpret rules, values, and norms around water access, and the eight design principles for scheme management (Hargrave & Van de Ven, 2006). However, because smallholder farming is highly unequal in terms of asset ownership, and is dominated by a patriarchal system (Sinyolo & Mudhara, 2018; Phakathi & Wale, 2018), based on their power and status, some farmers may influence decisions which exclude marginalised farmers. For example, those who are water secure may resist new institutions and deliberately close doors to innovations, or only accommodate those that bolster their status quo (Clever & De Koning, 2015).

Variables such as group size, the education level of group members, gender composition of members and leaders, etc., either inhibit or enhance the speed of design and implementation of institutional change. It is difficult to monitor and enforce rules in bigger groups because of increasing transactional costs for rule enforcement due to free-riding among members (Gezahegn et al., 2019). In addition, studies have shown that groups dominated by males tend to be more successful because male farmers have superior access to resources in rural areas, which are dominated by patriarchal systems (Barham & Chitemi, 2009; Sinyolo & Mudhara, 2018). Therefore, regulated farmer-led institutional innovations are vital to eliminate power disparities within schemes.

5.3. Research methodology

5.3.1. Sampling procedure and study area description

The sampling procedure outlined in detail in Chapter 3 was followed and this chapter focuses on the 28 farmer groups in the four irrigation schemes in the EC and KZN. The selection criteria included the number of years the scheme had been in operation, number of beneficiaries, land size, and occurrence of water management challenges such as free-riding issues, weak penalty systems, and weak monitoring mechanisms. The study targeted groups rather than individual farmers because institutional innovations in the smallholder sector are mainly implemented at group level (Tambo, 2018). The group leaders were the main

participants who provided all the data on group socio-demographic characteristics in terms of gender, education, and age. Several studies have reported challenges in relation to water access, management, and distribution among irrigators in these irrigation schemes (Dirwai et al., 2019; Mnkeni et al., 2010; Sharaunga & Mudhara, 2016; Yokwe, 2009). Therefore, the current study aimed to investigate what farmers had done to solve the challenges around poor institutional arrangements.

5.3.2. Approach to identify farmer-led institutional innovations

Institutional changes were considered innovations when they met five criteria: (a) they should be new or significantly improved rules, norms, processes, and procedures; (b) they should add value; (c) they should be legitimate; (d) they should have been implemented within three years; (e) they should have been initiated and led by farmers with no or very limited external help. Newness was measured at the community level, which meant that an institutional change had to differ significantly from the group's previous ones, and be new to their community, for it to be considered an innovation. While the innovation literature generally uses the lower standard of 'new to the innovator', Raffaelli and Glynn (2015) argue that institutional innovations should at least be new to the innovator's community.

However, farmer-led innovation may be perceived as problematic for environmental sustainability (in terms of exploiting water resources and water shortages downstream) (de Bont & Veldwisch, 2020). In this study, value and legitimacy were defined and measured in a broader manner to encompass sustainability for the community and other users of the irrigation water source. Value addition was according to the perceptions of the groups, while legitimacy was according to both group members and external actors such as officials from the provincial Departments of Agriculture, Rural Development and Water Affairs as well as other local development agencies, who evaluated sustainability. A period of three years was considered long enough to capture innovation activities and reduce the recall problem. Armbruster et al. (2008) highlight that for institutional innovation activities, the period used to categorise innovators should be longer, because shorter periods may categorise imitators as innovators and inventors as non-innovators.

The steps employed by Tambo (2018), with some variations, were followed to identify and document institutional innovation among the selected irrigating groups. For example, the study did not use contests, as this was considered ill-suited for the identification of institutional innovations. Firstly, FGDs were conducted with between 10 and 15 participants (including irrigators, extension officers, and NGO representatives). At least one FGD was held with each selected group, focusing on the broad water management/ access challenges farmers were facing, initiatives irrigators had implemented to address these challenges, and examples of institutional innovations the groups had implemented. Extension officers and other development officials participated in some of these FGDs, and provided further information on some of the innovations implemented by the irrigators over the years, particularly with regard to sustainability to ensure that water resources were not over-exploited. The discussions centred on the eight design principles for water management covering norms, processes, and regulations with regard to equitable distribution of water, conflict resolution, sanction mechanisms, participation, and transparent decision-making in the scheme.

Secondly, interviews were conducted at group level with either a group chairperson, treasurer, or secretary. Insights from field observations and FGDs were used to design the questionnaire used in the second round to collect information on specific examples of institutional innovations. The group leaders were asked to provide specific information on some of the innovations identified during FGDs, as well as to identify others that might have been omitted. Questions were also posed on group characteristics such as group size, education levels, gender composition, etc. Thirdly, key informant interviews were conducted with mainly extension officers, who confirmed the extent to which the examples of institutional innovations were new to the community, or were initiated and led by farmers. They also evaluated the social and environmental sustainability of the reported innovations, following Tambo's (2018) study. The verification process resulted in some institutional changes being rejected because they were not new to the community, or were not sufficiently led by farmers.

5.3.3. Thematic Analysis

Thematic analysis was employed to analyse the data from the FGDs and key informant interviews. This qualitative method is appropriate when the researcher's objectives are to understand the current practices of groups or individuals and to present and interpret themes

within a dataset (Braun et al., 2014; Buryatia, 1998). It is a technique used to categorise and analyse patterns of meaning in the dataset (Braun & Clarke, 2006). Thematic analysis presents datasets in themes (patterns and meaning of data) and highlights the important themes. Themes are explicit or implicit content patterns, which can be drawn from theoretical ideas, known as a deductive approach, or from the raw data, known as an inductive approach. The data analysis followed the four stages described by Ritchie et al. (2003). The first stage was identifying initial themes within the data set and revisiting the study's objectives. Secondly, the data was labelled and sorted manually according to the issues discussed. Lastly, the data was summarised, synthesised and used to provide more insight into the individual quantitative data collected. To improve the validity and credibility of the results, the researcher needs to share the report or the results with the participants for data accuracy through a process known as member checking (Birt et al., 2016).

This study used Ostrom's eight design principles as themes to categorise and present a narrative analysis of the nature of institutional innovations implemented by farmer groups. Since the study aimed to identify institutional innovations implemented in the past three years, this firstly called for a historical narrative that elaborated "how and why" institutions change and innovate. Through these narratives, the study identified groups that implemented incremental or radical innovations. The data on group dynamics in terms of the number of innovations implemented, group age, size, and education level were presented using descriptive statistics.

5.4. Empirical results and discussion

5.4.1. Characteristics and examples of institutional innovations

The FGDs with the irrigators, and interviews with group leaders generated a total of 86 institutional changes that they considered potentially innovative. The verification stage, which included key informants (mainly extension officers) who confirmed the extent of the institutional changes identified by the irrigators, led to 32 institutional changes being rejected. A total of 63% of reported innovations were accepted and 37% were rejected. These changes were considered not to be new to the community (26), or not sufficiently led by farmers (8).

Table 5.1 shows that a total of 54 institutional changes met all the criteria. Of the 28 groups, 21 (75%) reported at least one institutional innovation that met the criteria, and they were thus considered innovators. Only seven groups (25%) had not implemented any institutional innovations. This suggests that most of the irrigation groups in irrigation schemes are engaged in innovative activities to improve their institutions. Almost all innovations reported were incremental (94%), involving adjustment or reinterpretation of rules and regulations, as per the literature (Libecap, 1993; North, 1993; Raffaelli & Glynn, 2015). As expected, radical institutional innovations, which involved implementation of new institutions leading to significantly different ways of doing things, were very rare across all the schemes, with only three examples identified.

Table 5.1: Nature of institutional innovations

Variable	Count	Percent (%)
<i>Number of groups engaged in at least one institutional innovation</i>		
Innovative group	21	75
Non-innovative group	7	25
Total	28	100
<i>Number of institutional innovations per irrigation scheme</i>		
Zanyokwe	21	39
Qamata	13	24
Mooi River	9	17
Tugela Ferry	11	20
Total	54	100
<i>Nature of innovation</i>		
Incremental innovations	51	94
Radical innovation	3	6
Total	54	100
<i>Inducement type</i>		
Problem-induced	53	98
Opportunity-induced	1	2
Total	54	100

Table 5.1 shows that 98% of the institutional innovations were in response to challenges or problems, and rarely did the irrigators innovate to exploit opportunities. Table 5.2 summarises some examples of institutional innovations implemented by farmer groups. Farmers in the irrigation schemes are interdependent as they share the same water distribution system and have to cooperate regarding routine canal maintenance, and payment for energy where pumping is involved, to ensure equal distribution (Muchara et al., 2014). However, due to the sharing of irrigation systems, many groups reported free-riding issues and that rule violations are rampant, as reported by other studies (Dirwai et al., 2019; Muchara et al., 2014). Due to this challenge, a group in Qamata, which has been using a progressive financial penalty system as a graduated sanction to disincentivise free-riding and rule violation, indicated that this did not achieve the desired results.

Table 5.2: Examples of institutional innovations implemented by farmer groups

Scheme	Inducing problem or opportunity	Previous practice or rule	Innovation	Type of change	Design Principle addressed
Zanyokwe	Poor meeting attendance	Taking register only	Introduced incentive mechanism to encourage meeting attendance. Consistent attendance is rewarded with two extra hours' access to irrigation water.	Radical	3, 4
	Lack of a fair say in decision making	Open voting system	Implemented secret voting system to address patriarchy's impact on decision making	Radical	3
	Lack of transparency in decision making	Committee took major decisions	Decisions implemented are solely based on the outcomes of a secret voting system	Incremental	3,4
	Low water pressure, leading to unequal water distribution	All villages used to irrigate simultaneously	Daily rotation roster based on villages due to low water in the Sandile Dam	Incremental	1
Qamata	Farmers stealing and irrigating during the night, exposing others to water insecurities	Verbal warning followed by financial penalty	Hired canal rangers to guard water in dams overnight	Incremental	1, 8
	Rule violations and free riding problems	Monetary penalty based on the seriousness of the offence	Forfeiture of group benefits depending on the seriousness of the offence	Radical	5

Tugela Ferry	Free riders, farmers not following irrigation roster	Verbal warning followed by financial penalty Only	Reporting such issues to traditional authorities after three warnings	Incremental	5, 8
	Opportunity: the pipe system recently implemented when the scheme was revitalised	None	Use the level of participation in canal cleaning to determine who irrigates first as they share one pipe within a subsection in a block	Incremental	1, 2
Mooi River	Poor participation in canal cleaning	Taking register only	Taking register, a penalty of R20 and being the last to irrigate according to their weekly rotation plan	Incremental	4, 5, 8
	Unsustainable financial contribution for diesel procurement led to water insecurities	Monthly collection during production season	Established weekly or daily money collection fund	Incremental	2, 3

It was noted that the majority of the farmers in the Qamata group did not pay the penalty because the monetary value was not high enough to disincentivise free-riding and because it was difficult to enforce this mechanism. To improve design principle 8, the farmers implemented a new penalty system where free-riders forfeit certain group benefits depending on the seriousness of the offence. For example, some had been deprived of using the group's tractor during planting and of buying inputs with the group to reduce transactional costs. This form of penalty system was legitimate as the group's members collectively negotiated and implemented the procedure. Moreover, since farmers are rational agents, the majority valued this sanction to maximise the utility of being a group member, because the cost of being caught outweighed the benefits. The chairperson indicated that this was working and there were relatively fewer incidents of free-riding.

Participation in a group comes with an opportunity cost for attending group meetings. The time spent on meetings could be used for other activities. However, meeting attendance remains important for the purposes of communication. The results showed that a group in the Zanyokwe irrigation scheme was challenged by a high rate of absenteeism, which hindered effective and efficient communication. Meeting spaces provide opportunities for groups to craft and implement new rules and regulations on water access. However, absenteeism resulted in poor implementation as most farmers were not aware of the changes. It made it difficult for committee leaders to hold farmers accountable for violating new rules as they could claim that they were not aware of them. Taking a register had not improved the situation over the past few years.

To improve participation in meetings, the farmers implemented an incentive where consistent attendance would be rewarded with an additional two hours' access to irrigation water for the next full production season. In general, the group has a scheduled monthly meeting; however, special meetings are called when there are pressing issues. The attendance register is used as a tool to identify deserving farmers to be rewarded based on consistent attendance and punctuality. This innovation has been successful and useful in improving meeting attendance.

Moreover, during the FGDs, farmers indicated that two more hours' access to water for irrigation makes a significant difference to their crops, given high temperatures and persistent

drought. This is in line with Muchara and Mbatha (2016), who highlighted the need for robust institutional strategies to incentivise and motivate farmers to participate in canal maintenance. According to the farmers, the strategy employed in Zanyokwe was useful, novel, and legitimate, and improved participation in meetings. To ensure the sustainability of this innovation, the weekly irrigation slot was adjusted to ensure that water resources were not depleted as Amathole Water regulates the amount of irrigation water released from the dam to avoid over-exploitation of water resources. Previously, farmers were able to irrigate during weekends, but this privilege was now reserved for those who consistently attended meetings. The Department of Water Affairs did not have to increase the water allocation, since farmers re-allocated already available resources. However, simply attending meetings without making any significant contribution, may undermine a fair say in decision-making.

In most irrigation schemes located in rural areas, the patriarchal system dominates, and it is regarded as taboo for a female to argue with a male (Sharaunga & Mudhara, 2016). To address the exclusion of female farmers as well as poorer farmers from decision making, a group in Zanyokwe replaced its open voting system with a secret ballot. It seemed that this improved transparency in management of the scheme. This was not expected, given that the farmers are located in a space which embraces patriarchy, but it is a critical component of the transformation that is required in rural areas.

Among many challenges, water theft in the balancing dams has been reported to be a hindrance to equal water distribution among farmers (Sharaunga & Mudhara, 2016). A group in the Qamata irrigation scheme was challenged by theft of water at night by farmers. While some farmers cited this as representing “survival of the fittest”, it resulted in conflict which undermined collective action. As a result, the group resorted to hiring canal rangers to guard the water in the overnight dam. While this was an effective institutional innovation, farmers were unable to continue to pay the canal rangers, and they stopped hiring guards. Indeed, financial capital is the most critical factor that determines the success of innovations (OECD, 2018).

Water insecurity is the result of both physical and economic water scarcity. However, economic issues, such as a lack of the financial capital required to improve infrastructure and procure

fuel, expose farmers to water insecurity. The study found that in Mooi River and Tugela Ferry, about three groups were financially challenged with regard to procuring diesel and electricity. This exposed them to water insecurity, as they could not pump sufficient water to irrigate their plots. To improve timely payment of water charges, this group established a fund called '*phosa esivivaneni*' (*throw a stone in a pile*), which means to come together as a group and commit to a common purpose. Farmers contribute a minimum of R5 a day for financial security for rainy days. Although one of the members of the committee commented that, "paying R200, or R100 monthly is burdensome, particularly in January, where they have to take children back to school", this scheme eased the financial burden. In Tugela Ferry, as a result of the rehabilitation of the scheme in 2013, a shared pipe system was designed for farmers to irrigate from their infield canals. As a result of this change, some groups in Tugela Ferry implemented a rule that states that farmers who consistently participate in canal cleaning are the first to irrigate in a week, as farmers use a rotation system where they share a pipe, and they generally have access to irrigation water once or twice per week.

Farmers implemented various institutional and water management strategies. Other groups implemented a diverse internal crops plantation calendar system, based on crop water requirements. For example, while some members plant maize, which requires much water, others cultivate tomatoes. Some groups bought an expensive seed variety which is highly resistant to drought to reduce the use of irrigation water. Others covered their crops with black plastic sheets to reduce evaporation. In Qamata, all the farmer groups rejected the government's proposal to establish WUAs, because they are perceived as a tool to make them pay for irrigation water. Farmers should play a prominent role in the establishment of context-specific solutions and government should regulate and support their interventions and ensure that institutions implemented are in the context of the wider landscape in order to avoid the capability trap (Andrews et al., 2013; Mdee & Harrison, 2019).

Some groups adopted technological innovations to address unequal distribution of water due to their geographical location. For instance, a group in Tugela Ferry bought a mobile diesel pump to improve water security. However, other groups were not as creative as they simply increased monetary penalties and reported free-riders to the traditional authorities to enforce rule penalties. For example, in Block 7B in Tugela Ferry, free-riders were only reported to

traditional authorities to enforce penalties among members. However, the group felt the need for a nested collective organisation. It therefore innovated by including the traditional authorities in its steering committee as a form of nested collective organisation rather than just reporting free-riders when challenges arose. When the traditional authorities are more involved in running irrigation schemes as part of the community, farmer-led innovation stands to be supported, legitimate, and value-laden. As shown in Table 5.3 most groups implemented innovations to improve collective choice arrangements, monitoring, graduated sanctions, and conflict resolution.

Table 5.3: Institutional innovations per design principles

Design principles	Innovation n=54	Percentage (%)
1. Clearly defined boundaries	3	5.6
2. Congruence between the resource environment and its governing structures	5	9.3
3. Collective choice arrangements	15	27.8
4. Monitoring	10	18.5
5. Graduated sanctions	12	22.2
6. Conflict resolution mechanism	8	14.8
7. Recognition of right to organise	1	1.9
8. Nested enterprises	0	0.0
Total	54	100

This was to improve equal water distribution because of water shortages due to the location of plots and theft; and to reduce non-compliance because of free-riding issues among group members.

5.4.2. Institutional innovations and group characteristics

Table 5.4 presents the groups' characteristics according to their innovation status. It indicates that, on average, innovative groups were smaller than non-innovative groups. This is in line with Barham and Chitemi (2009) and Gezahegn et al. (2019) who argue that bigger groups confront challenges in enforcing rules and regulations because of increased monitoring and

enforcement costs as well as diverse ideologies and power dynamics among members, which reduce the pace of institutional innovations (North, 1993).

Table 5.4: Group characteristics according to innovation status

Variable	Categories	Innovators (n=21)	Non- innovators (n=7)	Total
No. of Innovations		54	0	54
Group size	Group size	48	67	53
Gender	Male	0.47	0.43	0.46
	Female	0.53	0.57	0.54
Age group	15 – 39	0.19	0.17	0.19
	40 – 59	0.26	0.18	0.24
	50-59	0.32	0.40	0.34
	>60	0.23	0.26	0.24
Education level	No education	0.42	0.36	0.41
	Primary	0.31	0.26	0.30
	Secondary	0.25	0.27	0.25
	Tertiary	0.03	0.02	0.02
Average plot size	Hectares	1.58	1.23	1.49
Prop. of female leadership	% of groups lead by females	0.10	0.14	0.11
Group conflict	1=Yes	0.43	0.71	0.50
Meeting attendance	1=Yes	0.29	0.38	0.36

During the FGDs, some chairpersons indicated that big groups faced significant challenges in monitoring and ensuring that each member abides by the rules and regulations. In one of the groups in Tugela Ferry, the chairperson proposed sub-dividing the farmers into smaller groups to improve management, because bigger groups exclude most impoverished farmers from decision-making which tends to be concentrated in the management committee.

Females and older farmers with low levels of education or that never attended school generally dominate smallholder farming. The study found that innovators and non-innovators had almost the same level of education and that both groups were dominated by female members. Males tend to migrate to urban areas in search of economic opportunities while women remain in the rural areas to take care of their children (Cousins, 2013; Dirwai et al., 2019; Yokwe, 2009). Youth participation in farming is still relatively low (19% in innovative groups and 17% in non-innovative groups). This was expected, because most studies conducted in South Africa in the smallholder sector (see Sharaunga & Mudhara, 2016; Sinyolo & Mudhara, 2018; Yokwe, 2009) found that older farmers dominate smallholder agriculture, as the youth do not perceive agriculture as an appealing career because as it takes time to reap the harvest and earn cash. Furthermore, there was low attendance of meetings in both groups. However, on average, non-innovative groups had a highest percentage of conflicts (71%) than innovative groups (43%). This may be related to the relatively bigger group size for non-innovative groups due to diverse ideologies. In total, only three groups (one non-innovative and two innovative) were led by a female chairperson. This was expected, because these schemes are located in rural areas that are dominated by the patriarchal system, which recognise males as capable and suitable leaders and discourages leadership by women (Cousins, 2013; Sharaunga & Mudhara, 2016).

5.6. Summary

This chapter documented farmer-led institutional innovations implemented in the past three years by 28 farmer groups in four smallholder irrigation schemes in KZN (Tugela Ferry and Mooi River) and the EC (Qamata and Zanyokwe). These schemes have existed for more than 30 years, and management of their activities had been transferred to farmers. Moreover, these schemes were regarded as hotspots for management failure. Induced institutional innovation theory was employed as a conceptual framework. It posits that scarcity and competition for water resources will induce farmers to innovate to deal with their context-specific challenges. Understanding the nature of innovations and how farmers institutionally innovated is vital for policy interventions. This chapter employed a qualitative method and employed descriptive and thematic analysis to analyse the data from the FGDs and key informant interviews.

The themes were categorised based on Ostrom's eight design principles, which act as a blueprint for managing common-pool resources. The results indicated that only 21 groups were

capable of implementing institutional innovations to improve management of their scheme and water security. A total of 86 innovations were reported but only 54 of these met the criteria specified above and were thus regarded as novel, legitimate and useful. The majority of innovations were reported in Zanyokwe (39%), while Qamata reported 24%, and Tugela Ferry and Mooi River 17% and 20%, respectively. Based on the induced innovation theory, the results indicate that EC schemes face more challenges than those in KZN, as most innovations reported were problem induced rather than opportunity induced.

Moreover, the nature of the innovations reported was mostly incremental (94%), while only 6% were radical. These results support the literature that argues that most institutional changes are incremental, as the previous institutions influence or shape the future trajectory. Based on Ostrom's design principles, most groups instigated innovations to improve collective choice arrangements, monitoring, graduated sanctions, and conflict resolution. This was due to weak monitoring and free-riding problems that are significant bottlenecks in managing common-pool resources. Furthermore, the results indicated that innovative groups were smaller in size, in line with the results presented in Chapter 4 that support the promotion of smaller groups to enhance sustainable development in these irrigation schemes. The conclusions and policy implication are presented in chapter 7.

The next chapter present the empirical analysis institutional innovations for improved water security: empirical evidence from four smallholder irrigation schemes in South Africa.

CHAPTER 6: INSTITUTIONAL INNOVATIONS FOR IMPROVED WATER SECURITY: EMPIRICAL EVIDENCE FROM FOUR SMALLHOLDER IRRIGATION SCHEMES IN SOUTH AFRICA⁴

6.0. Abstract

Smallholder irrigation schemes have been identified as an important vehicle to reduce poverty. However, most of these schemes have performed below expectations in South Africa due to, among other factors, weak institutions that have led to persistent water insecurity among irrigators. This study investigated the extent to which institutional innovations can improve water security levels among irrigators. A sample of 401 irrigators across four irrigation schemes in KZN and EC was interviewed. Using both an objective (actual water applied m³, calculated using the velocity area method) and a subjective (perceived water security) measure of water security, the results indicated that there were high levels of water insecurity across the four irrigation schemes, with Qamata and Mooi River irrigators considered more water insecure. The study found that improving the rules of the game (institutional innovations) was associated with improved water security. Farmers belonging to innovative groups achieved significantly higher levels of water security than those belonging to non-innovative groups. Moreover, water secure farmers produced higher maize output and earned more than water insecure farmers. The study's findings suggest that, in order to achieve water security in irrigation schemes, it is crucial that irrigators be supported to find new or better ways to improve institutional arrangements and the rules, procedures and regulations governing water management and distribution. Farmers should be supported to solve their specific challenges relating to water insecurity through training and workshops where they could share ideas to improve innovations and water security.

Key words: smallholder irrigation, water security, institutional innovation, PCA, PSM, velocity area method

⁴ A condensed version of this chapter is under second review as Phakathi, S. Institutional innovations for improved water security: Empirical evidence from four smallholder irrigation schemes in South Africa to the *International Journal of Water Resources Development*.

6.1. Introduction

The first and second Sustainable Development Goals aim to end extreme poverty and hunger in all forms by 2030 (UN, 2015). Improving the water security of the smallholder irrigation sector is crucial to improve productivity and achieve these goals. Irrigation water security is defined as the relationship between the hydrological and governance conditions vital for each irrigator to sustain an agricultural livelihood for subsistence or commercial farming (Klumper et al., 2018). Projections suggest that irrigation farming can improve yields by between 100 and 400% (Rockstrom et al., 2009). Several scholars (e.g., Brewis et al., 2019; Sinyolo et al., 2014; Muller et al., 2009; Hussain & Hanjra, 2004) have shown that irrigation access is more effective as a poverty reduction mechanism if the irrigators are water secure. Access to irrigation is necessary but not sufficient to improve the welfare of irrigating farmers. Secure and reliable access to irrigation water incentivises a farmer to innovate and use new technologies which increase farming capacity, leading to improved productivity (Sinyolo et al., 2014; Wiggins, 2005; Hussain & Hanjra, 2004). This results in higher production and greater returns from farming, improving commercialisation opportunities (Hussain & Hanjra, 2004).

However, most irrigation schemes in SSA have become unreliable, and irrigators face persistent water insecurity. Several existing schemes confront a myriad of challenges such as water use inefficiencies, poor infrastructure maintenance, and weak or ineffective institutions, which expose farmers to water insecurity (Dirwaia et al., 2019; Siddiqi et al., 2018; Gomo et al., 2014; Muchara et al., 2014; van Averbeke et al., 2011). Achieving water security at the irrigator level is a function of the irrigation infrastructure (hardware) as well as software (human capacity, social, institutional or governance dimensions) (Dirwaia et al., 2019; Klumper, 2018; Muchara et al., 2014; van Averbeke et al., 2011). A number of studies have highlighted weak institutional arrangements as a critical impediment to successful management of water resources and water security (Dirwaia et al., 2019; Siddiqi et al., 2018; Gomo et al., 2014; Muchara et al., 2014; van Averbeke et al., 2011). Institutions refer to human-designed rules, norms and regulations to facilitate coordination among people and reduce uncertainty and free-riding (North, 1993; Ostrom, 2008). They are crucial in establishing individual rights to resources and providing mandates and stability in the complex and ambiguous world of economic relations (Ménard & Shirley, 2005). According to Prathapar et al. (2002), water

security is dependent on effective policies, processes, and procedures to inform water governance strategies, and the institutions in place have a significant influence. Gomo et al. (2014) and Siddiqi et al. (2018) elaborate that water conveyance must relate to its institutions for efficient water security in irrigation schemes.

Two issues have been identified as key in improving the effectiveness of institutions in smallholder irrigation scheme management. Firstly, as key actors in smallholder irrigation schemes, farmers should initiate or lead the establishment of institutional arrangements based on their context-specific challenges or opportunities to improve water security (de Bont & Veldwisch, 2020). It has been noted that institutions perform better when designed and implemented in a socially and politically acceptable manner with all relevant stakeholders (Raffaelli & Glynn, 2015). Dirwaia et al. (2019) and Rogers and Hall (2003) emphasise that farmers' primary function is to design and implement locally contextualised processes to ensure that scheme goals such as equitable water allocation and canal cleaning are met. Second, due to the evolving nature of water related challenges, it is vital for institutional arrangements to be regularly updated to improve the rules, norms, processes and procedures governing scheme water management. Institutional innovations refer to the design and implementation of new or improved rules, norms, processes and procedures that differ significantly from the previous ones, to improve scheme management and water security. Through these institutional innovations, farmers as the main actors can review and ensure that technological and social needs relate to current contexts.

While there is consensus on the need to improve water security, debate continues on how it should be measured, especially at the scheme or household level (Brewis et al., 2019; Boateng et al., 2018; Jenson & Wu, 2018). A wide range of indicators and measurements has been employed, with the choice depending on whether water security is evaluated at a national, regional, city or local scale (Falkenmark, 1989; Gleick, 1990; Lawrence et al., 2002; Sullivan, 2002; OECD, 2002; Cullis & Van-Koppen, 2007; Koop & van Leeuwen et al., 2015; Sinyolo et al., 2014; Young et al., 2019). Falkenmark (1998) developed a Water Stress Indicator at the national scale based on water available per capita. A country with less than 1 000 cubic metres per capita is regarded as a water scarce country, and when it is below 500 cubic metres per capita, the country faces absolutely water scarcity. Lawrence et al. (2002) developed a Water Poverty Index (WPI), which was applied by various scholars (Jemmali & Matoussi, 2013;

Perez-Foguet, 2010; Heidecke, 2006; Sullivian, 2002) on different scales as a multi-dimensional approach to evaluate the degree of water poverty.

Cullis and van Koppen (2007) used the Gini coefficient as a measure of water security at country level. In 2012, Lautze and Manthrilake developed a quantitative country level index comprising five dimensions, namely, “basic household needs (population with secured access to water), agricultural production (water required for agricultural production), environmental flows (renewable water resources), risk management (availability of storage) and independence for external shocks”. The Asian Development Bank (2007, 2013, 2016) updated Lautze and Manthrilake’s (2012) index to track water security in Asian and Pacific countries. The updated index comprises of the water security dimensions of household, economic, urban environmental and resilience. However, holistic indexes do not consider the local context based on institutional arrangements, overlooking the challenges of accessing water at the community level due to issues of power and affordability. To address this gap, Young et al. (2019), Brewis et al. (2019), Boateng et al. (2018), and Jenson and Wu (2018) measured domestic water security in rural and urban areas across diverse low- and middle-income countries. For example, Boateng et al. (2018) developed a household water insecurity scale for postpartum women in western Kenya. Young et al. (2019) extended Boateng's index and measured household water insecurity experiences across diverse low- and middle-income countries. Brewis et al. (2019) adapted the household food insecurity access scale as an indicator of water insecurity in low- and middle-income countries in Africa.

Indices developed to measure smallholder irrigation schemes have been more subjective, with little focus on objective indicators (Dirwai et al., 2019; Sinyolo et al., 2018, 2014; Sharaunga & Mudhara, 2016). Sinyolo et al. (2014) relied on farmers’ perceptions based on five key water security attributes (consistency of supply, sufficient water supply, water quality, affordability and water rights) to cluster farmers as either water-secure or insecure, which is crucial given various institutional arrangements in smallholder irrigation schemes. For example, Dirwai et al. (2019) measured water adequacy using a categorical binary perception. Sharaunga and Mudhara (2016) and Sinyolo et al. (2018) focused on the number of days a farmer had access to irrigation water, which has shortcomings because of recall problems and inaccuracies in measuring hours of irrigation. Klumper et al. (2017) also used a subjective perceptions

indicator to create an overall water security index among different farm types. These indices all played a crucial role in developing the concept of water security.

The dominant measurement dimension with regard to local schemes remains subjective indicators, mainly measuring perceptions of governance issues (Brewis et al., 2019; Boateng et al., 2018; Dirwai et al., 2019; Jepson & Wu, 2018; Sinyolo et al., 2018, 2014; Sharaunga & Mudhara, 2016; Young et al., 2019). Quantitative indicators such as measuring water quantity and quality are usually used at the national level (Falkenmark, 1989; International Water Management Institute (IWMI), 1992), because such data is readily available and accessible. However, qualitative measures dominate at the local level, particularly the smallholder irrigation schemes, because farmers do not have water measuring devices to determine the volume of irrigation water applied. Dickson et al. (2016) emphasise that the dimension of water quantity at community level remains a crucial challenge; hence, case studies focusing on rural areas might need to measure sufficient quantities. However, employing quantitative measures at scheme level is time-consuming and expensive because data has to be collected over an extended period.

This study builds on this previous work and develops an objective water security indicator for water quantity at the local scheme level. Even though water security is dynamic, creating an objective indicator for water quantity at scheme level is imperative because both qualitative and quantitative data are required to assess the what and why of community water security status (Dickson et al., 2016). Therefore, this study firstly employed the Marsh-McBirney Model 2000 to calculate the flow velocity area in the canal to derive the discharge rate. Then the velocity in m^3s^{-1} was multiplied by the time taken to irrigate in hours in a day, the number of days a farmer had access to water to derive the estimated actual water quantity applied in one production cycle in m^3 . The study collected data on water quantities on a weekly basis to improve the data reliability and overcome recall problem. For robustness checks, a water security perception index was generated using PCA. The study further investigated the relationship between belonging to an innovative group and an individual irrigator's water security status. An institutional innovation index was generated at the group level. Lastly, the PSM was employed to evaluate the impact of water security on productivity. To the best of the researcher's knowledge, no study has empirically linked institutional innovations to water security in the smallholder irrigation sector. Institutional innovations that are farmer-led are

crucial to the performance of smallholder irrigation schemes because farmers as the primary agents better understand their local context compared to other stakeholders. The topical literature on inclusive innovation (Cozzens & Sutz, 2014; Fressoli et al., 2014; Gupta, 2012) emphasise the importance of not only ensuring that marginalised or poor people benefit from the outcomes of innovation but also ensuring their participation in innovation processes. Therefore, linking institutional innovations with water security among many outcome indicators will shed light on the success and capability of farmers as innovators, not just as recipients of innovations. This will better inform how various stakeholders can assist farmers in solving their problems rather than imposing or offering readily available solutions. In particular, stronger institutions at the scheme level are crucial for the efficient management of water resources, which requires institutional innovation to overcome many challenges, including water insecurity.

The chapter is organised as follows: the following section discusses the conceptualisation framework for water security and institutional innovation, the research methodology and empirical methods and lastly, the summary is presented.

6.2. Conceptual Framework for water security and institutional innovation linkages

Water security is dependent on the institutional framework made up of procedures, processes, technologies, and socio-economic factors (Dirwaia et al., 2018, 2019; Sinyolo et al., 2014; Klumper et al., 2017). It entails efficient delivery of the right quantity of water at the right time (Dirwaia et al., 2019). Designing and implementing socially acceptable processes and procedures is the primary function of farmers in ensuring that the scheme's goals, such as equitable water allocation and canal cleaning, are met (Dirwaia et al., 2019; Rogers & Hall, 2003). Therefore, for efficient water management and water security in the irrigation schemes, water conveyance must relate to its institutions, which involves participatory techniques and management practices (Siddiqi et al., 2018; Gomo et al., 2014). This implies that resilience in the schemes requires the relationship between water control infrastructure and institutional arrangements to be robust, functional, and efficient to improve water security. Figure 6.1 illustrates that water security is dependent on various factors such as hydrological factors (rainfall), physical infrastructure (dams, canals), institutional arrangements (rules and regulations) and socio-economic characteristics (education, age, gender, wealth).

Intensifying climate change accompanied by low precipitation patterns and high temperatures have exacerbated physical water scarcity. It is projected that the number of individuals who will be affected by water insecurity will increase fourfold by 2025 due to climate change (Choi et al., 2016). Aging infrastructure and poor maintenance further compound water insecurities. On the other hand, socio-economic factors such as age or wealth status may hinder access to water even where it is physically available. For example, an older farmer may not be physically fit to access irrigation water or the farmer may not be able to access water due to affordability issues (Sharaunga & Mudhara, 2016; Sinyolo et al., 2018). Gender also plays a significant role in water access as most irrigation schemes are located in rural areas, where patriarchal systems dominate, with males have preferential access to water (Gomo et al., 2014).

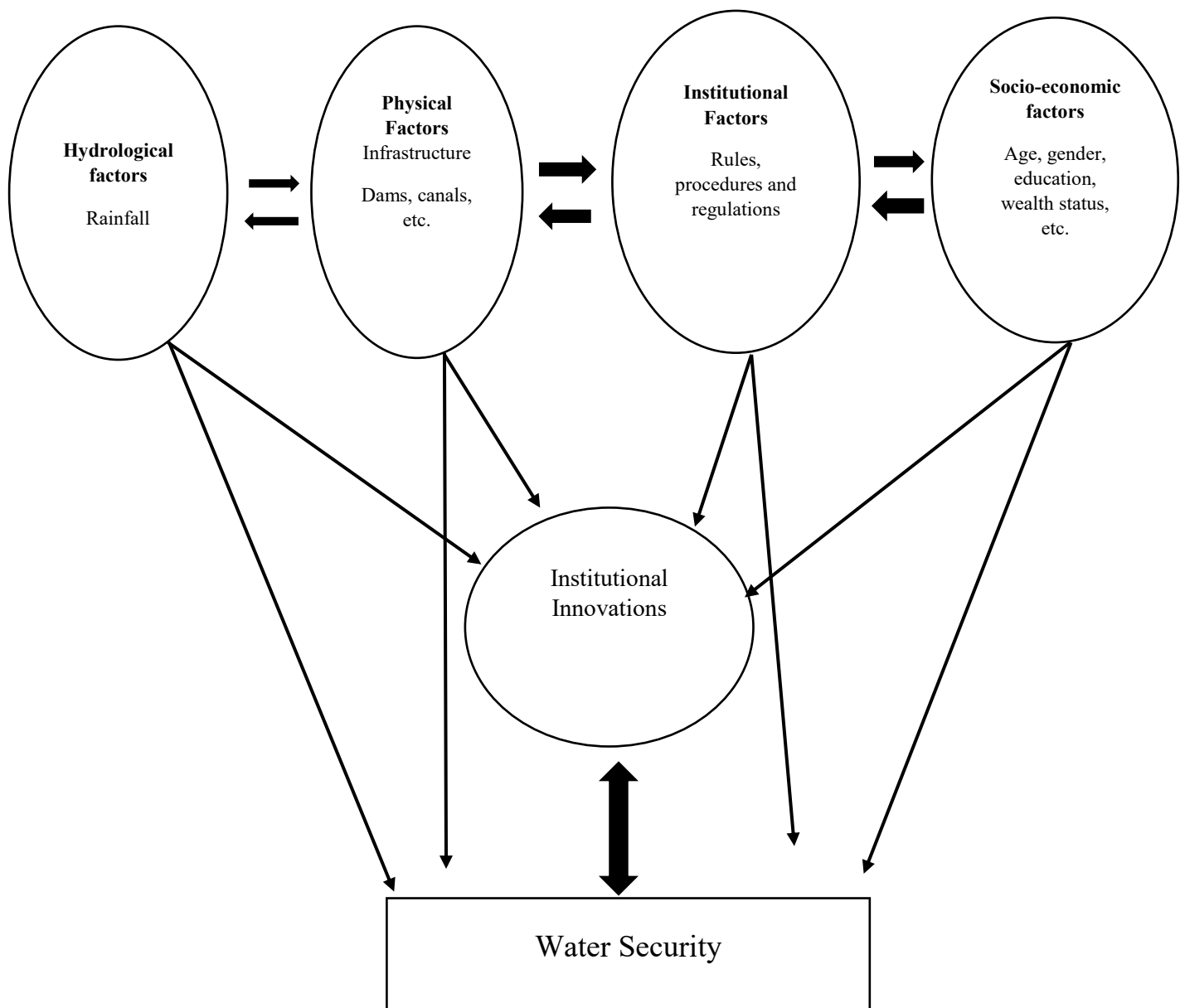


Figure 6.1: Water security and institutional innovation conceptual framework

Many scholars have identified weak institutional arrangements as a key factor which has resulted in poor maintenance and unequal distribution of water, exacerbating water insecurity in smallholder irrigation schemes (Dirwaia et al., 2019; Siddiqi et al., 2018; Gomo et al., 2014; Muchara et al., 2014; van Averbeké et al., 2011). Strong institutions (useful, novel and legitimate) are required to facilitate coordination among individuals and manage water resources (North, 1993; Ostrom, 2008). The rules in place must be useful and legitimate to enforce social cohesion and equity and improve sanction mechanisms to reduce free-riding and transactional costs. However, given the changing nature of water insecurity, institutional

innovations are required to contextually create the strong institutional arrangements that are crucial for the management of water resources. Institutional innovations, which refer to the design and implementation of new or improved rules, norms, processes and procedures that differ significantly from the previous ones, create an enabling societal environment that motivates people to use their capabilities to the fullest degree (OECD, 2018; Gatzweiler & von Braun, 2016; Raffaelli & Glynn, 2015). Therefore, institutions should change over time in order to remain relevant in dealing with modern-day challenges. Through institutional innovations, farmers and key stakeholders can review and create novel, useful and legitimate procedures that relate to the context of each scheme (Raffaelli & Glynn, 2015).

Institutional innovation can lead to strong institutions as it enables farmers to adopt new ways of doing things. For example, Sharaunga and Mudhara (2016) and Muchara et al. (2014) highlighted that inadequate monitoring and sanctions in the irrigation schemes make a significant contribution to water insecurities. Therefore, it is the responsibility of farmers as the primary actors to innovate, re-design and implement new institutions that will regulate water use in the schemes. Through farmer-led institutional innovations, farmers, as rational actors, can implement institutions that will relate to their socio-economic background, and technical aspects to manage the scheme better. Successful implementation of strong institutional innovation is likely to improve scheme management and enforce scheme maintenance, which can directly improve water security, among other outcomes.

6.3. Research methodology

6.3.1. Sampling approach and data collection

The multi-stage sampling approach explained in the previous chapter was employed. A list obtained from extension officers and group chairpersons was used to randomly select 401 irrigators, ensuring that at least 10% of the population was sampled from each scheme to represent the entire population. The sample size of 401 was motivated by data adequacy for the proposed empirical model, such as the logit model, PCA and OLS. According to Costello and Osborne (2005), the ratio of PCA observations to a variable should be at least 10:1. Moreover, the study adhered to ten observations per parameter for the logit and OLS model (Long & Freese, 2014). Therefore, the sample size of 401 was adequate for data analysis.

Data were collected in 2019 during the production cycle by four enumerators in each scheme who spoke IsiZulu and IsiXhosa, the home language in the schemes. Structured questionnaires, FGDs, and key informant interviews were employed (see Appendix B). The questionnaires were translated into the farmers' home languages. The enumerators were trained, and the questionnaires were pretested before the survey. A sample of five irrigators in different groups was interviewed in each scheme during the pretesting. A few questions which were not clear were edited to make them more explicit. Pretesting also helped in the translation of the questionnaires into local languages, improving the readability and validity of the questionnaire. After modifying the questionnaire, the five irrigators from the blocks selected for pretesting were interviewed again, mainly for the modified questions. However, only 15 were willing to be interviewed again, which resulted in five irrigators being removed from the sample. The questionnaire covered questions relating to socio-demographic characteristics, water security perceptions and crop productivity. It is important to note that the target was an irrigator responsible for managing the plot and making farming decisions, whether or not they are household heads.

6.3.2. Institutional innovation indicator

An institutional innovation index was captured following the robust procedure outlined in Chapter 4. Firstly, the following rigorous criteria were set to categorise a group as innovative: (1) The group should have implemented new or significantly improved rules, norms, processes and procedures to manage water resources and solve their challenges; (2) the innovations should be value adding and legitimate; and (3) they must have been implemented, initiated and led by farmers in the past three years. Various FGDs were held with the irrigators, group leaders, extension officers in the Department of Agriculture and an NGO representative to identify institutional innovations, and verify the institutional innovations reported by group leaders as novel, legitimate and useful. Thereafter, individual irrigators were categorised as either belonging to an innovative institution or not.

6.3.3. Method for measuring water quantity objectively using the Marsh-McBirney Model 2000 Flo-Mate

To generate an objective measure of water security, a velocity area method was used to calculate the discharge rate at a particular cross-sectional area in every secondary canal in the Tugela Ferry, Mooi River and Qamata irrigation schemes on a weekly basis to overcome recall problem and improve data reliability. Four research assistants in each scheme were employed during this production season to collect the data weekly. The velocity area method finds the area of a given cross-sectional point of the canal and multiplies it by the velocity of water that passes through it (Gomo et al., 2014). The Marsh-McBirney Model 2000 Flo-Mate was used to measure water flow. Marsh-McBirney is a portable flow-meter designed for use in both the field and the laboratory. Since there are no flow meters in these schemes, this method was deemed less costly and reliable, as it gives good estimation of water flow (Gomo et al., 2014). The velocity area method is endorsed for temporary flow measurements such as research studies and in the absence of hydraulic structures (Gomo et al., 2014; Martin, 2009).

Water flow is not uniform through the entire channel of a cross-sectional area; therefore, to calculate water flow, each secondary canal was subdivided into three equal segments. Fixed-Point Averaging (FPA) (average velocities over a fixed time) was used to calculate the water velocity at each segment. The time limits for measuring water flow using the Marsh-McBirney Model 2000 Flo-Mate range from two (minimum) to 120 (maximum) seconds for FPA. The maximum time (120 seconds) was used for all the measurements in the schemes. The study measured water flow at various secondary canals supplying different blocks since the water flow rate varies depending on a farmer's plot position (head, middle, and tail). The following steps were followed to derive the discharge rate:

1. The cross-sectional length (width) of the canal was measured using a tape measure.
2. The canal was then divided into smaller cross-sections of equal segments. To determine the distance between these three smaller cross-sectional segments, the canal's total width was further divided by the number of segments.

$$\text{Cross Sub section width (m)} = \frac{\text{Canal cross sectional width}}{\text{number of segments}} \quad (6.1)$$

For the segments that were deeper than 0.5 metres, the velocity readings were measured at 0.2, 0.6, and 0.8 depth, while for shallow segments that were less than 0.5 metres.

3. Water flow or velocity was measured at the centre-line of each sub-segment across the sectional area. To determine the centre-line of each segment, each sub-cross-sectional width was further divided by two.

4. To calculate the discharge rate from the secondary canal, the shape of each canal was taken into consideration, and an area of each segment was calculated as follows;

$$A = D_i * W_i \quad (6.2)$$

Where;

A = Area of the cross-sub sections in m²

W_i = width in metres (constant across channel segments)

D_i = depth of the water at a particular sub-section.

5. To calculate the total discharge rate for each secondary canal, the average from each channel was derived using this formula;

$$Q = V * A \quad (6.3)$$

Where: Q = Canal discharge (m³.S⁻¹)

A = Flow area (m²)

V_i= Average velocity (m³. S⁻¹)

To calculate the quantity of water applied by each farmer for the whole season, the number of irrigation hours and the total number of irrigation schedules in the number of days a farmer had access to water was multiplied by the discharged quantity of water.

$$Q_t = T * \text{No Days} * Q \quad (6.4)$$

Q_t = Total irrigation discharged per season in m³

T = Time taken to irrigate in hours a day

No Days = Number of days a farmer had access to water

Q = Canal discharge

6.3.4. The CropWat Model

Increased physical water scarcity due to intensifying climate change requires greater water use efficiency in the irrigation schemes. Improved water use efficiency is the primary strategy to save water and to be able to feed the growing population in light of water scarcity. Therefore, programmes or models to estimate the crop water requirement and irrigation schedule play a crucial role in guiding irrigation schedules. The CROPWAT model was employed to estimate the crop water requirements (CWR) to assess if farmers met the crop water requirement, which is the quantity of water needed to compensate for the cropped field's evapotranspiration loss (FAO, 2001, 2000). The CROPWAT 8.0 was developed by the FAO Land and Water Development Division (FAO, 1992) as a decision-making tool to calculate crop water and irrigation requirements. The crop water requirement is calculated based on the FAO Penman-Monteith method. This method uses monthly data on maximum and minimum temperature, humidity, sunshine and wind speed to calculate the reference evapotranspiration (ET_o).

The crop water requirement (Crop) over a production cycle is estimated using the reference ET_o. The data for the Penman-Monteith method was obtained from South African Weather Services stations in the local areas where each of these irrigation schemes are located. This tool helps to determine how irrigation management can be improved to increase water use productivity given varying water supply. It enables researchers or farmers to develop irrigation schedules under different management environments. CROPWAT allows organisations to calculate the water supply required for different crop types based on production cycles and climate. This model can also be used to assess irrigation practices among farmers and crops' performance under irrigation or rain-fed farming. The CROPWAT 8.0 model uses monthly climatic data to calculate the reference ET_o rate. The climatic data include temperature, humidity, rainfall and wind speed (FAO, 2000).

The velocity flow measurements explained above were used and compared with the crop water requirement generated using CROPWAT to assess the actual water applied by farmers in the irrigation schemes. It is important to note that water security is dynamic; hence, the limitation of this objective measure is that it captures the quantity dimension of water security. However, investigating water quantities is crucial given the increasing level of water insecurity which threatens livelihoods. Farmers can obtain better information on how to allocate and distribute available water quantities. Farmers were then categorised as water secure or insecure based on

whether they met the water requirement for the main crop grown. Thereafter, the logit model was employed to determine the factors influencing farmers' water security status.

6.4. Empirical Methods

6.4.1. The Logit Model

The logit or probit model can be used to determine the factors influencing water security since a dependent variable is binary, taking a value of 1 if water secure and 0 if water insecure. According to Cakmakyapan and Goktas (2013) and Maddala (1983), the logit model is more suitable for a sample size larger than 300 observations. Since the sample size for the study was 401 observations, the logit model was used to determine the factors influencing water security among farmers. The estimated conditional probabilities of the logit model lie between 0 and 1. It uses the logistic cumulative distribution function as shown below.

$$Pi = \frac{1}{1+e^{-zi}} \quad (6.5)$$

Pi presents the probability of being water secure and Zi represents the exogenous variables ($Z_i = \beta_0 + \beta_1 X_i$) shown and discussed in Table 6.1 below. The logit model is derived from the logistic cumulative distribution function by linearising the logistic function. This is achieved by linearising the odds ratio between the probability of being water secure and the probability of being water insecure. Therefore, the probability of not being water secure is given by 1-Pi, as shown below.

$$1 - Pi = \frac{1}{1+e^{-zi}} \quad (6.7)$$

To derive the odds ratio, the formula is given as

$$\frac{Pi}{1-Pi} = \frac{1+e^{zi}}{1+e^{-zi}} = e^{zi} \quad (6.8)$$

Then taking the natural log of the odds ratio, the logit model is given as

$$Li = \ln\left(\frac{Pi}{1-Pi}\right) = \beta_1 + \beta_2 X_i + \mu_i \quad (6.9)$$

The logit model becomes increasingly large and positive as the odds ratio increases from 1 to infinity. The intercept β_0 is the value of the log-odds in favour of Y when X is zero (Y=1 and X=0). The slope coefficient β_1 measures the change in L for a unit change in X. The Akaike Information Criterion was used to select the variables into the model, and multicollinearity was checked using the VIF. The key variables used in the model are presented in Table 6.1 below.

Many factors have been found to influence water security at the irrigation scheme level (Dirwaia et al., 2019; Siddiqi et al., 2018; Sinyolo et al., 2018, 2014; Gomo et al., 2014; Muchara et al., 2014; van Averbeke et al., 2011). For example, farmers may be water insecure even where the infrastructure supplies enough water to the scheme. This may be due to socio-economic and institutional factors such as weak institutional policies, affordability issues, plot location, education level, gender, and experience in WUAs (Brewis et al., 2019; Klumper, 2017; Sharaunga & Mudhara, 2016; Muchara et al., 2014; Sinyolo et al., 2018, 2014). Table 6.1 below shows the variables included in the estimation models, their measurement scales, and their expected relationship with water security.

Socio-economic variables such as age, education, gender, years in a WUA, and years in a farmer cooperative are expected to have a positive association with water security. Education enables a farmer to better understand and interpret information disseminated by extension officers during irrigation training workshops (Sinyolo et al., 2018). Improved ability to interpret information facilitates better farm management skills as well as water conservation strategies (Muchara et al., 2014). Gender plays a significant role in access to water in rural areas dominated by a patriarchal system, where male farmers have superior access to many resources, including water (Sharaunga & Mudhara, 2016). Sinyolo et al. (2018) reported gender inequality in water access between male and female farmers, as males had more days to access water.

Wealth status measures such as land size also play a significant role in influencing water security. A farmer's welfare status enables him/her to contribute financial capital to the scheme's maintenance, which gives him/her the right and power to claim water. Moreover, experience in a WUA enables a farmer to participate in decision making related to scheme management, such as water distribution and allocation (Dirwaia et al., 2019; Siddiqi et al., 2018). Through irrigation training, farmers acquire the necessary skills, strategies, and

knowledge over time to deal with water challenges (Sharaunga & Mudhara, 2016; Muchara et al., 2014).

Table 6.1: Variable description for factors influencing water security

Variables	Definition	Measurement	Expected Sign
Dependent			
WATERSEC INDEX	PCA index (subjective water security)	Index	
WATER SECURITY	Water security status	1= Water secure 0= Water insecure	
Explanatory Variables			
INSTI_INNOVATION	A farmer belongs to an innovative group or not	1= Innov; 0= Non-Innov	+
INSTIT POLICIES	Perception of policies	1= good; 0=bad	+
MEMBER OF GROUP COMMITTEE	Farmers is a leader or member of a committee	1=yes; 0=No	+
AGE	Farmer's age	Continuous	+
EDUC	Farmer's highest level of education	Continuous	+
GENDER	Farmer's gender	1 = male; 0 = female	+
HHS	Household size	continuous	+
TOT_HA	Land owned	continuous	-
INCOME/CA	Rand value from non-farm income	Continuous	+
YEARS_FARMER_COOP	Number of years in farmer group	Continuous	+
YEARS_WUA	No. of years a farmer has been a member of a WUA	Continuous	+
HEAD_POSITION	Farmer's plot position	1=head; 0= otherwise	+
GRAVITY_MODE	Mode of extracting water	1=gravity; 0= otherwise	-
PART_CANAL_CLEANING	Farmer has participated in canal cleaning in the past 12 months.	1= Yes; 0 = No	+
CONTR_FINANCE_MAINTENANCE	Contributing finance for maintenance	1= Yes; 0 = No	+
INSTI_PERCEPTION_POLICIES	Farmer's perception of institutional policies	1=good 0=bad	+
INFRASTRUCTURE_CONDITION	Condition of infrastructure	1=good 0=bad	+
TUGELA_FERRY	Irrigators in Tugela Ferry	1=Tugela Ferry 0=otherwise	+
QAMATA	Irrigators in Qamata	1=Qamata 0=otherwise	-
ZANYOKWE	Irrigators in Zanyokwe	1=Zanyokwe 0=otherwise	+/-
MOOI_RIVER	Mooi River	1= Mooi River 0=otherwise	+/-

Being a member of a cooperative improves networking and sharing of information on water management. Participating in the management of the scheme, either through providing labour for canal cleaning or contributing financial capital to scheme maintenance give a farmer the right to claim water. Moreover, the location of a farmer's plot is a crucial factor as irrigators located in the head position are more likely to be water secure because they are the first to access water from the main source. The irrigation system used by different farmers also has a significant effect as those relying on gravity feed may experience a lower flow rate than those using electric or diesel pumps. For robustness check, the study adopted a subjective farmer perception measure to investigate the factors influencing farmers' water security using PCA, which is described in the next section.

6.4.2. Principal component analysis to generate a subjective index for water security

The study used PCA to construct a subjective water security index. This is a commonly used technique to construct an index that provides a simple, non-parametric method to reduce complex data to smaller components that can be easily and meaningfully interpreted (Achia et al., 2010; Sinyolo et al., 2014). Given a set of correlated variables, the PCA generates a set of uncorrelated components which are the weighted combinations of the initial set of variables that are linear in dimension (Jolliffe, 2002).

The PCA linearly transforms an original set of explanatory variables into a new set of uncorrelated variables called principal components. The new set of variables is ordered so that the first few principal components capture most of the variation present in all the original variables. The first principal component is the linear combination of observed variables that maximally separates, subject maximising the variance of their components' scores. The second component is formed from the variability remaining in the data set after the variance associated with the first components. It is the linear combination of observed variables that extracts maximum variability uncorrelated with the first component. The following components also extract maximum variability from residual correlations and are orthogonal to all previously extracted components (Tabachnick & Fidell, 1983). The choice between using Principal Components (PC) or Factor Analysis to solve for multicollinearity depends on the researcher's assessment of the fit between the common factor model, the data set, and the research goals. For this study, PCA was the better choice. Factor analysis is more suitable when the study aims

to obtain a hypothetical solution uncontaminated by unique and error variability rather than an empirical summary of the results (Tabachnick & Fidell, 1983).

$$PC_1 = a_{13} X_1 + a_{14} X_2 + \dots + a_{1n} X_n \quad (9)$$

$$PC_m = a_{am1} X_1 + a_{am2} X_2 + \dots + a_{amn} X_n \quad (10)$$

Where a_{mn} denotes the weight for the m^{th} PC and the n^{th} variable.

The generated components are structured in such a manner that the first principal component explains the largest amount of variation in the original data set compared to other PCs. Either a correlation matrix (comparable scales) or covariance (different scales) matrix may be used to generate PCs depending on how the data was measured (Morrison, 2005; Vyass & Kumaranayake, 2006). The Kaiser criterion was used to determine the number of PCs to be retained. KMO, a reliability test, was used to test the appropriateness of conducting a PCA.

Farmers were asked to rank their perception of the level of water security using a five-point Likert scale (1=strongly disagree to 5=Strongly agree) (Sinyolo et al., 2014). Farmers are rational agents, and they plan their agricultural production based on perceptions of water security. The key water security items included were ten variables on water reliability, water consistency, sufficient water quantity, satisfaction with the quality of water, ability to control water that reaches the plots, willingness to pay for water, ability to pay for water, and the right to claim secure and flexible irrigation time. This study added flexible irrigation time to the variables employed by other studies (Sharaunga & Mudhara, 2016; Sinyolo et al., 2014) because female farmers have many responsibilities. After computation of the two dependant variables, the OLS method was employed to investigate the factors influencing water security among farmers in the scheme.

6.4.3. Propensity score matching

Propensity score matching that was described in Chapter 4 was used to determine the impact of being water secure on farm productivity measured by output harvested and crop income. The study compared the productivity of farmers who were water secure against those who were water insecure. It is assumed that W_i represents the farmer's water security status i , where W_i

= 1 if the farmer is water secure and $W_i = 0$ if the farmer is water insecure. If a farmer is water secure, farm productivity is represented by Y_{1i} . Therefore, if the i th farmer is water insecure, farm productivity is represented by Y_{0i} . The average treatment effect (ATE) denotes the weighted average, which tells us about the expected effect of being water secure on crop productivity for the whole population (Cobb-Clark & Crossley, 2003).

$$ATE = E[\Delta i] = E [Y_{1i} - Y_{0i}] \quad (1)$$

$$= E [Y_{1i} - Y_{0i} | W_i = 1] Pr (W_i = 1) + E [Y_{1i} - Y_{0i} | W_i = 0] Pr (W_i = 0), \quad (11)$$

where $E[\Delta i]$ is the anticipated effect on household i ; Pr is the probability of being water secure; and the other variables are as explained above. However, the study aimed to evaluate the effect of being water secure on those farmers who are water secure, which is the average treatment effect on the treated (ATT). ATT represents the possible change in productivity gained by being water secure

$$ATT = E [\Delta i | W_i = 1] = E [Y_{1i,t} | W_i = 1] - E [Y_{0i,t} | W_i = 1], \quad (12)$$

where $E [\Delta i | W_i = 1]$ represents the expected treatment effect; $E [Y_{1i,t} | W_i = 1]$ denotes the selected outcome variables, and $E [Y_{0i,t} | W_i = 1]$ is the ATT for the productivity (output and crop incomes) variables of the irrigators if they were not water secure (Nguyen, 2006).

6.5. Empirical results and discussion

6.5.1 Water security levels of irrigators

Table 6.2 present the results on irrigation crop water requirement and the objective average quantity applied by farmers during one production cycle measured using the Marsh-McBirney Model 2000 Flo-Mate of water. Using data from South African Weather Services, crop water requirement was calculated using the CropWat 8 model. Data for the Mooi River and Tugela Ferry irrigation schemes was collected from the same weather station as these schemes are in close proximity to each other and share a station. As shown in the Table 6.2, the four main crops cultivated by farmers were maize, cabbages, potatoes and tomatoes. It is important to note that some farmers cultivated more than one crop; however, only the key main crop was analysed per farmer. On average, the results point to water insecurity as irrigation water applied

was less than that required, particularly among farmers located in the tail position.

Table 6.2 illustrates that the degree of water security in Tugela Ferry was much better than that in other schemes. This is in line with Dirwai (2019), who reported that 86% of Tugela Ferry farmers had an adequate water supply, compared to 24% of water-secure farmers in the Mooi River irrigation scheme. In the Qamata and Mooi River schemes, water insecurity was severe, with various factors, such as poor infrastructure maintenance, resulting in poor flow rates, restricting farmers' access to irrigation water.

Table 6.2: Irrigation CWR and the average estimated actual irrigation water applied

Scheme		Maize	Cabbages	Potatoes	Tomatoes
Tugela Ferry (n=117)	CWR	5928	5090	4370	7189
	H	6341	5214	4223	6832
	M	5321	4992	3290	5365
	T	2214	2018	2280	2396
Mooi River (n=101)	CWR	5928	5090	4370	7189
	H	4803	4911	4019	6523
	M	4300	3508	2873	5034
	T	2980	2001	2102	1985
Qamata (n=96)	CWR	6087	5697	4807	-
	H	5328	5308	4500	-
	M	3502	2902	2753	-
	T	2403	2301	1983	-

CWR = crop water requirement generated using CROPWAT 8, H = applied by head position;

M = applied by middle position, T = applied tail position

Source: Authors' calculations

The average canal water flow in $M^3 \cdot S^{-1}$ was 0.1 to 0.5 in Tugela Ferry, 0.34 in Mooi River and 0.29 in the Qamata irrigation scheme. Poor water flow in Qamata was caused by several factors linked to both the breakdown of infrastructure and poor institutional set-up. As shown in Figure 6.3 (a), Qamata irrigation scheme extracts water from the Lubisi Dam; however, the dam is almost empty due to rising water scarcity. Water released at the Lubisi Dam flows through the Lanti weir through a 27 km canal in length (Figure 6.3b). Farmers in the middle tail reported

that it takes about four days (compared to one day in the head position) for water released from Lubisi Dam to reach the scheme's middle position due to leakages that cause slow water flow (see Figure 6.3). Those located in the tail position are the worst impacted due to their geographic location. The figure shows the state of infrastructure in the Qamata irrigation scheme.



Figure 6.3: Condition of main canal infrastructure in Qamata irrigation scheme

Authors such as Machethe (2004) and Muchara et al. (2014) attribute poor infrastructural maintenance to the rushed process of IMT, which posed challenges to farmers' ability to manage and maintain the schemes. Political reforms in South Africa to redress apartheid inequalities further contributed to the failure of IMT because less attention was paid to capacitating farmers to effectively manage the schemes (Senanayake et al., 2015). In Africa, this process was not as gradual and smooth as in Asia (Facon, 2013). Furthermore, the South

African government has failed to recover capital costs because the smallholder irrigation schemes are viewed as welfare rather than investment projects, and farmers are regarded as too poor to contribute to capital costs (Mundra & Garg, 2013). Hirsch (2013) critiques this welfarist approach as unsustainable (lack of accountability and responsibility) and not *pro-poor* because it compromises farmers' commitment to the management and ownership of the schemes.

Irrigation infrastructure is deteriorating in Qamata, and is threatening the sustainability of the scheme and farmers' livelihoods. The major problem in Qamata is that the WUA established to oversee the irrigation scheme's management is not active. Irrigation management committees and WUAs are legal organisations mandated to oversee irrigation schemes' operation and maintenance (Samad, 2002). This involves collecting money or organisation of labour to operate and maintain infrastructure. The process of IMT was not successful as farmers still do not understand the importance and role of a WUA.

Farmers perceive the WUA as a platform used by the government to charge for irrigation water use rather than as a means of farmers taking ownership of the scheme. As a result, the schemes' maintenance and operation have been poor because WUAs have not been active in collecting capital to contribute to maintenance (Gomo, 2010; Namara et al., 2011). Farmers' refusal to pay for irrigation water is based on their belief that water is a gift from God, but this limits the budget for scheme maintenances. Weak institutional arrangements to enforce collective action result in farmers' low level of participation in managing the scheme, negatively impacting canal maintenance (removing sand drift), which compromises efficient delivery of irrigation water (Samad, 2002). Moreover, Figure 6.4 shows that the secondary canals, balancing dams for water storage, are also in bad condition due to poor maintenance.



Figure 6.4: State of infrastructure in the Qamata irrigation scheme

Effective management of the scheme calls for the design of rules, procedures, and frameworks that are compatible with technical, physical, and socio-economic dynamics (Roger & Hall, 2003). Poor institutional arrangements to maintain and manage the scheme have been cited as the leading cause of water insecurity and water inadequacy (Sinyolo et al., 2014; Muchara et al., 2014; Gomo et al., 2016; Dirwai et al., 2019). Institutional innovation ensures that the scheme’s conveyance relates to an institution's infrastructure and socio-economic factors. Due to the poor institutional framework in Qamata, there are high levels of wastage as the water controls are accessible to all. Some community members open the valve to secure water for domestic use and do not close it. The wasted water sometimes overflows in the lei dams due to lack of control. In the past, the Department of Water and Sanitation proposed that it work with traditional leaders, farmers, and community members to reduce water loss by establishing local structures to manage water resources for each irrigation area. However, this has not come to fruition because of misconceptions and a lack of understanding of WUAs.

In Tugela Ferry, the scheme was rehabilitated in 2016, and the infrastructure was improved and was in good condition in 2020. The WUA and scheme committee are active, and farmers are working together to clean the main canal and secondary canals that feed their plots.



Figure 6.5: Condition of infrastructure in the Tugela Ferry main and secondary canals

Dirwai (2019) reported that the Tugela Ferry irrigation scheme has a robust institutional setup which resulted in clear and well-defined scheme goals such as equitable water allocation and participation in canal cleaning.



Figure 6.6: Condition of infrastructure in the Mooi River scheme

Figure 6.6 shows the Mooi River irrigation scheme canal. The scheme is currently under rehabilitation; working valves have been installed to control water in the secondary canals. However, as illustrated in the figure, stones that fall from the mountain tend to block the water flow.

As presented in Table 6.2, the farmers were categorised into two categories, water secure or water insecure based on whether they met the crop water requirement. The dependent variable was a binary and the logit model was used to determine the factors influencing water security; these are discussed in the following section.

6.5.2. PCA subjective water security index

Table 6.3 presents the PCA results used to generate a perception-based water security index. Farmers were asked to rank their perception of water security (5-point Likert scale) over a set

of ten correlated water security variables. The use of PCA generated uncorrelated components in which each component was a linear weighted combination of the initial ten water security variables. The sample size of 401 irrigators was aligned with Garson’s (2008) rule of 10, which states that there should be at least 10 cases for each item. As shown in Table 6.3, 10 cases were used, implying that at least 100 were required based on the rule of 10. Moreover, the use of ordinal data violated the assumption that PCA has to be used when data is continuous. In addressing this problem, a polychoric correlations matrix was generated and used instead of the Pearson correlations (Howe et al., 2012). The Kaiser-Meyer-Olkin (KMO) test was used to test for the reliability of the variables included in PCA for sampling adequacy. The scale reliability coefficient was 0.85, greater than the recommended cut-off of 0.8 and is considered reasonable for PCA use (Antony & Rao, 2007). A KMO measure of more than 0.8 indicates that correlations are compact and that factor analysis should yield reliable factors. Bartlett’s test of sphericity was highly significant at a 1% level, indicating that a correlation matrix was not obtained from a population with zero correlation.

Table 6.3: Water security index generated using PCA

Variables	PC1
Water reliability	0.84
Water consistency	0.87
Flexible irrigation time	0.93
Sufficient water	0.91
Satisfaction with water quantity	0.95
Control water reaches plots	0.44
Satisfied with water quality	0.58
Willing to pay for water	0.34
Able to pay for water	0.46
Right to claim secure	0.11
Eigen Values	4.91
Percentage explained	0.81
Scale reliability coefficient	0.85
N	401
Bartlett’s’ test: χ^2 (66)	3299.88
Prob>χ^2	0.000

One principal component was retained using the Kaiser criterion (with an eigenvalue greater than one). PC1 explained about 81% of the variance in the data set. The rule of thumb for a cut-off indicates that a variable should at least have a rotated factor loading of 0.4 to be considered important (Antony & Rao, 2007). A factor loading of 0.4 was used as a cut-off point for dominant variables in this study. The results in Table 6.3 show that almost all variables were dominant; the first five variables (reliable water source, consistent water supply, flexible irrigation time, and sufficient water quantity) have high factor loadings of above 0.8. The variable “satisfied with water quality” factor loading was also high at almost 0.6, while the variable “able to pay for water” has a factor loading of 0.46. The variable “ability to control water that reaches the plot” has the lowest factor loading of 0.44.

The low factor loading for the variables “willingness to pay for water” and the “right to claim for water” implies that most smallholder irrigation farmers do not need to pay for water to be water secure. Most use a gravity-fed system in these schemes, and the government still covers the total cost of irrigation water; therefore, they are irrigating free of charge. Therefore, PC1 represents an irrigator who is water secure. These irrigators have a reliable and consistent water source, and the irrigation time is flexible as the majority have to take care of their households, particularly children, before heading to the irrigation scheme. This index shows that these irrigators obtain sufficient water, and they are satisfied with the quantity of water reaching their plot. However, they are not willing to pay for water as they are currently receiving it free of charge, with the government covering the total cost. PC1 was then used as a subjective index for water security perception in the OLS regression to investigate if belonging to an innovative group is positively associated with water security.

Table 6.4 shows the descriptive analysis of the variables included in the OLS model to determine that factors that influence water security. Most of the reported socio-economic descriptive variables (age, education, gender, etc.) are similar to those presented in Chapter 4. The results show that 46.38% of the farmers were water secure during the production season, while 53.62% were not secure. This indicates the extent of water scarcity and also the need for farmers to continually innovate to improve water distribution. The results show a statistically significant difference between the two groups, water secure and insecure irrigators, in several variables, as shown in Table 6.4. Water secure irrigators generated more income, belonged to innovative groups, were more educated, and were dominated by male irrigators.

Table 6.4: Descriptive statistics for the variables, (n=401)

Variables	Mean			
	Pooled sample N=401	Water Secure n=186	Water insecure n= 215	T-test
WATER SECURE	0.46 (0.50)	-	-	-
INCOME	2548.78	3260.009 (560.52)	(1933.48) (173.68)	2.39***
INSTI_INNOVATION	0.67 (0.47)	0.77 (0.01)	0.59 (0.03)	4.08***
INSTITUTIONAL POLICY PERCEPTION	0.29 (0.45)	0.29 (0.03)	(28.4) (0.03)	0.26
MEMBER OF COMMITTEE	0.21 (0.41)	23.7 (0.03)	18.6 (0.027)	1.24
AGE	53.69 (11.16)	53.79 (0.79)	53.59 (0.77)	0.18
EDUC	4.49 (4.50)	5.37 (0.33)	3.72 (0.29)	3.73***
MARRIED	0.58 (0.49)	0.54 (0.03)	0.60 (0.03)	1.34
GENDER	0.33 (0.47)	0.45 (0.03)	0.22 (0.02)	4.87***
FULL-TIME FARMER	0.89 (0.31)	0.91 (0.02)	0.87 (0.02)	0.27
TOT_HA	1.36 (1.80)	2.05 (0.16)	0.75 (0.07)	7.71***
ACCESS TO EXTENSION	0.58 (0.49)	0.59 (0.03)	0.57 (0.03)	0.38
YEARS_FARMER_GROUP	3.14 (4.54)	3.73 (0.36)	2.63 (0.27)	2.43***
YEARS_WUA	0.26 (1.67)	0.46 (0.16)	0.16 (0.55)	2.28**
HEAD_POSITION	0.27 (0.44)	0.29 (0.03)	0.24 (0.02)	0.98
GRAVITY_MODE	0.85 (0.36)	0.86 (0.02)	0.84 (0.02)	0.6
PART_CANAL_CLEANING	0.20 (0.40)	0.29 (0.033)	0.11 (0.02)	4.46***
CONTRIBUTING FINANCE TOWARD MAINTENANCE	0.34 (0.47)	0.40 (0.03)	0.27 (0.03)	2.63***
INFRASTRUCTURE CONDITION	0.29 (0.46)	0.30 (0.03)	0.28 (0.03)	0.38
QAMATA	0.24 (0.43)	0.26 (0.03)	0.21 (0.03)	1.04
TUGELA FERRY	0.34 (0.48)	0.34 (0.03)	0.33 (0.03)	0.20

Table 6.4 also shows that water secure irrigators have more hectares of land under production and have been members of farmer groups and WUAs for a longer period of time. Moreover, water secure irrigators participated more in canal cleaning and in contributing to scheme maintenance. The income of the water secure irrigator was R3 260, while for water insecure farmers, it was R1 933.48, a difference of R1 326.52. This is aligned with the conceptual framework and other scholars who indicated that being water secure increases production, leading to higher income.

As reported in Chapter 5, 21 groups reported implementing at least one institutional innovation while seven did not. The results show that 67% of the irrigators belonged to innovative groups which implemented institutional innovations in the past three years to improve water security and scheme management (see Chapter 5). Farmers were further asked to indicate their perception of institutional policies as they share the same water sources, and 29% ranked their policies as good while 71% described them as bad. The study further examined the water security status of the leaders, and 29% of the irrigators were members of the committee, including the chairperson, deputy chair and secretary. The average age of farmers was 54, indicating that older farmers dominate irrigation schemes. This is in line with Sinyolo et al. (2018), Gomo et al. (2014) and Muchara et al. (2014), who reported relatively low youth participation in agriculture in KZN in the Mooi River and Tugela Ferry irrigation schemes. The age of water secure and insecure irrigators was similar, with an average of more than 52. There is a need to incentivise the youth to join the smallholder sector to introduce new ideas that can improve the schemes' sustainability.

The results show that smallholder irrigation farming is dominated by farmers with relatively low education levels with an average of seven years of schooling. There is a statistically significant difference in education level between the two groups, with water secure farmers having an average of seven years of schooling while their water insecure counterparts had an average of three years of schooling. Fifty-four percent of the water secure farmers were married, while the figure stood at 60% among water insecure farmers. The results show a statistically significant difference in terms of gender between water secure and insecure irrigators. The majority of irrigators (89%) were full-time farmers that rely solely on irrigation farming for their livelihoods. In terms of hectares under production, there is a statistically significant difference between these two groups, with water secure irrigators' plots averaging 2.05 hectares, while those of water insecure farmers averaged 0.75 hectares. The two groups

had equal access to extension services. The results show a significant difference in the number of years in the farmer group, with water secure farmers having more than three years while water insecure farmers indicated less than three years.

Water user associations were established to enable farmers to participate in water management; however, the results indicate that only 26% of the farmers were part of a WUA, suggesting a relatively low participation rate in water management. Moreover, there is a statistically significant difference between the two groups, as 46% of water secure irrigators were members of a WUA compared to 16% of water insecure farmers. A total of 27% of farmers were located in the head position within the canal, and 85% of irrigators used the gravity irrigation system. An average of 20% in the pooled sample reported having contributed labour to canal cleaning, while 34% reported having contributed financially. The majority of farmers described the condition of the irrigation infrastructure as bad (71%), with only 29% indicating that it was good.

6.5.3. Regression results on factors influencing water security

The study estimated two separate regression models to determine the factors influencing water security among the irrigators. Firstly, the quantity of water applied by farmers during one production cycle was measured using the Marsh-McBirney Model 2000 Flo-Mate. Thereafter, the CROPWAT model was employed to calculate whether a farmer met the irrigation crop water requirement. Farmers who met the irrigation crop water required for the main crops were categorised as water secure and those who did not were categorised as water insecure. The logit model was used to determine the factors influencing water security. Moreover, since the above method focused on the quantity of water applied, the study used PCA as a subjective index to measure the level of water security. The OLS model was employed since the PCA index was a continuous dependent variable. The data were first tested for the presence of multicollinearity using the VIF approach. The VIF is a technique used to detect multicollinearity in the dependent variables. It quantifies how much the variance of the estimated co-efficiencies are inflated due to the presence of multicollinearity. The general rule of thumb indicates that when the VIFs of each predictor exceed four, there is a need for further investigation and estimates to correct for multicollinearity (Gujarati, 2009). Moreover, VIFs exceeding ten indicate the presence of serious multicollinearity, which requires correction. The results in Table 6.5 show

that no variable's VIF exceeded four, and the mean VIF is 1.4, indicating relatively low levels of multicollinearity.

Table 6.5: VIF for dependent variables

Variable	VIF
INSTI_INNOVATION	1.68
INSTITUTIONAL POLICY PERCEPTION	1.04
MEMBER OF COMMITTEE	1.06
AGE	1.31
EDUC	1.51
MARRIED	1.14
GENDER	1.43
FULL-TIME FARMER	1.27
TOT_HA	1.93
ACCESS TO EXTENSION	1.54
YEARS_FARMER_COOP	1.41
YEARS_WUA	1.19
HEAD_POSITION	1.06
GRAVITY_MODE	1.46
PART_CANAL_CLEANING	1.21
CONTRIBUTING FINANCE TOWARD MAINTENANCE	1.48
INFRASTRUCTURE CONDITION	1.17
TUGELA FERRY	1.58
QAMATA	2.19
MEAN VIF	1.4

As explained above, the PCA water security index measured farmers' perceptions of water security. Table 6.6 shows the results of the logit and OLS models on factors associated with water security. An F-value of 141.11 and 12.65 indicate that both models are highly significant at a 1% level, indicating that the data fits the models reasonably well. An R^2 value of 0.25 and 0.386 is high considering that it is cross-sectional data. The results are comparable as similar variables are significant in both models, indicating the robustness of the data in explaining the factors influencing water security. In both models, being part of an innovative institution, the

farmer's gender, hectares under production, years in a WUA, participating in canal cleaning, and being located in the Tugela Ferry scheme were all statistically significant and positively affected a farmer's water security. Dysfunctional infrastructure negativity influenced water security in the logit model and using the gravity model negatively influenced it in the subjective index.

As expected, the results show a positive relationship between a farmer belonging to an innovative group and individual water security in both models. Belonging to an innovative group was positively and highly associated with increasing water security. The logit results show that the likelihood of being water secure increases by 0.11% when the farmer belongs to an innovative group. The innovative groups improved their rules and regulations governing water management, such as strengthening sanction mechanisms, collective action and incentivising members to participate in canal cleaning. This will result in better management of water resources, which could improve the water security level. Dirwai et al. (2019) noted that farmers' poor participation in selecting appropriate procedures (selecting operational methods to convey water, maintaining infrastructure, and distributing water into the canal) results from a weak institutional setup. Therefore, water security depends on the strong institutional setup required to manage water resources efficiently. Groups which continually innovate to solve current challenges are more likely to improve their degree of water security.

As expected, being a group leader (chairperson, deputy chairperson, secretary) increased the likelihood of being water secure by 0.051 percentage points. Group leaders have the power to influence water management decisions in the scheme, which will favourably impact their access to irrigation water. Also, as expected, a positive association was established between education level and water security in both models. Educated farmers are better able to acquire and interpret information disseminated through various forums, such as irrigation training workshops. This result is different from Sinyolo et al. (2014) and Sharaunga and Mudhara (2016), who found that education was an insignificant factor in the Tugela Ferry and Mooi River schemes. The results in both models show a positive relationship between being a male farmer and water security at a 1% significance level.

Table 6.6: Factors influencing water security

Variables	Model 1= Logit				Model 2= OLS PCA Index	
	1= Water Secure; 0= Water insecure		Marginal Effect		Coefficient	Standard error
	Coef.	Standard error	Coefficient	Standard error		
INSTI_INNOVATION	0.893***	0.333	0.154	0.055	0.461***	0.138
INSTITUTIONAL POLICY PERCEPTION	0.405	0.270	0.070	0.046	0.153	0.112
MEMBER OF COMMITTEE	0.516*	0.315	0.089	0.054	0.297***	0.126
AGE	0.030***	0.013	0.005	0.002	0.005	0.005
EDUC	0.054*	0.033	0.009	0.006	0.034***	0.014
MARRIED	-0.173	0.262	-0.030	0.045	-0.007	0.108
GENDER	0.697***	0.310	0.120	0.052	0.370***	0.127
FULL-TIME FARMER	1.668***	0.463	0.287	0.075	0.860***	0.181
TOT_HA	0.654***	0.128	0.113	0.020	0.240***	0.039
ACCESS TO EXTENSION	-0.012	0.295	-0.002	0.051	0.000	0.125
YEARS_FARMER_COOP	0.048	0.033	0.008	0.006	0.024*	0.013
YEARS_WUA	0.282***	0.111	0.049	0.019	0.099***	0.033
HEAD_POSITION	0.522*	0.285	0.090	0.048	0.124	0.116
GRAVITY_MODE	-0.674*	0.383	-0.116	0.065	-0.454***	0.168
PART_CANAL_CLEANING	1.345***	0.345	0.232	0.055	0.715***	0.138
CONTRI FINANCE FOR MAINTENANCE	0.359	0.311	0.062	0.053	0.259**	0.128
INFRASTRUCTURE CONDITION	0.300	0.278	0.052	0.048	-0.042	0.119
QAMATA	-0.350	0.432	-0.060	0.074	0.013	0.173
TUGELA FERRY	1.519***	0.327	0.262	0.051	0.644***	0.132
_CONS	-5.923	1.103			1.095	0.410
LR chi2=141.11 Prob>chi2 =0.000 R-square = 0.254					F=12.65 Prob= 0.000 R-square=0.386	

* = 10%, ** = 5% and *** = 1% significance level

Being male increases an irrigator's probability of being water secure by 0.12 percentage points. This was expected because gender inequality is still prevalent in rural areas dominated by patriarchal social systems. Decision-making bodies are subject to cultural power dynamics, which marginalise and exclude women from participating in collective decision-making processes to manage the scheme (Sharaunga & Mudhara, 2016:5). Sinyolo et al. (2018) investigated gender differences in water access in the Mooi River and Tugela Ferry irrigation schemes. Their study revealed that male farmers had more access to water than female farmers. In both models, there is a positive association between being a full-time farmer and water security. Being a full-time irrigator increases the likelihood of being water secure by 0.28 percentage points. These farmers dedicate more time to agricultural farming and can therefore attend irrigation training and meetings, and irrigate within their scheduled irrigation time.

Moreover, the results indicated a positive relationship between total hectares of land owned by a farmer and water security in both models. Land represents a farmer's wealth status; thus, those with larger plots are assumed to have more wealth to improve access to irrigation water. The number of years in a WUA was positively associated with being water secure at 10% level in both models. This was expected because being a member of a WUA increases farmers' knowledge and information on water issues and related decisions. Moreover, the WUA is a platform where a farmer's voice can be heard, and a platform to fight for and claim water security. As expected, there was a positive relationship between water security and the number of years a farmer had been a member of a farmer group in the logit model. Belonging to groups enables farmers to gain social capital as they share information about irrigation procedures. Moreover, belonging to a farmers' group for a number of years builds experience in dealing with water insecurity, with a positive effect on their perceived water security. Furthermore, as expected, farmers located in the head position along the canal are more likely to be water secure by 0.09 percentage points. These farmers receive irrigation water first, and they are more likely to obtain sufficient quantities of water to grow their crops. This finding is in line with Sinyolo et al.'s (2014) study in Tugela Ferry, which also found that farmers located in the head position are more likely to be water secure.

Participating in the scheme's maintenance through labour or contributing finance is imperative for efficient management of the scheme. As expected, the results indicate a positive relationship between participating in canal cleaning and water security at a 1% significance level in both

models. Farmers indicated that participating in canal cleaning through physical labour was more effective as they can see who participates, thus increasing a farmer's right to claim water. Muchara et al. (2014), also emphasised the importance of collective action in canal cleaning through labour. As expected, farmers in the Tugela Ferry irrigation scheme were more water secure than those in the other schemes due to good scheme maintenance (see Figure 6.5 above).

Moreover, the study investigated the impact of being water secure on maize output and income per hectare since it was grown by 191 farmers (n=101 water insecure and 90 water secure), making it possible to analyse the impact using PSM. The study assessed whether those farmers who are water secure produced more maize and earned more profit as stated in the conceptual framework. Propensity score matching which was explained in Chapter 4 was used to analyse the impact and the results are presented below.

6.5.4. The impact of water security on maize output and income

The study further investigated the impact of being water secure on maize output and income per hectare. Maize is the most important grain crop in South Africa, and most of the farmers that participated in the study cultivated it (n=191). According to the conceptual framework, water secure farmers are likely to produce more output and earn more income. The t-test in Table 6.7 shows a statistically significant difference between water secure and insecure irrigators. On average, the performance of the secure water irrigator was higher than the water insecure. Water secure irrigators produced 1 313.65 kg/ha of maize compared to 708.32/ha kg produced by water insecure irrigators. Moreover, water secure irrigators' average income from maize was recorded at R3 983.80 compared to R1 697.87 received by water insecure irrigators in a single production cycle. Although the water secure irrigators produced more maize output, there is room for improved productivity in these smallholder irrigation schemes.

According to Mnkeni et al. (2010), farmers have the capacity to produce more than three tons per hectare of maize. Fanadzo et al. (2010) and Sinyolo et al. (2014) reported that farmers in smallholder irrigation schemes in Limpopo and KZN produced more than two tons of maize compared to one-and-a-half recorded in this study among water secure farmers. However, increasing water scarcity accompanied by intensified heat stress posed a substantial threat to productivity. During field observation during the harvesting period, a few farmers who

indicated that they had sufficient access to water harvested less output because of the intensified heat, which caused some of the maize to dry up, as the majority of farmers harvest when they have a buyer. Farmers need to perceive themselves as fully water secure in order to invest in modern farming technologies such as fertiliser, improved seeds and pesticides that are crucial for increased productivity.

Table 6.7: Maize productivity by water security status (n=191)

	Water Secure (n = 90)	Water Insecure (n = 101)	T-test
Maize Output (kg/ha)	1313.65 (125.12)	708.32 (47.53)	4.71***
Maize Income (Rands/ha)	3983.80 (689.35)	1697.87 (196.24)	3.36***

The study also analysed the impact of water security on maize output and income using PSM. To successfully implement PSM, the generated propensity scores must balance, satisfying the conditional assumption for the treatment effects estimates to be unbiased. This means that the covariates or confounders must be independent of the treatment status. The PSMATCH2 and PSTEST in Stata (Leuven & Sianesi, 2003) were employed to test if this condition was met. The p-value of equality of means was examined to determine if there was any significant difference between the covariates of the water secure and water insecure irrigators. The rule indicates that, after matching, the t-test must be insignificant to show that the two groups are similar in characteristics in order to produce unbiased results so that the impact is only attributed to water security status (Baker, 2000; Leuven & Sianesi, 2003). Moreover, as explained in Chapter 4, the percentage bias after matching must be less than 20 for the conditional independence assumption to be satisfied.

Table 6.8 below presents the results from matching quality between water secure and water insecure farmers. “Psmatch2” after kernel matching was used to test the difference before and after matching. After matching, the results showed no statistically significant difference in all the covariates between water secure and water insecure irrigators because the P-value of the equality of means for all the covariates is insignificant. This indicates that the groups

have similar characteristics, unlike in Table 6.4 above (unmatched sample), which indicates a statistically significant difference between the two groups in several variables. This signifies that the difference in the water secure and water insecure confounder means equals zero, implying that the propensity score is balancing, as shown in Table 6.8.

Table 6.8: Matching test quality for covariates

Variables	Means		% Bias	% Reduction in Bias	P-value of the equality of means
	Water secure	Water insecure			
INSTI_INNOVATION	0.72	0.65	16.0	61.0	0.17
INSTITUTIONAL POLICY PERCEPTION	0.31	0.34	-7.3	-177.6	0.54
MEMBER OF COMMITTEE	0.22	0.21	2.6	78.8	0.82
AGE	53.75	53.63	1.0	43.2	0.93
EDUC	4.92	4.90	0.5	98.8	0.97
MARRIED	0.54	0.56	-4.3	67.7	0.71
GENDER	0.39	0.33	7.8	83.9	0.52
FULL-TIME FARMER	0.91	0.93	-5.8	54.7	0.57
TOT_HA	1.27	1.16	6.3	91.6	0.54
ACCESS TO EXTENSION	0.55	0.49	12.4	-218.3	0.29
YEARS_FARMER_COOP	2.84	3.52	-15.0	37.7	0.29
YEARS_WUA	0.27	0.55	12.6	43.3	0.21
HEAD_POSITION	0.28	0.26	5.0	49.1	0.66
GRAVITY_MODE	0.83	0.80	8.0	-24.5	0.52
PART_CANAL_CLEANING	0.24	0.21	8.1	81.7	0.51
CONTRIBUTING FINANCE TOWARD MAINTENANCE	0.38	0.38	-0.5	98.2	0.97
INFRASTRUCTURE CONDITION	0.33	0.38	-11.6	-204.2	0.34
TUGELA FERRY	0.43	0.54	2.1	-105.0	0.84
QAMATA	0.28	0.30	-5.0	52.3	0.68

Furthermore, to test if the conditional assumption is fully satisfied, R-squared after matching for each algorithm must be relatively low. The overall model must have an insignificant p-value and mean standardised bias of less than 20% (Baker, 2000; Leuven & Sianesi, 2003). Table 6.9 shows that the mean standardised differences in all the covariates are below 20% after matching, implying that the balancing requirement is adequately satisfied. For example, the kernel algorithm shows that the unmatched mean standardised bias was above the threshold at 21, but after matching, it fell significantly to 8.1, within an acceptable threshold. Furthermore, the neighbour algorithm indicates that the conditional dependency assumption was satisfied as the unmatched sample had a mean of 20.8 and the matched sample had a mean standardised bias of 15.9.

Table 6.9: Summary of quality-matching test

Algorithms	Sample	Pseudo R-square	Wald chi-square (p>chi2)	Mean standardised bias	Median standardised bias
Kernel Matching	Unmatched	0.258	142.710 (0.000)	21.0	12.9
	Matched	0.032	13.610 (0.806)	8.1	7.3
Neighbour	Unmatched	0.278	73.49 (0.000)	20.8	12.9
	Matched	0.106	22.17 (0.178)	15.9	14.2

Moreover, the results in Table 6.9 show that the pseudo-R-square of 0.258 for the kernel algorithm of the unmatched sample was high compared to 0.032 of the matched sample. This illustrates that the conditional assumption was satisfied because the kernel algorithm pseudo-R-square after matching decreased significantly to 0.032, which is relatively low. The table shows that the same results were observed for the neighbour algorithm. Furthermore, the overall summary of the quality of means presented by the Wald chi-square (p-value) for all the selected algorithms after matching are insignificant. Therefore, the data was suitable for applying PSM as all the conditional assumption tests were adequately met.

The study proceeded to use PSM to evaluate the impact of water security on maize output and income measured by total maize harvested in kilograms per hectare and income generated. The nearest neighbour and kernel were used to estimate the average treatment effect on the water secure (Baker, 2000; Nguyen, 2006). The results in Table 6.10 show that the estimated effect values across all the algorithms are very similar with minimal differences, implying that the estimates are robust. They indicate that water security has a positive impact on maize output and income. Water secure farmers produced 569-622kg more maize than water insecure farmers.

Table 6.10: PSM results on maize productivity based on the differences in mean values estimated for matched water secure and water insecure maize farmers. (n=191)

Outcome variable	Nearest neighbour	Kernel matching
Maize output/ha	569.01*** (184.32)	622.90*** (176.19)
Maize income	2 037.81** (1 111.35)	2 096.290*** (859.220)

Moreover, the income generated from the maize crop by water secure irrigators exceeded that of water insecure irrigators by R2 037-R2 096. The results are consistent across these two matching algorithms, indicating robustness. Indeed, access to irrigation farming is not sufficient; as elaborated in the literature, farmers must be water secure to improve output and livelihood outcomes (Brewis et al., 2019; Sinyolo et al., 2014; Muller et al., 2009; Hussain & Hanjra, 2004).

Propensity score matching relies solely on observed characteristics; therefore, the study tested the sensitivity of the results to hidden bias using the Rosenbaum sensitivity test (Rosenbaum, 2002; Nguyen, 2006). This test indicates how strongly an unobservable variable must influence the selection process to undermine or reverse the findings based on the matching of observables reported in Table 6.10 above. The Rosenbaum sensitivity test was run after kernel matching to determine how strongly an unmeasured confounding variable(s) must affect the selection into treatment to change the results, which show a positive effect – as presented in Table 6.10. Table 6.11 shows that the results are highly insensitive to hidden bias, as it would take considerable

increases in the odds of treatment to change the conclusions reached on the positive impact of water security on maize output and income presented in Table 6.10 above.

Table 6.11: Rosenbaum bounds test for sensitivity analysis

Gamma	Maize income	Maize output
r	Upper bound	Upper bound
1	0.000	0.000
31	0.001	0.015
61	0.013	0.062
91	0.034	0.010
121	0.057	0.137
151	0.079	0.164
181	0.099	0.18
211	0.116	0.201
241	0.132	0.23

The results become insignificant after 181 gamma interactions for maize income, indicating highly insensitive results. Moreover, for maize output, the results become insignificant at gamma 121, indicating that they are highly insensitive to hidden bias. Therefore, there was no need to control for the unobserved covariates because the data was not sensitive to hidden bias. In summary, water security improves farmers' maize output and income. Improving water security in the irrigation schemes remains crucial to achieve the Sustainable Development Goals such as reducing poverty and food insecurity.

6.11. Summary

This chapter examined whether institutional innovations are important for improving water security. Water security was measured using two approaches. Firstly, an objective water quantity index at an irrigation scheme level was generated using a velocity area method to examine to quantity of water applied by farmers. The actual water applied by the irrigator at a particular plot was measured over one production cycle. The CropWat 8 model was then used to determine whether farmers met the crop water irrigation requirement for the main crop

grown, and farmers were categorised as water secure or insecure. Secondly, a water security perception index was generated using PCA, where farmers were asked to rank their perception of water security. Two models, logit and OLS, were used to investigate whether there was a positive association between being water secure and belonging to a group that implemented institutional innovations in the past three years.

A sample of 401 farmers was used to determine the factors influencing water security. However, to examine the impact of water security on maize productivity, a sample of 191 farmers was analysed because the majority grew maize; hence, the number of observations for maize crops allowed for the application of PSM. The results indicated that 54% of irrigators were water insecure. Moreover, there was a positive relationship between belonging to an innovative group and water security. In terms of socio-economic status, the results indicated that older, educated, male, full-time farmers were water secure.

Turning to institutional arrangements, the results show that farmers in a leadership position, those whose plots are in the head position, and those with more years in a WUA and farmer co-operatives were more likely to be water secure. Furthermore, in terms of governance, the results showed that participating in canal cleaning was positively associated with water security. The PSM results on maize productivity indicated a positive impact of water security on maize harvest and maize income. Water secure irrigators produced 569-622 more kg per ha of maize and earned an additional R2 037.81 in maize income. Therefore, access to irrigation water is not sufficient; farmers must be water secure to improve their performance. The conclusions and policy implications are presented in the following chapter.

CHAPTER 7: CONCLUSION, RECOMMENDATIONS AND FUTURE RESEARCH DIRECTIONS

7.1. Recapping the purpose of the research

Smallholder irrigation schemes are crucial in light of intensifying water scarcity exacerbated by climate change. Irrigation mitigates the risk of unreliable rainfall as it enables farmers to produce crops throughout the year. Despite the importance of irrigation schemes in fighting poverty, their potential is limited by weak institutional arrangements and a lack of collective action which are vital for effective management. Numerous studies highlight poor institutional arrangements as the main hindrance to successful performance of these schemes. The literature shows that without sound institutional arrangements and successful collective action, the transaction cost associated with managing common-pool resources increases and this may result in over-exploitation of the resource, leading to water insecurity. In turn, water insecurity disincentivises farmers to adopt improved technology such as fertiliser and improved seed variety, leading to poor productivity, farm incomes and asset ownership.

Improving institutional arrangements through innovations is crucial to address water insecurity. The government regards farmers' groups as a necessary institutional arrangement to reduce transaction costs, improve social networks, and increase livelihood outcomes. However, little is known about the internal dynamics of these farmer groups, how they operate, and whether or not they are inclusive, as well as what makes certain groups more successful than others. Furthermore, there is a paucity of research on whether these farmer groups embrace institutional innovations to improve water security and strengthen their design principles that are crucial for collective action.

It is against this background that this study aimed to examine and understand internal group dynamics in four irrigation schemes (extent of inclusiveness, cohesion, trust) using collective action theory. It also investigated the impact of being a member of a farmer group on household welfare (water access, fertiliser use, household income and asset holdings) using PSM. Given the importance of innovations in the 21st century, the study's second objective was to employ institutional innovation theory to examine the nature of institutional innovations in these groups and determine the factors that enhance or inhibit innovation. It investigated whether the institutional innovations implemented were important in improving water security by assessing

the relationship between belonging to an innovative group and water security status. The impact of being water secure on productivity was also investigated using PSM. The sample consisted of 28 farmer groups and 401 irrigators in four irrigation schemes located in KZN and EC Province. Propensity score matching, the logit model, linear regression, PCA, thematic analysis and descriptive statistics were employed to analyse the data. The overarching conclusions and policy implications for all the empirical chapters are present in the next section.

7.2. Conclusions

The study's key objectives were to investigate whether smallholder farmers should continue to operate in groups and to examine if farmers are capable of implementing institutional innovations that are novel, useful and legitimate, and to determine the nature of these innovations (incremental or radical) and their role in improving water security. The results support organising farmers into groups because members' welfare outcomes improved in comparison to non-members. The study found that group membership was positively associated with higher levels of fertiliser use, water access, incomes, and asset holdings. Group members enjoyed an additional four days' access to water in a month and applied at least 130 kg/ha more inorganic fertiliser than non-group members. Group members also had a higher household income per capita and assets than non-group members.

However, the results revealed a heterogeneous effect among group members, with the benefits varying according to members' socio-economic characteristics and internal group dynamics. The findings indicate that the effect of group membership was stronger for households with a lower propensity to join a group, suggesting negative selection into group membership. Farmers who were men, more educated, and who did not have access to credit benefitted the most from group membership. This highlights the need to ensure that farmer groups are inclusive of the most marginalised farmers, i.e., women and the uneducated. The study further contributed by examining the internal group dynamics rather than just categorising farmers based on their group membership status to investigate what makes certain groups more successful. In general, the analysis indicated that members in smaller groups dominated by men and characterised by high levels of group

cohesion benefited more from group membership. The study's findings suggest that organising farmers into groups is a promising strategy to improve access to water and adoption of technology, and for poverty reduction. The government and private donors should thus continue to promote the formation and organisation of farmers into groups.

However, the results indicated the need to pay particular attention to the size of groups. Group size significantly impacts cooperation because the extent of collective action decreases as the group size increases. The study's results support the hypothesis that groups should be smaller for effective management and rules, and healthy boundaries. The results indicated that smaller groups had more access to water, used more fertiliser, and earned slightly more income than bigger groups. Moreover, group cohesion among the smaller groups was superior to that of bigger groups. During the FGDs, some group leaders complained that the size of the group they were leading created many conflicts due to different ideologies and individual farmer goals and visions for farming. These leaders noted that different levels of passion, drive, norms and integrity within bigger groups result in increased transactional costs of managing the groups. While bigger groups benefit from economies of scale, without trust, cohesion and unity, such benefits are not sustainable because farmers drift away and farm individually.

Moreover, the study examined the nature of institutional innovations among farmer groups. The criteria for innovation was as follows: (a) they should be new or significantly improved rules, norms, processes, and procedures; (b) they should add value; (c) they should be legitimate; (d) they should have been implemented within three years; (e) they should have been initiated and led by farmers with no or very limited external help. The results indicate that smallholder farmers are capable of implementing institutional innovations that are context-specific in addressing their challenges. Of the 28 groups interviewed, 21 (75%) adopted institutional innovations in the past three years. The results align with the induced institutional innovations theory, which states that individuals or groups are induced to innovate to solve problems or add value to current situations. A total of 98% of the reported innovations were problem induced, with only 2% opportunity induced. The main reasons for innovating were to stimulate and strengthen the eight design principles recommended by Ostrom as a blueprint for management of common-pool resources. The main problem that induced farmers to innovate was water shortages. This is in line with North who postulated that competition is the primary driver of institutional change. Moreover, North emphasised that scarcity of resources is the

main exogenous factor that induces organisations to implement change in order to remain competitive. However, the fact that 98% of the reported innovations relate to solving problems may be indicative of the fact that the smallholder farmers face so many supply side constraints that keep them from performing well financially. Furthermore, research, the government and the media in general focuses more on the challenges that the smallholder farmers face. Therefore, it is crucial that the focus should be more on exploiting opportunities and opportunities where institutional innovation may contribute towards the farmers being able to exploit the market opportunities. The nature of the reported innovations is aligned with the theory which states that institutional innovations are generally an incremental and path-dependent process because farmers learn and develop new institutions in the context of already existing formal and informal rules. Most groups implemented innovations to improve collective choice arrangements, monitoring, graduated sanctions, and conflict resolution. This was due to weak monitoring and free-riding problems that are significant bottlenecks in the management of irrigation schemes.

Moreover, the study examined whether institutional innovations are important for improving water security. The study firstly contributed by measuring water security objectively at the secondary canal on a weekly basis to improve the measure rather than only relying on a subjective water-security index. Moreover, the subjective PCA index was further used for robustness check. The generated water security indexes presented in chapter 6 exhibited similar results in terms of factors influencing water security, thus making results comparable and robust. The results in both models indicated the importance of institutional innovations in improving individual farmer's water security. Belonging to an innovative group was positively associated with water security. Institutional innovations resulted in improved rules and regulations, which enforced and strengthened the eight design principles crucial for management of the schemes. As a result, water distribution, canal cleaning, and collective action improved, which positively associated with water security. The findings support the literature that argues that water security depends on effective policies, processes, and procedures that inform water governance strategies. Moreover, the results indicated that water secure farmers produced more maize and earned more revenue than water insecure farmers. These results support the conceptual framework, which postulated that access to irrigation farming is not a sufficient condition; farmers must be water secure in order to improve their performance.

However, the results highlighted that women, who dominate smallholder irrigation farming, are more water insecure than male farmers. The patriarchal system in rural areas excludes women from participating in decision making on irrigation water management, such as scheduling and water distribution. In rural areas, it is taboo for women to express their opinions; hence, women's participation remains low in irrigation scheme management. Moreover, the results presented in Chapter 6 revealed that being a member of a WUA was positively associated with improved water security. However, very few farmers in these four schemes are part of a WUA. This is because WUAs are regarded as a tool used by the government to charge for irrigation water, which farmers believe should be free because water is a gift from God. The WUAs, which are a government-led institutional arrangement, aim to give farmers full responsibility to manage water resources at the local level. Therefore, to improve the coordination and management of water resources at national level, there is a need to incentivise farmers to join a WUA.

In Qamata, where there is no active WUA, the scheme infrastructure is in dire condition. Weak institutional arrangements and farmers' poor participation in the scheme's management pose a significant challenge to its sustainability and threaten water security. The growth theory highlights the importance of developing and maintaining infrastructure for economic growth and development. The poor state of infrastructure hinders the potential economic growth which could be gained in the irrigation schemes. Bryan's (2013) study in Indonesia indicated that farmers' contributions (as little as 10%) towards scheme maintenance had a positive influence in encouraging efficiency and legitimising their role in management of the scheme. Therefore, there is a need to re-design and reconceptualise how policymakers view smallholder farmers (as too poor to contribute) as it exacerbates the dependency syndrome. This is not to suggest that the government should withdraw support from farmers, but strategies to enforce or incentivise modest contributions from farmers towards scheme maintenance are crucial. The government needs to develop a strategy to recover the capital cost to enforce farmers' full ownership of the schemes. Capacitating farmers in using water resources efficiently is crucial for the sustainable use of water as a scarce resource. The government should audit irrigation water users that are not registered under a WUA and implement measures to incentivise participation in these structures. Government, private companies and NGOs should

support farmers to maintain the infrastructure where transactional costs are too high. However, this must be done with caution to avoid the dependency syndrome.

The results in the empirical chapters revealed high levels of inequality between male and female farmers in terms of access to capital assets. The results presented in Chapter 4 showed that male farmers were more likely to participate in farmers' groups and benefit from being a member. Moreover, the PSM heterogeneous impact results indicated that male farmers benefited more from membership in terms of income per capita and asset holdings. Using the t-test to determine the significant differences between male and female outcomes in Chapter 4, the results indicated that males enjoyed more than two additional days' water access, used almost 50kg more fertiliser, and earned R12 839.12 more than female farmers. The findings presented in Chapter 5 on institutional innovations illustrated that groups dominated by male farmers were more innovative than those dominated by female farmers. Furthermore, groups headed by a female chairperson were not as innovative as those headed by males. Chapter 6 further revealed that male irrigators were more water secure than their female counterparts. These results signify a high level of gender inequality in the context of smallholder irrigation farming.

These inequalities in terms of resources and welfare outcomes are mainly influenced by the patriarchal social system, which views men as superior and thus more fit to hold leadership positions, wield moral authority, and enjoy social privilege and control of property. There is a crucial need for programmes to empower women in rural contexts. The government and private organisations that offer gender awareness programmes should include farmers and rural communities in general. The traditional authorities could also play a significant role in changing perceptions of men as superior to women. Therefore, it is recommended that the traditional authorities such as Kings and Induna (king liaison) to address gender inequality in their areas of jurisdiction.

Furthermore, the results indicated the need to invest in improving farmers' human capital. They point to a low level of education, with the majority of farmers only having attained primary level. More than 40% of the farmers in these groups had never attended school.

Education is vital in assisting farmers to conceptualise and understand the training offered and to apply the knowledge gained. The results presented in Chapter 4 showed that educated farmers benefited more from group membership in terms of fertiliser use, income and asset holdings. Moreover, groups with more educated farmers reported a higher number of innovations. Education is crucial to improve rural development; therefore, stakeholders and government should continue offering production, marketing and innovations training.

Smallholder irrigation schemes are crucial in rural areas, and the government should continue to strategically invest in these schemes as they are located in rural areas with high levels of poverty. However, the study's results show that much remains to be done to improve the performance of the irrigation schemes. Farmers need to take full ownership, accountability, and responsibility and not hide behind the notion that they are too poor to contribute to the maintenance and operation of scheme infrastructure and irrigation water fees.

In conclusion, the study contributed to the literature by conceptualising and operationalising institutional innovation in the context of smallholder irrigation schemes through integrating the importance of legitimacy in the process of institutional innovation. The operationalization of the concept improved the collection of data which was inclusive of the poor and voiceless marginalised farmers, especially women. Smallholder farmers are challenged by unequal power dimensions, which excludes marginalised farmers from decision-making. Therefore, the study emphasise the importance of institutional innovations in ensuring that farmers remain competitive and relevant in solving today's challenges rather than relying on solutions implemented by external actors such as the government. Moreover, the reported innovations in these studies can be adopted by various irrigation schemes through social networking to improve scheme management, water security, and collective action.

7.3. Recommendations

7.3.1 Recommendations to farmers and policy makers

The government and private donors should continue to promote the formation and organisation of farmers into groups. However, it is recommended that smaller groups must be promoted for sustainability of farmer groups because smaller groups were more innovative and attained better outcomes. Heterogeneities in terms of identity pose challenges to collective action due to different ideologies influenced by culture, religion or experiences. Therefore, policymakers could consider smaller groups as a possible strategy to incentivise farming in groups. The government's strategy to reduce the transaction cost by dealing with farmers in groups should not result in a toxic working environment. Farmers and the government should implement an industry channel model with "sub-units within the same department". Therefore, instead of subdividing farmers into groups of 100 based on their location (villages), it is recommended that there should be various smaller groups specialising in producing different crops within these villages. To reduce the government transaction cost of offering training and workshops to smaller groups, a secondary group should be formed based on farmer location (villages), comprising of all the leaders of the groups within the same village. The larger groups would only meet when attending general training that is not specific to a particular group.

Such an arrangement would also help to reduce conflict and distrust, leading to democracy and inclusiveness within the groups. At the same time, farmers would be able to market collectively in cases where they cannot meet the quantity required by the market. There is a need for these farmer groups to improve and farm formally in a more structured and coordinated manner. However, this calls for trust and improved social capital among members. Holding other things constant, no rational person forms a business partnership with someone they do not trust. For a business to thrive, the vision, mission and trust among the partners are crucial. Collective action will be more successful if group members have the same interests, vision and norms. Farming outcomes could be enhanced if smaller groups are promoted and strategies are adopted to promote trust, reciprocity, and group commitment. Determining the exact size of a group is a subject for further research.

The results showed that farmers are capable of coming up with institutional innovations that are farmer-led, useful, novel, and legitimate. While such innovations promote water security,

external actors such as the government should guide, support, and regulate farmer-led schemes to ensure that the innovations implemented are both socially and environmentally sustainable (eliminate negative externalities such as over-exploitation of water resources and power disparities). The innovative agency of the irrigators should be acknowledged and harnessed to strengthen irrigation institutions and performance. The focus should be on strengthening the institutions designed by farmers themselves, as these are locally contextualised and socially embedded, and hence legitimate. Institutional changes that build incrementally on current institutional arrangements are more likely to succeed than radical changes. The results indicated that innovative groups were smaller in size, and that they cooperated better, and enjoyed higher levels of social cohesion than bigger groups. The study's findings are in line with the literature that asserts that social capital is a source of wealth that can be used to eliminate inequality and is firmly embedded in the notion of trust and norms. They suggest that small groups should be actively promoted, while tailored training should be offered based on groups' specific needs to improve institutional innovations in the smallholder irrigation sector in South Africa.

Moreover, the results shown persistent gender inequality in these schemes which must be addressed. The study recommends a need for transformation in rural areas. The traditional authorities, government, and the private organisations must implement programs which will raise the role and importance of women in decision making. Moreover, the private organisation with the government partnership must also implement projects which will mainly empower woman through providing training, production assets and production and leadership skills. Moreover, awareness programs or workshops on gender inequality should also reach these schemes as it will play a considerable role in the gender-inequality transformation. Most importantly, the traditional authorities must play a significant role in changing the perception of men as more superior than women. Therefore, the traditional authorities such as Kings must consider appointing women as Induna, as this will play a huge role in changing the negative perception that women cannot be good leaders.

The results indicated low level of education among farmers in the smallholder irrigation schemes. It is therefore recommended that the extension officers from various NGOs, private organisation and the government must continue to offer training to improve farmer's human capital. This can be done through offering workshops, which will educate farmers on various

farm management skills. Furthermore, these stakeholders (government, NGOs, private companies) must open more opportunities for exchange visit, where group leaders can get an opportunity to learn about different institutional arrangement, production techniques from other schemes outside the province or even the country. This will help in learning and adopting some context specific innovations or ways for better managing the schemes. Moreover, Farmer-led institutional innovation must be prioritised and capacitated, while the government and traditional authorities must regulate but not impose rules and regulations to farmers. Farmers must be at the centre and participate in policy implementation. This can be improved through allowing farmers to participate in the formulation of policy, implementation and valuation of policies.

7.3.2. Recommendations to collective entities (Water management)

In the irrigation schemes covered in this study, farmers lack water measuring devices, which could assist them in determining the crop water requirement. The government, farmers and private organisations should collaborate and install such devices. Moreover, this water measurement tool could assist farmers and the government to calculate charges for irrigation water used by farmers. Increasing competition for water requires that it be valued as a scarce resource. Therefore, procedures and technological tools should be in place for efficient irrigation water pricing. Valuing water resources means that there is a need to attach a price tag to irrigation water to incentivise its more efficient use in light of rising water scarcity. This does not mean that the government should not subsidise water, but farmers must contribute.

The government also needs to improve service delivery, such as constructing tar roads and infrastructure to improve access to physical capital assets. On the other hand, farmers' mind-set needs to change, and farming should be viewed and treated as a business. If the schemes' performance continues to remain below expectations, the government may be forced to withdraw support for smallholders because taxpayers' money must be used accountably. Active involvement of farmers in designing institutions in partnership with the government, and private companies and NGOs, is crucial to improve their performance.

7.4. Limitations of the study and recommendations for future research

The first limitation of the study was that only 28 groups were identified in these irrigation schemes, which hindered the performance of econometric analysis to gain in-depth understanding of the factors associated with institutional innovation at group level. While the sample size of 401 irrigators was significant in understanding the impact of water security and farmer groups on farmers' welfare, future studies should sample more farmers for a deeper understanding and improved representation of the entire population. Due to time and financial constraints, the study was limited to KZN and the EC provinces. Further research is required to compare and contrast the nature of institutional innovations in various provinces, gain a deeper perspective of the nature of farmer-led institutional innovations in various irrigation schemes and identify the factors hindering or enabling farmer-led innovations. This is imperative in the era of the fourth industrial revolution since there is little documentation of farmer-led innovation in the smallholder sector. The study found that most innovations were problem- rather than opportunity-driven. Further research is thus required to evaluate whether smallholder farmers are only innovative in order to solve problems or are constantly experimenting with new ways to remain competitive and active in improving water security. Therefore, there is a need to validate these results using a more comprehensive sample and possible using a panel data.

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APPENDIX

Rhodes University Department of Economics and Economic History Group Questionnaire on Institutional Innovation for Improved water security

Note: The information captured in this questionnaire is strictly confidential and can be used for further research and academic publication. Participation in the survey is voluntary and no financial or non-financial benefits are paid during or after participation. Participants can withdraw from the survey anytime they feel like doing. However, your cooperation is highly appreciated.

This questionnaire will be administered to a group leader or anyone who runs a group.

Signature of interviewee:

Identification

Group Name		Scheme	
Interviewee name		Position in your group	
Cell no			
District		Local Municipality	
Date of interview		Enumerators' name	

Codes: Scheme 1= Zanyokwe 2= Mooi River 3= Tugela Ferry 4= Qamata

A. Group Composition

A1. Who initiated the formation of the group? 1= Farmers 2= NGO 3= Government 4= Other specify	
A2. In which year was the group formed?	
A3. How many members are currently active in the group?	
A4. How many were you when the group was formed?	
A5. What is the joining fee in your group? (Zero if none)	
A6. Is the group registered with any authority? 1= Yes 0= No	
A7. If yes, which authority are you registered with? 1 = Companies and Intellectual Property Registration office (CIPRO) under department of trade and industry 2=Government department (Specify, e.g., Department of agriculture 3=?)	
A8. If no, what is the main reason? 1= Not interested 2= Lack of information about where to register 3= Registration too cumbersome/ complicated 4=Too costly 5=other specify	
A9. What are the criteria to join your group?	
A10. How many females are in your group?	
A11. How many males are in your group?	
A12. How many members in your group attained the following education levels?	No education at all
	Primarily level (grade 1 to 7)
	Lower Secondary level (grade 8-11)
	Upper secondary (grade 12)
	Post-secondary (certificate)
A13. What is the age composition of your group members?	Tertiary level
	15 - 29
	30 - 39
	40 - 49
	50-59
A14. How is the committee selected? 1= Elected by group members 2= Members volunteer 3= Selected by extension officer 4=Other, Specify	60 and above

A15. Do you have youths who holds the following positions? 1= Yes 0= No	Chairperson	
	Secretary	
	Treasury	
A16. How many females in your group hold these positions in the committee?	Chairperson	
	Secretary	
	Treasury	
A17. How are the roles assigned within group members? 1 = Assigned to members by the committee 2= Chosen by members 3= Assigned according to personal expertise		
A18. What is the primary objective of the group? 1= Buying inputs together 2= Producing/ farming together 3= Marketing output together 4= Multipurpose group 5= Other specify		
A19. In the past 30 days (or 60 days), how many times has your group met?'		
A19. In general, do your group members work well or co-operate well with each other? 1= Very well 2 = Well 3 = Not well		
A20. Is the chairperson of a group, or any other group leader, a member of water user association? 1= Yes 0=No		
A21. In generally, how would you rate the level of water security among your group members 1= Good 2= Fair 3=Bad		
A22. In general, do you think your group members are competent 1= Very competent 2= Competent 3= No competent		
A23. In general, do you think your group members have hope and confidence in farming 1= Agree 2= Neutral 3=Disagree		

B. Please indicate if your group own the following production assets as a group?

Assets	1= Yes 0= No	How many
B1. Tractor		
B2. Truck		
B3. Bakkie		
B4. Harvester		
B5. Cultivator		
B6. Trailer		
B7. Water tank		
B8. Fertilizer sprayer		
B9. Wheelbarrows		
B10. Hand Hoes		
B11. Processing-machine		
B12. Storage facilities such as	Silos	
	Granaries	
	Barns	
	Storeroom cold room	
Other specify		

C1. In the past 12 months, did your group receive any credit support?	1= Yes 0= No	
C2. In the past 12 months, did your group receive government or private support for the following? 1= Yes 0= No	Inputs (seeds and fertiliser)	
	Financial	
	Production training	
	Irrigation training	
	Marketing training	
C3. In the past 3 years, has your group established networks or contacts to market products 1= Yes 0= No		
C4. In the past 3 year, has your group established new networks with other actors in the agricultural sector to exchange information 1= Yes 0= No		
C5. In general, do the majority of group members attend group meetings? 1= Yes 0= No		

C6. In the past 12 months, has your group experienced any conflicts among members 1= Yes 0= No	
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D. In general, is your group satisfied with the following?

1=strongly dissatisfied 2=dissatisfied 3=neutral 4=satisfied 5=strongly satisfied

Infrastructure	
D1. Agricultural water supply	
D2. Storage facilities for produce	
D3. Equipment (s) for agricultural produce (tractors)	
D4. Access to credit	
D5. Extension support service	
D6. The training and skills offered by extension officers	
D7. Access to hectares of land for agricultural produce	
D8. Networks with other actors in the agricultural sector	
D9. Market access	

E. Which activities do you do together in your group? Complete table below indicating whether the activity is done as a group

Activities	E1. Do you conduct this activity as a group? 0= Not at all 1= Sometimes 2= regularly	E2. Have you introduced any new or significantly improved method of conducting this activity in the last 2–3 years? 1= Yes 0= No If yes please Specify	E3 Who developed or introduced the new or improved method? 1= Farmers 2= NGO 3=Extension Officers
a. Land preparation			
b. Input procurement			
c. Planting			
d. Weeding			
e. Irrigation			
f. Harvesting			
g. Securing output market for commodities			
h. Hiring of transport for marketing			
i. Hiring of tractors/machinery for agricultural activities			
j. Marketing of agricultural produce			
k. Input procurement			
l. Negotiating market prices for the produce			
m. Any other (please specify)			

G. In terms of water access, have you implemented new ways, procedures and rules to ensure the following?

In the past 3 years, have you implemented new or significantly improved rules	1= Yes 0= No	Give details?
a. To improve the participation of group members in sharing responsibilities for canal maintenance, repairing broken canals, repairing infield canals and repairing pumps, etc		

b.	To ensure that every plot receive water irrespective of their location (lower end vs upper end)		
c.	To solve water conflicts among farmers		
d.	To ensure that all group members contribute financially toward scheme maintenance		
e.	To ensure that water charges are paid regularly		
f.	To ensure that group members participate in the important irrigation water meetings		
g.	To improve reporting unlawful diversion or use of irrigation water from the canal		
h.	To improve fair, say in decision making through decentralization?		
i.	To improve transparent or equitable distribution of water among farmers		
j.	To improve group cohesion or trust among members		
k.	To ensure that farmers irrigate within their allocated slots		
l.	To effectively punish those who irrigate during another farmers time		
m.	To ensure that water share is equitable among scheme members		
n.	To improve the penalty system for non-compliance		

In the past 3 years, have your group implemented new or significantly improved methods for organising routines and procedures for the following;	J1.1= Yes 0= No	J2. Sources of innovation ideas 1= Extension agents 2=NGOs 3= Family members 4= Other farmers 5=Traditional knowledge 6= Own idea?
a. Keeping records of farming knowledge, experiences or practises so that it is easily accessible to refer to in the future		
b. Acquiring relevant production or marketing information from different sources		
c. Improving your own farming skills		
d. Implementation of management systems for general production or inputs purchases		
e. Decentralizing decision making for flexibility among your group members		
f. Centralization for improved accountability among your group members		
g. Team building among your group members		
h. Distributing responsibilities among your group members		

i. Including opinions or views of all your group members to ensure free democracy		
j. Collaborating with other farmers		
k. Collaborating with key actors (suppliers, customers, extension officers, research organisation etc.)		

H: Water security and Market participation at group level

H1. How much do you pay for water & water related charges?	
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H2. If you pay for irrigation water and water related charges as a group, please rate the extent to which you agree with the following statement pertaining to water security in your group.

1. Strongly disagree 2. Disagree 3. Neutral 4. Agree 5. Strongly agree

a. In the past 3 years, our group has been able to pay for water charges and water related services in time.	
b. In the past 3 years, our group has been able to pay enough money to buy diesel or electricity to pump water	
c. In the past 3 years, our group experienced water insecurities because of inability to pay for water changes and water related charges	
d. The group will never fail to pay for water charges and water related charges	
e. The group does not owe any debt to (Eskom or any) for electricity (irrigation)	
f. The group does not owe any debt for irrigation water fees	
g. The group is still willing to pay for water and water related charges	

I. Please rate the extent to which you agree with the following statement pertaining to water security among your group members

1. Strongly disagree 2. Disagree 3. Neutral 4. Agree 5. Strongly agree

a. Water source that supplies our plots never dries up (reliable)	
b. We always get water in to the plot(s)	
c. We are generally satisfied with quantity of water we receive in the plot(s)	
d. Irrigation water that reaches our group members is not too salty	
e. We are generally satisfied with the colour of water that reaches our plots	
f. In general, our group members are satisfied with the level of water quality in my plot	
g. Our group members are able to control the quantity of water that reaches their plot (s)	
h. The time allocated for irrigating to our group members does not interfere with other livelihoods activities	
i. Water that reaches our group members plot (s) is sufficient for our cropping requirements	
j. The group is able to enforce the rights to access water	
k. Our group has never experienced water conflicts	
l. Conflict resolution mechanisms are effective in our group	
m. Our group members are permitted to exchange their irrigation slots with other farmers	
n. The group members are generally satisfied with the level of water quality that reaches our plots	
o. Our group members are willing to pay for water charges and water related services	
p. Our group members are able to pay for water charges and water related services	

J1. In the past 3 years, have you implemented new or significantly improved way of doing the the following?

	1= Yes 0= No
a. Improve market intelligence such as obtaining market access or broadening market opportunities	
b. Improve bargaining power or negotiation skills to ensure fair trade such as better prices	
c. Transporting output to the markets	
d. Setting prices for output produced or services provided	
e. Ensuring compliance with food safety and quality assurance standards	
f. Reduce transaction costs as a result of bulk buying	
g. Improve access to best available technology to improve production efficiencies and quality of products	

h. Value addition and agro-processing	
i. Improve access to knowledge networks within the supply chain	
j. Product design and packaging	
k. Selling during periods of market shortages	

J2. What is the distance from the farm to an all-weather road in km?	
J3. How many hours does it take to walk from the farm to the nearest all weather road?'	
J4. How many hours does it take to walk from the farm to the nearest town or market centre?'	
J5. How many hectares of land were under production in the last 12 months?	
J6. What was the percentage of output that your group was able to produce in the last 12 months? 1= 0% 2= 30% 3= 50% 4= 70% 5= 100%	
J5. How satisfied is your group with the level of production? 1=strongly dissatisfied 2=dissatisfied 3=neutral 4=satisfied 5=strongly satisfied	
J5. What percentage of the output was the group able to market in the past 12 months? 1= 0% 2= 30% 3= 50% 4= 70% 5= 100%	
J6. How would you rate the level of market performance of your group in the past 12 months? 1=Very Poor 2=Poor 3=Average 4=Good 5=Excellent	
J7. Give reasons for your answer in J2.	

M. Poverty/ Food security outcomes

M1. How many of your group members would you consider as?	a. Very poor	
	b. Poor	
	c. Neither poor nor rich	
	d. Rich	
	e. Very Rich	
M2. How many of your group members would you consider as?	a. Very food insecure	
	b. Food insecure	
	c. Neither food insecure nor food secure	
	d. Food secure	
	e. Very food secure	

M3. In general, how do you judge your group members poverty status? 0=Very poor 1=Poor 2=Average 3=Rich 4=Very rich
M4. In general, how do you judge your group members food security status? 0= Worse 1= Better 2=Good
M5. In general, how do you judge your group market access in relation to other groups? 0=Very poor 1=Poor 2=Average 3=Rich 4=Very rich
M6. In general, how do you judge your group production level in relation to other groups? 1=Very low 2=Low 3=Medium 4=High 5=Very high

Siyabonga! Siyabulela

INDIVIDUAL FARMER QUESTIONNAIRE

**Rhodes University
Department of Economics and Economic History**

Note: The information captured in this questionnaire is strictly confidential and can be used for further research and academic publication. Participation in the survey is voluntary, and no financial or non-financial benefits are paid during or after participation. The respondent should be the (actual) household head or anyone well informed about the household. Participants can withdraw from the survey anytime they feel like doing. However, your cooperation is highly appreciated.

Signature of interviewee:

Identification

Name of a farmer		Cell No of a farmer	
Scheme		Local Municipality	
Ward No		District Name	
Enumerators' name		Date of interview	

Codes: Scheme 1= Zanyokwe 2= Mooi River 3= Tugela Ferry 4= Qamata

A. COMPLETE THE FOLLOWING TABLE BELOW WITH THE DETAILS OF THE IRRIGATOR. IF THE IRRIGATOR IS NOT THE HOUSEHOLD-HEAD, FILL IN THE DETAILS OF THE HOUSEHOLD HEAD ALSO.

A1. Household head	A2. Age	A3. Gender	A4. Marital status	A5. Educ level	A6. Main occupation
1= Yes 0= No		1= Male 0= Female	1=Single 2=Married 3=Divorced 4=Widowed	No of completed years in education in grades	1=Fulltime farmer 2=Student 3=Regular salaried job 4=Retired 5=Temporary job 6 =Unemployed 7=Self-employed 8 =Other (specify)

Household head refers to the de facto household head that stays in the household for 4 or more days per week

A7 What is the total number of your household members**?	
A8 How many of the household members are adults (15 years old or more)?	
A9 How many of the household members are children (less than 15 years old)?	
A10 How many of the adult household members cannot work because of chronic sickness or old age?	
A11 How many of the household members are permanently employed?	
A12 How many of the household members are temporarily employed?	
A9. How many years have you been involved in farming (years)?	
A10. How many household members help with or are involved in farming regularly?	

***Please include only those who stay in the household for 3 or more days per week*

B. LAND HOLDING

B1. What is the total size of land the household has access to?	Irrigated land	
	Dry-land	
	Irrigated land	

B2. How many hectares of the land that the household has access to, was cultivated last season between October 2017 and September 2018?	Dry-land	
B3. How did you acquire the land and what was the size in hectares?	Allocated by Inkosi	
	Inherited	
	Leasing/ renting	
	Bought	
	Land reform?	
	Leasing/ renting Other (Specify).....	
B4. How do you feel about your land size? 1= Too small 2= Just right 3= Too large		
B5. Are you satisfied with the hectares of land you have access to? 1= Yes 0= No		
B6. If No, how many hectares of land would you prefer to expand your production?		
B7. Rate the quality of your land for crop production. 0= Poor 1=Average 2=Good		
B8. Are you permitted to choose which crop to grow? Yes=1 No=0		
B9. Are you permitted to put your land into fallow (uncultivated) and to cultivate it once the fallow period is over? Yes=1 No=0		
B10. Are you permitted to freely bring improvements (building canals, infrastructure, etc.) to the land? Yes=1 No=0		
B11. Are you permitted to dispose of crop output after harvest freely? Yes=1 No=0		
B12. Do you have the right to prevent the grazing of others' livestock from your plots Yes=1 0=No		
B13. Are you permitted to sell your piece of land? Yes=1 No=0		
B14. Are you permitted to rent your piece of land against cash? Yes=1 No=0		
B15. Are you permitted to give land as a gift to other people? Yes=1 No=0		
B16. In general, are you satisfied with the present tenure security of your land? Yes=1 No=0		

C. INCOME SOURCES AND SUPPORT SERVICE

Please fill in the table below by stating your total monthly income from each category from Oct 17 –Sep 18.

	C1. Amount per given time	C2. How often? (e.g., monthly)	C3. Number of times in the past 12 months	C4. Total Amount
a. Remittances				
b. Arts and craft				
c. Permanent employment				
d. Temporary employment				
e. Social grants				
f. Crops				
g. Crops – rainfed				
h. Livestock				
i. Forestry				
j. Fishing				
k. Other (please specify)				

C5. Do you use some of your grant money to buy agricultural inputs? Yes=1 No=0	
C6. If Yes, how often do you do that? 1 = Sometimes 2= Always	

C7. Have you ever taken credit or used any loan facility in the past 12 months? 1=Yes 0=No	
C8. If yes, what was the main source of credit/loan? 1= Relative or friend 2= Money Lender 3= Savings club 4=Input-supplier 5=Output-buyer 6=Financial-institution (Specify name of institution.....)	

C9. If No to C7 above , please specify the reason(s) (multiple answers possible) 1= interest rate is high 2= I couldn't secure the collateral 3= I have got my own sufficient money 4= I am risk averse 5. Lack of information about where to apply for credit 6. Long distances to credit suppliers 7. Difficult application process 8. Not meeting requirements 6=other, please specify.....	
C10. If you took credit or loan what was the purpose of the loan/credit? 1= Family emergency 2= Agricultural purposes 3= other (specify.....)	
C11. Were you able to pay back the loan/credit in time? 1=Yes 0=No	
C12. Did you receive funding or any other sources of funding support from the government in the past 12 months? 1=Yes 0=No	
C13. Did you have any contact with the extension officer since October 2017? Yes=1 No=0	
C14. If yes in C13, how often did you contact extension officers? Sometimes=1 Always=2	
C15. If yes on C13, did you invite the extension officer? Yes=1 No=0	
C16. What is the distance to the extension office? Km	
C17. Did you or a member of your household receive any training from the government or any other organisation 1- Yes 0= No	

D. PHYSICAL HOUSEHOLD ASSET ENDOWMENTS: INDICATE ASSETS THAT YOU HAVE ACCESS TO

D1. Indicate production Assets you have access to.	D2. Do you own or hire the assets? 1. Own 2. Hire	D3. Number of Assets held if owned	D4. Total current value owned?	D1. Indicate if you have access to the following production Assets	D2. Do you own or hire the assets? 1. Own 2. Hire	D3. No of assets if owned	D4. Total current value of owned assets
a. Hand Hoes				L. Wheelbarrow			
b. Shovels/spades				0. Cultivators			
c. Ox-drawn plough				p. Private small car			
d. Wheelbarrow				q. Truck			
e. Trailer				r. Bakkie			
f. Tractor				s. Cell phone			
g. Tractor-drawn plough				t. Fertilizer spreaders			
h. Hand Hoes				u. Motorcycle			
i. Shovels/spades				v. TV			
j. Trailer				w. Bicycle			
k. Water Tank				x. Radio			
l. Hand Hoes				y. other (specify)			
m. Shovels/spades				z. other			
n. other							

D. Please indicate your livestock production and marketing activities by completing the table below

Livestock Type	D1. Cattle	D2. Sheep	D3. Goat	D4. Chicken	D5. Ducks/goose	D6. Donkey	D7. Pigs	D8. horse	D9. Other Specify
a. Number owned today									
b. Money spent on feeds, chemicals, vet services, etc., since January 2018									
c. Number sold since January 2018									

d. Total amount from sales since January 2018 (Rands)									
e. Main market livestock									
f. Number slaughtered for family purpose									
g. Number given to others as gifts, fines, etc., since January 2018									

*Main market codes: 1=Local butchery 2=Supermarket 3=Neighbours 4=Hawkers 5=other (specify)

D10. What is the primary purpose or function for keeping livestock 1=Sales 2=Consumption 3=Wealth 4=Draught power 5=Cultural reasons 6=Other	
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F. COLLECTIVE ACTION & GROUP COHESION

F. Which group do you belong to? Please feel in the table below;

Group	F1. No of years as a group member?	F2. What is your position in your group 1=General Member 2= Chairperson 3 = Secretary 4= Treasury	F3. What is your level of participation in decision making? 1= Low 2= Moderate 3 =Very high	F4. Are you satisfied with your level of participation in decision-making processes? 1= Not satisfied 2= Neutral 3= Very satisfied
a. Farmers' co-operative or association				
d. Water User Association				
e. Saving and credit group (Stokvel)				
f. Religious group (church etc.)				
h. Burial societies				
i. Women groups (WARD)				
j. Youth groups (YARD)				
g. other (specify)				

F5. If you are member of a farmer association or a co-operative, please answer the following questions from F5 to F10.

If not a member, please jump to F11.

a. What is the name of your farmer association or co-operative?	
b. Who is your group chairperson?	
c. Is it registered with the department of trade and industry under CIPRO? 1= Yes 0= No	
d. Do you believe and trust your group leader (s) in ensuring the positive impact on your group? 1= Yes 0= No	

F6. On the scale of 1 - 5 please rank the following questions related to your perception of how you feel in your co-operative or farmer association group.

5= Strongly Agree 4= Agree 3= Neutral 2= Disagree 1= Strongly Disagree

	Rank
a. I am treated fairly in a group	
b. There are feelings of unity and togetherness among the group members	
c. There is little conflict in the group.	
d. It is easy to talk openly with all members of the group.	
e. I am free to share information with other group members	
f. Everyone in the group does his/her fair share of responsibilities.	
g. There are clear roles and accountability for each member of the group.	
h. I can trust the group members	
i. I trust my group leaders.	

j. My group leaders are competitive	
k. The purpose of the group is clear.	
l. I do not feel like part of the group	
m. I have a common set of norms and values with other group members.	
n. I consistently receive support or help from other members	
o. I am receptive to feedback and criticism	
p. prefers not to spend time with members in the group	
q. I look forward to participating in the group meetings	
r.	

F7. Do you think your group abides by the following principles?

5= Strongly Agree 4= Agree 3= Neutral 2= Disagree 1= Strongly Disagree

a. Voluntary and open membership without discriminating on the basis of gender, marital status, religion, etc.	
b. Democratic member control by ensuring that every group member actively participates in setting policies and making decisions (equal voting rights).	
c. Equitable member economic participation (member's benefits in proportion to their transactions with the group)	
d. To autonomous and self-help (group is not entirely dependent on government support, but they are actively ensuring that the group is successful)	
e. Providing education and training to improve the effective contribution of group members	
f. The importance of group co-operation among members	
g. To ensure that policies implemented concerns the community and provide sustainable development of the community at large.	

F8. Are you still interested in remaining as a group member? 1= Yes 0= No	
F9. In general, how do you perceive policies and regulations in your group? Poor = 1, fair = 2, good = 3	

F10. Please rank the extent to which you agree with the following statements. Being part of a farmer group has the increased access to; 1= Strongly disagree 2= Agree 3= Neutral 4= Agree 5= Strongly Agree

a. Affordable supply of inputs	
b. Technical services support during production.	
c. Help for irrigation, machinery farming, and pest control	
d. Market information	
e. Help to market and sell products at better prices at a lucrative market.	
f. Assistance to the product processing	
g. Financial assistance	
h. Government subsidies	
i. Training on agricultural farming	
j. Transportation of products at reduced cost	
k. Other, please specify	

F11. On a scale of 1- 5, please indicate why you are not part of farmer group?

1= Strongly disagree 2= Agree 3= Neutral 4= Agree 5= Strongly Agree

a. Lack of local leaders to establish	
b. Prefer to work alone to avoid free-riding problems	
c. Membership costs are too high.	
d. Its time consuming (i.e., attending meetings, teaching other group members).	
e. Lack of information and understanding about relevant groups	
f. Lack of trust that farmer groups can run services (access to market access, input) well	
g. Distrust in group leaders	
h. Lack of training and directions	
i. Lack of supervision on financial disclosure	
j. Lack of government's support	
k. Lack of relevant policies and legislation to ensure that groups are run effectively	
l. Not interested in sharing profit and knowledge with other farmers	
m. I am concerned about disclosing financial status to other group members.	

n. I am concerned about weak leaders' ethics and management level.	
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G: INSTITUTIONS, GOVERNANCE, AND WATER ACCESS

What was your level of involvement in the following activities for the year 2017 to 2018?

0. None (never involved) 1. Low 2. Average 3. High 4. Very high (always involved)

	Rank
Labour-based participation	
a. Canal cleaning (removing debris, overgrown grass, etc.)	
b. Repairing broken main canals	
c. Repairing infield canal	
d. Repairing pump	
Financial based participation	
e. Contributing finance towards irrigation pump maintenance	
f. Contributing finance towards irrigation maintenance (buying material, paying the maintenance people, etc.	
g. Contributing finances towards the Water Users' Association (WUA)	
Participation in decision making processes	
h. Attending irrigation meetings	
i. Attending irrigation/water related training	
j. Giving ideas on water use and allocation in meetings	
k. Engaging authorities regarding water issues in the area (information dissemination)	
l. Distributing information about water issues (written or verbal)	
m. Helping other farmers to manage/conservate water Other(specify)	
Participation in regulation and control	
Reporting unlawful diversion or use of water from the main canal	
n. Reporting theft/damage of water management devices (canal gates, flow meters or pumps)	
o. Reporting leakages along the canal for repairs	
p. Canal cleaning (removing debris, overgrown grass, etc.)	

G2. IRRIGATION WATER SECURITY

a. How far is your homestead from the irrigation scheme? 0= (0 - 0.5km) 1= (0.6 –1.5km) 2= (1.6 - 2.5km);	
b. 3= (2.6 - 4.0km) 4= (>4km)	
c. What is the position of your plot(s) from the main water supply or canal? 1= Head 2= middle 3= tail	
d. Do you pay to access irrigation water? 1=Yes 0= No	
e. Do you have a water licence for irrigating? 1= Yes 0= No	
f. In the past 30 days, how many days did you have access to irrigation water?	
g. Generally, how many hours do you have access to water during your irrigation slots?	
h. Are you satisfied with the number of irrigation hours you have access to per day?	
i. 1. Strongly disagree 2. Disagree 3. Neutral 4. Agree 5. Strongly agree	
j. What type of irrigation system are you using for irrigating your crops? 1= Sprinkler 2= flood irrigation 3= Drip irrigation 4= Centre pivot	
k. The mode of diverting or pumping water into my plot is efficient? 1= Not efficient 2= Efficient 3= Very Efficient	
l. Are there water measurement devices at the specific diversion points where you get water for your irrigation? 1=Yes, 0=No	
m. Do you have the capacity to invest in an efficient irrigation system? 1=Yes 0= No	
n. Dysfunctional water infrastructure is a major challenge for accessing water? 1=Yes 0= No	
o. Have you ever been involved in water-related conflicts, with fellow farmers, community members or authorities? 1= Yes, 0=No	
p. How satisfied are you are with the current irrigation system? 1= Very unsatisfied 2= Satisfied 3= moderately satisfied 4= Satisfied 5= Very satisfied	
q. The number of irrigation supply turns where no water was provided at a time of entitlement during the last irrigation 30 days.	
r. In the last 30 days, how many numbers of irrigation turn did you missed because no delivery was provided in the canal in the irrigation season	

s. How many total numbers of irrigation turns were scheduled for the last irrigation season?

G3. Please rate the extent to which you agree with the following statement on water security to your irrigation

1. Strongly disagree 2. Disagree 3. Neutral 4. Agree 5. Strongly agree

	Rank
a. Water source never dries up (reliable)	
b. I always get water in my plot(s)	
c. Access to irrigation time for my plot (s) is flexible (can irrigate anytime)	
d. Water that reaches my plot is sufficient for my cropping requirements	
e. I am satisfied with the quantity of water I receive in my plot(s)	
f. I know how many hours are required for irrigating my crops	
g. I am able to control the quantity of water that reaches my plot (s)	
h. Irrigation water that reaches my plot is not too salty	
i. I am satisfied with the colour of water that reaches my plot	
j. I am satisfied with the smell of water that reaches my plot	
k. I am generally satisfied with the level of water quality in my plot	
l. I am willing to pay for water charges and water-related services	
m. I am able to pay for water charges and water-related services	
n. I have never failed to pay for water charges and water-related services	
o. I will never fail to pay for water charges and water-related charges	
p. The time allocated for irrigating my plots does not interfere with other livelihoods activities	
q. I can enforce my rights to access water	
r. I decide how to use the water that reaches in my plot	
s. I am permitted to exchange my irrigation slots with other farmers	
t. I never experienced water conflicts in my plots	
u. I know who to approach if I don't have water into my plots	
v. My right or claim to water is secure	
x. Water sharing is equitable among scheme members	
y. Conflict resolution mechanisms are effective	
z. The penalty system for non-compliance is effective	
AA. I am always consulted when decisions that affect the flow or supply of water are made.	
bb. Water management decision-making processes are transparent and fair	

G5. SOCIAL RELATIONS. Please complete the following table regarding your social relations with water management.

	Response
a. Do you have any good personal relations with canal rangers? <i>1=Yes, 0=No</i>	
b. Do you have any good personal relations with committee members? <i>1. Yes 0=No</i>	
c. Do you have any good personal relations with Indunas/Inkosi? <i>1.=Yes 0=No</i>	
d. Are you consulted when decisions that affect the flow or supply of water are made? <i>0 = Never; 1. At times; 2. Regularly</i>	
e. Are you aware of what is deliberated in water-related meetings by the committee members? <i>1. Yes 0. No</i>	

H. CROP PRODUCTION MARKETING

H1. Crops (Code A)	H2. Area Planted (ha)	H3. Type of irrigation system (Code B)	H4. Fertilizer Cost	H5. Herbicide cost	H6. Pesticide cost	H7. Quantity harvested	H8. Quantity sold	H9. Sell price per unit	H10. Market outlet sold Code C	H11. Market distance from farm (km)	H12. Quantity consumed at home

Code A: 1= Maize 2= Beans 3= Cabbage 4= sugarcane 5= Carrot 6= Spinach 7= Butternut 8= Calabash 9= Pepper
10= Sweet potato 11= Tomato 12= Chillies 13= Lucerne 14= other

Code B: 1= Drip irrigation 2= Sprinkler 3= Flood irrigation Code C: 1= Local shop 2=Shops in town 3=Neighbours 4=Contractor 5=Hawkers 6=other (specify)

H13. Did you hire any labour for your farming activities since October 2018? 0=No 1=Yes	
H14. If Yes in H21, how much did it cost you to pay them?	Permanent Temporary
H15.If you hired tractor for land preparation, how much did you spend	
H16. If you hired oxen for land preparation, how much did you spend	

H17. Have you ever failed to sell your product due to lack of buyers? 1=Yes 0=No	
H18. Generally, how would you rate your level of market access? 1=very poor 2=poor 3= average 4=good 5=very good	
H19. What is the distance from your homestead to the nearest road in minutes?	
H20. What alternative mechanisms are there for you to transport your produce to the selling points?	

II. Please rate to what extent you agree with following statements on the scale 5-1 regarding your marketing.
5= Strongly Agree 4= Agree 3= Neutral 2= Disagree 1= Strongly Disagree

a. I receive poor prices	
b. I often find it difficult to market and sell my products.	
c. I often find it difficult to access market information.	
d. I have established networks or contacts to market my products.	

12. To what extent do you consider the following as constraints to your farming operations?
5= Strongly Agree 4= Agree 3= Neutral 2= Disagree 1= Strongly Disagree

a. Lack of access to inputs (fixed and variable inputs)	
b. Large (unaffordable) increase in input prices	
c. Production shortfall below normal	
d. Market price decline for outputs sold.	
e. Weak infrastructure	
f. Weak level of electricity supply	

J5. During the last three years, how important were the following factors in hampering your innovation Activities? Please rate to what extent you agree with following statements.
5= Strongly Agree 4= Agree 3= Neutral 2= Disagree 1= Strongly Disagree

a. Lack of own funds	
b. Lack of credit	
c. Lack of institutional support such as extension support	
d. Lack of skills	
e. Lack of collaboration with farmers and other key actors	
f. Difficulties in obtaining government grants	
g. Lack of support from family	
h. Lack of resources	
i. Innovation cost too high	
j. Innovation is not important	

M. Please rate on how you perceive yourself as a farmer in the following

1=strongly disagree 2=Disagree 3=Neutral 4=agree 5=strongly agree

a. I enjoy new challenges and opportunities	
b. I do not give up easily when faced with challenges.	
c. I am confident in farming as an economic activity.	
d. I have taken more risk to improve production.	
e. I have been able to cope with shocks such as weak market access, low prices, etc.	
f. I am solely dependent on government support and government is responsible for my wellbeing.	
g. I am market-oriented and produce for the market.	
h. I have a clear vision of how the farm business will grow.	

i.	I always try new crops and cultivars, and alternative technologies to increase productivity, diversify production and reduce risk.	
j.	I take calculated risks to make the farm profitable.	
k.	I take huge risks, sometimes risking group assets and security.	
l.	I manage farming business as a long-term venture with a view to making it sustainable.	
m.	I always cooperate with others, network and utilize contacts effectively.	
n.	In generally, I am very competitive.	
o.	I am very flexible and always willing to adapt.	
p.	I am always willing to learn new things.	
q.	I have bookkeeping and farm business skills.	
r.	I am business-oriented	
	I work long and irregular hours to meet demands.	

Water flow measurements

Name of the block (s) or group supplied by the Secondary Canal	Canal Shape	Canal Width (m)	Sub-Section Width for each cross-sectional area	Depth of water in the canal from each sub-section (m)					Velocity of water from each subsection from different depths					Discharge Rate	
				D1	D2	D3	D4	D5	V1	V2	V3	V4	V5		

Siyabonga! Siyabulela! Thank you!